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Session 1

2050 perspective: how to increase the yield?

ORAL PRESENTATIONS

Climate Change Impacts On Processing Tomato Production

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Introduction

The majority of climate change impact studies focused on wheat, maize, rice, and soybean, while vegetable crops have not received sufficient attention. Food and nutrition security require essential vitamins and micronutrients, fiber, with a per capita fruit and vegetable consumption (excluding tubers) that should exceed 400 g/day (Choudhury et al., 2020). Tomato is one of the most important vegetables and ranks second only to potatoes by acreage, production, yield, commercial use, and consumption (FAOSTAT, 2022). Tomato is cultivated across the globe due to its adaptability to a wide range of soil and weather conditions. There are two types of cultivated tomato, the one for fresh consumption and the one used for industrial transformation (processing) which is usually grown under field conditions.

Most of the published research on the impacts of climate change on processing tomato has been done at regional or local level. Gustafson et al. (2021) developed a methodology to assess the impact of climate change on the processing tomato supply chain in the United States. In South East Italy, it was found that negative impact of projected climate on water and nutrient use efficiency on processing tomato (Rinaldi et al., 2007; Ventrella et al., 2012; Giuliani et al., 2019; Cammarano et al., 2020).

Processing tomatoes are important because they are used for tomato paste, tomato sauce, ketchup and other tomato-based products. About 40 million tons are processed yearly, thus making it the world leader vegetable for processing. The main production zones are located in the temperate regions around the 40th parallels both North and South. Processing tomato production is concentrated in ten major "tomato baskets" around world that produce 85% of the global processing tomato. Among the ten countries three of those, i.e., USA, Italy and China, account for 65% of the global production.

A current research main gap is the lack of an up-to-date biophysical assessment of the potential impact of climate change in these three countries using the latest climate projections (CMIP6) and a protocol that makes the results comparable with the results from other global efforts.

Materials and Methods

The crop model used to simulate processing tomato is Cropping System Model (CSM)-CROPGRO-Tomato as part of the DSSAT models' suite. The model was calibrated for different tomato genotypes the different agro-ecological environments using published scientific literature and validated at regional level using the data downloaded from the World Processing Tomato Industry as highlighted in Cammarano et al. (2022). For the gridded simulations the model was setup with the Global High-Resolution Soil Profile Dataset, and five bias-adjusted global climate models (0.5° x 0.5°) by the Inter-Sectoral Model Intercomparison Project (ISIMIP) based on the CMIP6. Three Shared Socioeconomic Pathway and Representative Concentration Pathway (SSP-RCP) scenarios were used: low (SSP1-2.6), high (SSP3-7.0), and very high (SSP5-8.5) greenhouse emissions and related socio-economic conditions and atmospheric carbon dioxide concentrations.

Results

Simulation results showed that processing tomato production in the three main producing countries (the United States, Italy and China) will decrease by 2050 under an ensemble of projected climate scenarios, with smaller changes for lower emissions SSP1-2.6 (+0.2 to -9.9%) and more severe for the higher emissions SSP3-7.0 (+8.6 to -8.6%) and very high emissions SSP5-8.5 (+6.5 to -15.2%) (Figure 1). The water requirement for irrigation is projected to increase by 5 to 50%, depending on the region. In China the projected water requirements were lower than California and Italy. China has a potential to become the most important region for processing tomato production by 2050 overtaking California as a main processing tomato production hub. That is due to the projected air temperature increase which tends to minimize the beneficial effect of higher carbon dioxide concentrations. Increase in air temperature causes an increase in irrigation required to meet the crop's water demand, lowering the efficiency of irrigation. Projected water demand for irrigation can be challenging for future water resource management, which is critical in locations such as southern California and Italy. This suggests that these locations might not be able to sustain the actual levels of processing tomato production. On the other hand, cooler producing regions, such as China and northern parts of California, might increase their competitive advantage being less affected by projected temperature patterns.

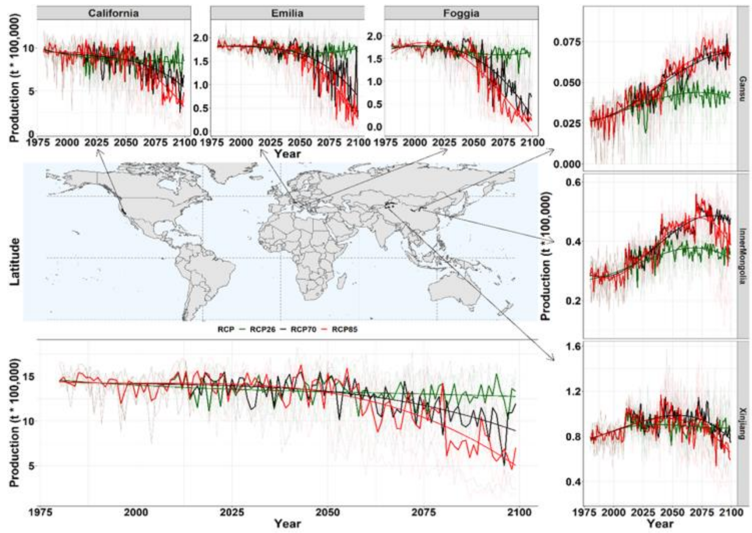

Figure 1. Simulated treds of the Global processing tomato production for China, Italy, and the USA for the SSP1-2.6 (green line), SSP3-7.0 (black line), and SSP5-8.5 (red line). The small panels represent each individual regions as named on the boxes.

Conclusions

Our study is the first impact assessment using a system-based modelling approach to quantify the potential impact of climate change on processing tomato production for three major tomato processing regions across the globe. Future work needs to include additional political and socio-economic information to be integrated in similar studies to assess changes in the whole system to evaluate shifts in the value chain including processing plants and transportation lines that may be anticipated.

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How Production Intensity Could Affect Sustainability And Milk Quality In Dairy Farm

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Introduction

Increasing food production and quality in a sustainable manner is a key factor to fulfil the needs of global human population growth. Sustainable intensification strategy can reduce environmental impacts, through improvements in the milk production per cow and feed efficiency, as well as by increasing the net primary production of the utilized agricultural area (UAA) and the input efficiency (Gislon et al., 2020). An environmentally sustainable milk production must therefore be achieved through the use of cropping/forage systems and practices that allow the most efficient use of resources and the lowest environmental impacts per unit of product (Capper, 2011). The aim of this work was to evaluate the effects of three different levels of production intensity per unit of UAA on milk quality and sustainability in different farms of Northern Italy.

Materials and Methods

Twenty-four dairy farms in Northern Italy were selected and assigned to three classes of milk production intensity levels: LOW (<15 t fat-protein corrected milk (FPCM)/ha), MEDIUM (from 16 to 30 t FPCM/ha) and HIGH (>31 t FPCM/ha). Data covering herd composition, livestock production systems, livestock feed management, crop cultivation and management were collected through on-farm questionnaires and registered data available on the farms. All the data concerning farm inputs and farm outputs were obtained through the analysis of all the farm invoices. The environmental impacts have been evaluated using the LCA methodology assessing the global warming potential (GWP). The system boundaries concerned a cradle-to-farm gate analysis. The functional unit considered was one kilogram of FPCM. Milk fatty acid profiles were determined by gas-chromatograph. Results were analysed for their statistical significance via analysis of variance utilizing the production intensity as fixed factor, with data from each intensity level pertaining to individual farm as replicates in the statistical model. The Bonferroni post-hoc test was used to interpret any significant differences among the mean values.

Results

Farms belonging to the HIGH group were characterized by lowest farm area and highest stocking rate, whereas, HIGH and MEDIUM groups had daily milk production, dry matter intake (DMI) and dairy efficiency greater than LOW farms (Table 1). LOW and HIGH milk farms were connected to high amount of multiannual forages and maize, respectively. LOW farms showed higher winter soil covering, higher areas without agrochemical inputs, lower plowed areas and lower mineral nitrogen application than HIGH farms. This resulted in lower GWP in LOW and MEDIUM farms than in HIGH farms, with a contrasting dilution effect of CH_4 emissions counteracted by higher emissions linked to purchased feeds. MEDIUM farms showed similar GWP to low farms but with herd performances close to those of HIGH farms. The lower the milk intensity was, the higher the milk quality, in terms of fatty acid profile, confirming that dairy cow diets based on high quality meadow forages showed higher C18:3n-3, CLA, n-3/n-6 ratio. The nitrogen balance showed an increase of input from LOW to HIGH farms, mainly due to inputs related to purchased feeds and mineral fertilizers. This resulted in a surplus of 105, 328 and 792 kg/ha in LOW, MEDIUM and HIGH farms, respectively.

Table 1. Farm and cropping system characteristics, GWP and milk quality of farms with different milk intensity levels.

	Milk Intensity				
	LOW (n = 8)	**MEDIUM (n = 8)**	**HIGH (n = 8)**	**SEM**	***P*-value**
Farm characteristics					
Milk Intensity (t FPCM/ha)	6.8^{c}	23.2^{b}	48.5^{a}	3.868	<0.001
Utilized Agricultural Area (UAA) (ha)	94^{a}	95^{a}	43^{b}	8.998	0.018
Stocking rate (LU/ha)	1.71^{c}	3.41^{b}	7.19^{a}	0.526	<0.001
Herd performances					
Milk FPCM per cow (kg/d)	22.1^{b}	34.5^{a}	36.0^{a}	1.521	<0.001
DMI (kg/d)	19.3^{b}	23.8^{a}	24.2^{a}	0.542	<0.001
Dairy efficiency (kg FPCM/kg DMI)	1.14^{b}	1.45^{a}	1.49^{a}	0.044	<0.001
Cropping system characteristics					
Maize (whole plant/ear silage, grain) (% UAA)	16	61	83	-	-
Winter cereals (silage grains) (% UAA)	5	6	9	-	-
Italian ryegrass (% UAA)	7	30	41	-	-
Other forage crops (% UAA)	1	1	1	-	-
Multiannual forages (alfalfa, meadows) (% UAA)	74	30	11	-	-
Double crop (% UAA)	3^{b}	28^{a}	45^{a}	4.7	<0.001
Winter soil covering (% UAA)	83	65	60	4.2	0.073
Plowed area (% UAA)	40^{c}	98^{b}	131^{a}	9.6	<0.001
Area without agrochemical use (% UAA)	73^{a}	31^{b}	13^{b}	6.5	<0.001
Mineral nitrogen inputs (kg N/ha)	28^{c}	110^{b}	159^{a}	14.48	<0.001
GWP					
Total (kg CO_2-eq/kg FPCM)	1.43^{b}	1.53^{b}	1.68^{a}	0.037	0.012
Purchased feeds (kg CO_2-eq/kg FPCM)	0.48^{c}	0.78^{b}	0.96^{a}	0.049	<0.001
CH_4 (kg CO_2-eq/kg FPCM)	0.70^{a}	0.52^{b}	0.52^{b}	0.024	0.001
N_2O (kg CO_2-eq/kg FPCM)	0.14	0.13	0.12	0.006	0.507
Other inputs (kg CO_2-eq/kg FPCM)	0.12^{a}	0.10^{ab}	0.08^{b}	0.007	0.030
Milk quality (g/100 g fat)					
C18:3n-3	0.73^{a}	0.57^{ab}	0.39^{b}	0.046	0.006
CLAc9t11+t7c9+t8c10	0.58^{a}	0.36^{b}	0.41^{b}	0.035	0.020
even_SFA	65.3^{a}	64.1^{ab}	62.9^{b}	0.375	0.021
MUFA	25.8^{b}	26.0^{b}	28.7^{a}	0.418	0.002
PUFA	3.68^{b}	4.76^{a}	4.03^{b}	0.167	0.019
n-3/n-6 ratio	0.64^{a}	0.35^{b}	0.25^{b}	0.055	0.007

CLA = conjugated linoleic acid, DMI = dry matter intake, FPCM = fat protein corrected milk, GWP = global warming potential, LU = livestock units, UAA = Utilized Agricultural Area.

Conclusions

A medium milk production intensity is a good way for a sustainable intensification strategy, by combining high inputs and production efficiencies, while maintaining a capability of recycling nutrients and reducing environmental pressure.

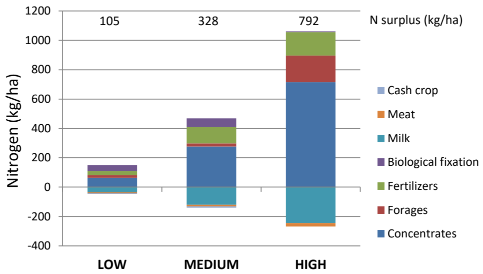

Figure 1. Farm gate nitrogen balance in the studied farms

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Acknowledgments

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The Effect Of Tree Rows On Yield Of Grain Crops: A Meta-Analysis On Agroforestry Systems In Temperate Climates

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Introduction

Silvoarable agroforestry consists of intercropping arable crops with largely spaced trees, where trees can be distributed following different designs, such as alley-cropping, scattered trees and line belts (Mosquera-Losada et al., 2009). Silvoarable systems are receiving increasing attention for improving resilience to climate change in temperate regions, by providing shade with their canopy and shelter through windbreak effect. However, preserving crop yield remains one of the most critical issues when implementing sustainable agroforestry systems, as significant yield losses are commonly documented in the interaction zone with trees (Pardon et al., 2018; Dufour et al., 2013). Here, a meta-analysis on agroforestry systems in temperate climates has been carried out in order to summarize the available knowledge on the impact of trees, arranged as rows, on yield of the neighboring arable grain crops. Although the related research questions are many, here the following are addressed:

i. Does the effect of the distance from the tree row vary according to crop species? It is expected that the distance from the tree line is less relevant on grain yield in winter vs. summer crops.
ii. Does the impact of trees on grain yield of the associated crops vary according to the distance from the tree row? It is expected that the most relevant yield reductions are observed in positions closer to the tree line.

Materials and Methods

A systematic literature search was conducted using Scopus and Web of Science, for peer-reviewed studies that investigated the grain yield of grain crops in silvoarable agroforestry systems (AF) as compared to adjacent controls under full sun without trees (C) (published from January 1980 up to December 2020). Only studies including trees arranged as rows were here considered, excluding scattered trees and hedgerows. Studies were retained in analysis when meeting the following criteria: (i) the study site is located in temperate regions, as defined by Köppen-Geiger climate classification (ii) empirical data of yield of field crops are available (reviews and modelling studies were excluded), (iii) trials considered natural open field conditions with real trees (pot, greenhouse and artificial shading experiments were excluded), (iv) true controls are present allowing yield comparison with and without tree rows. An overall amount of 18 original research articles were considered, allowing the calculation of standard deviation of the mean: 13 from Europe, 1 from North America, 1 from South America, 2 from Africa and 1 from Asia. Among crops, triticale and chickpea were excluded due to the poor number of observations, while analyses focused on wheat, barley, soybean and maize, with a total of 195 observations. According to their growing cycle and level of radiation required, winter and barley are also referred as winter crops, while soybean and maize as summer crops. The log response ratios (RR) was calculated as a measure of the effect size (Hedges et al., 1999), by calculating the logarithm of the ratio between the mean response of a crop in agroforestry (AF) at a certain distance from the tree row and the mean response of such crop in adjacent open field controls without trees (C). A positive response ratio (RR > 0) means that the presence of trees has a positive effect on crop yield, whereas a negative response ratio (RR < 0) indicates a negative effect; little or no effect are indicated by RR ≈ 0.

Results

Statistical analysis revealed lower crop yield in positions close to the tree rows and a gradual recovery as the distance-to-tree height ratio (D/H) increases (Figure 1). However, significant variations of the response ratio (RR) dynamics were revealed, depending on the crop species considered. Winter crops, such as wheat and barley, were confirmed to be less affected by tree competion than summer crops like maize and soybean. In particular, barley showed no effects of the tree line, as highlighted by poor regression coefficient (b=0.0259) and determination coefficient (R^2=0.03). In wheat, grain yield was slightly affected by the tree row, with small negative variation of the RR at D/H<1 (i.e., ln(D/H)=0, R^2=0.18). The strongest impact of the distance from the tree line was observed in summer crops, i.e. maize, and even more in soybean, with markedly lower yield when getting closer to the tree line.

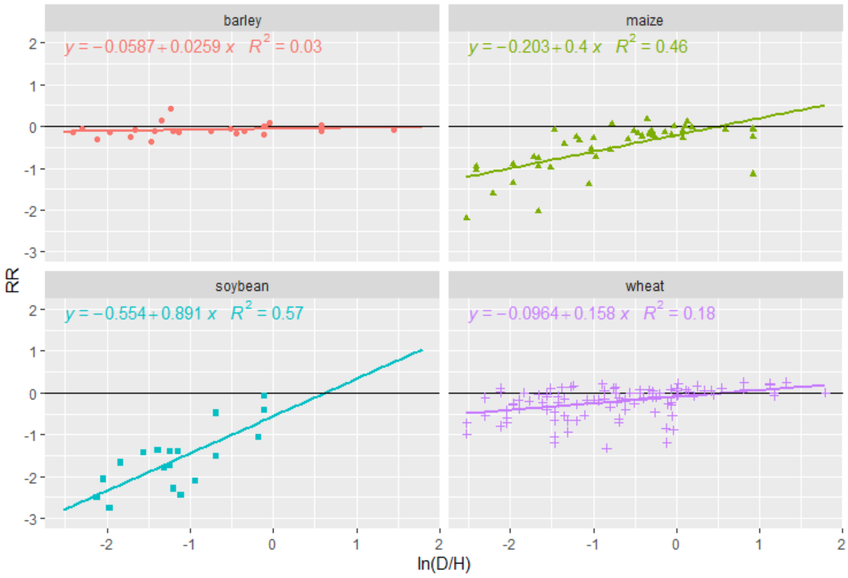

Figure 1. Effects of the distance from the tree rows on yield of grain crops as response ratio (RR). Negative values of ln(D/H) indicate distances from the tree row (D) lower than tree height (H), and viceversa. Each marker represents an individual observation.

Conclusions

In agroforestry systems with deciduous tree species, winter crops such as wheat and barley are less affected by tree competition compared with high light-demanding summer crops like maize and soybean. This depends on lower overlap of growing season with tree foliation duration, and likely to the C3 metabolism vs. C4 of maize, although the most sensitive crop was soybean. In order to maximize the productivity of silvoarable systems in temperate climates, it is suggested to include summer crops in rotation during the first years of the tree cycle, while further research is required to identify suitable crop varieties.

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The Role Of Seed Applied Biostimulant, Hybrid And Starter Fertilization On Maize Early Vigor And Grain Yield

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Introduction

Fast and uniform maize growth is essential to achieve high grain yield and quality, especially with early sowing and in rainy and cold springs, when the uptake of nutrients, mainly nitrogen (N) and phosphorus (P), by the root system, could be restricted. The use of hybrids more resistant to cold returns and the localized application of NP fertilizer in seed furrow guarantee a rapid maize growth, with yield and qualitative benefits (Blandino et al., 2022). Recently, the biostimulants are increasing of interest; they are substances and micro-organisms whose function is to stimulate plants to improve vigor, yield and quality, with no direct action against pests (Drobek et al., 2019). Most of them can be used to increase tolerance to abiotic stresses and in association with fertilizers in order to enhance nutrient uptake efficiency and reduce waste and pollution. Hence, in this study, the use of an innovative biostimulant seed treatment alone and in combination of other agronomic strategies have been evaluated.

Materials and Methods

A growth chamber experiment was set up in order to investigate the effect of a seed biostimulant, based on a bacterium (*Bacillus amyloliquefaciens* strain IT45), and a plant extract (*Cyamopsis psoraloides*). The experimental design was a factorial combination of two maize hybrids (different for early vigor but with the same FAO maturity class), two NP starter fertilizers at sowing placed in bands 5 cm close to the maize seed furrows (unfertilized vs. diammonium phosphate, DAP, applied at 150 kg ha^{-1}) and two seed treatments (untreated vs. biostimulant).

Sixteen kilograms of natural silty loam sub-alkaline soil, were weighed and placed, after mixing it thoroughly, in each plastic pot (27 cm length x 24 cm width x 28 cm height). Soil was not air dried, sieved, sterilized and mixed with quartz sand or other materials. Pots were placed in a controlled growth room with 50% relative humidity range, 12 h photoperiod, 700 μmol m^{-2} s^{-1} photosynthetically active radiation (PAR) and 14/17 °C (night/day) air temperature range. At 5 leaves emission stage (GS15) the plant height was measured in centimeters from the ground level up to the collar of the tallest fully developed leaf. At the same time, Leaf Area Index (LAI) was estimated according to Ruget et al. (1996). The Normalized Difference Vegetation Index (NDVI) and the Normalized Phosphorous Content Index (NPCI) were measured and calculated respectively by means the pistol grip (above each pot) and the leaf clip bundle (on the last unrolled leaf) using the NaturaSpec™ Portable spectroradiometer RS-5400®. At 49 days after sowing shoot biomass was determined for each plant plot.

In 2018 and 2019 growing seasons two field experiments were set up in North-West Italy: Carmagnola, in the same soil used in the growth chamber experiment, and Poirino (silty loam and sub-acid soil). The same experimental design of the growth chamber trial was adopted in each location and year. The treatments were assigned to experimental units in each site using a completely randomised block design with four replicates. Each plot consisted of 4 rows 0.75 m apart; the plot length and the alleys between the plots were 15 and 1 m, respectively. Ears were collected by hand at harvest maturity from 4.5 m^2 in the two central rows of each plot to quantify the grain yield. Grain moisture was analyzed using a Dickey-John GAC2100 grain analyzer. The grain yield results were adjusted to a commercial moisture level of 14%. Analysis of the variance (ANOVA) was performed for growth chamber and field experiment data with the maize hybrid, starter fertilization and biostimulant seed treatment as independent factors.

Results

As far as the NDVI value at GS15 is concerned (Table 1), the highest benefits in terms of plant growth and development, in the growth chamber experiment, have been observed on average for the starter NP fertilization (+60%), followed by the biostimulant seed treatment (+11%) and the use of a high early vigor hybrid (+8%). All compared factors significantly influenced plant heigh and LAI: on average the starter NP fertilization resulted in the highest increase, followed by the hybrid and the biostimulant seed treatment. The starter fertiliser and seed treatment significantly influenced dry shoot biomass: the fertilized plant at sowing showed the highest effect (+3.6 times than the unfertilized control) while the biostimulant seed treatment enhanced maize biomass by 21%.

In all field experiments starter NP fertilization significantly increase grain yield (+0.9 t ha^{-1}), while a significant effect of hybrid (+1.3 t ha^{-1}) and biostimulant seed treatment (+0.8 t ha^{-1}) were reported only in Poirino 2018 and Carmagnola 2019 (Table 2).

Table 1. Effect of the hybrid, starter fertilization and seed treatment on the agronomical parameters at five leaves emission stage (GS15) in the growth chamber experiment.

Factor	Source of variation	Plant height	LAI	NDVI	NPCI	Biomass
		cm	cm^2			g plant^{-1}
Hybrid	Control	11.83 b	164.81 a	0.25 b	0.14 b	1.08 a
	High early vigor	12.96 a	181.11 a	0.27 a	0.18 a	1.17 a
Fertilization	Control	9.84 b	93.33 b	0.20 b	0.12 b	0.40 b
	Starter	15.05 a	254.07 a	0.32 a	0.21 a	1.85 a
Seed treatment	Control	12.09 b	160.93 b	0.25 b	0.15 b	1.02 b
	Biostimulant	12.80 a	186.47 a	0.27 a	0.18 a	1.23 a

Table 2. Effect of the hybrid, starter fertilization and seed treatment on the grain yield (t ha^{-1}) for Carmagnola and Poirino field experiments in 2018 and 2019 growing seasons.

Factor	Source of variation	2018		2019	
		Carmagnola	Poirino	Carmagnola	Poirino
Hybrid	Control	17.15 a	16.13 b	14.88 b	14.98 a
	High early vigor	16.98 a	17.23 a	16.40 a	15.61 a
Fertilization	Control	16.56 b	16.24 b	15.24 b	14.87 b
	Starter	17.72 a	17.12 a	16.07 a	15.72 a
Seed treatment	Control	16.76 a	16.32 b	15.23 b	15.12 a
	Biostimulant	17.40 a	16.99 a	16.15 a	15.47 a

Conclusions

This study showed the importance of agronomic practice on maize development and productivity, especially in early sowings in temperate growing areas. The starter NP fertilization at sowing led to the highest benefit in all agronomic and environmental situation. High early vigor hybrid and the biostimulant seed application are practice that should be considered to increase crop growth and yield. The synergistic effect of a high vigor hybrid and the biostimulant seed treatment had a positive effect on grain yield (+7%) compared to the untreated control; whereas this productive advantage increases by 13% if all the factors analysed are taken into account (high early vigor hybrid, the biostimulant seed treatment and the NP starter fertilizer at sowing).

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Spectral phenotyping of bread and durum wheat grown in North and South Italy in response to N and S fertilization strategies for yield, quality and sustainability

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Introduction

The achievement of higher sustainability, both in terms of higher resource use efficiency and of lower GHGs emissions, is a challenging goal of the EU 'Farm to Fork Strategy', which aims to reduce the fertilizers use by 20% (Cortigiani et al., 2022). On the other hand, the lower inputs should not contrast with the demanding requirements of food in terms of quantity and quality. In order to achieve these goals it is suggested that the the smart agriculture approach, with the use of low-emissions fertilizers and digital farming, could help to optimize agronomic management for crops (Raimondi et al., 2021). Non-destructive spectral phenotyping of crop physiological status and, in particular, the variability of crop N demand is a key aspect to achieve sustainable goals. To this aim, the response of four bread and durum wheat genotypes to different N fertilization strategies, including N rate, S supply, timing and co-application of nitrification inhibitors, was assessed by crop spectral phenotyping, under two Mediterranean environments of North and South Italy, characterized by marked climatic differences.

Materials and Methods

The field experiments were conducted during two crop seasons 2019-20 and 2020-21 in North Italy at Carmagnola (44°50' N, 7°40' E; 245 m s.l.m.) and in South Italy at Foggia (CREA CI, 41°27′03" N, 15°30′06" E; 70 m s.l.m.), called respectively TO and FG. The two environments are characterized by differences in annual mean temperature (11.6 °C at TO, 16.7 °C at FG) and rainfall amount (765 mm at TO, 565 mm at FG). At TO, soil was classified as silty loam with 2.25% of organic matter, 0.163% of total nitrogen (Dumas), 14 ppm of available phosphorous (Olsen method) and pH 8.1; on the other hand, soil at FG was loam with 2.39% of organic matter, 0.193% of total nitrogen (Dumas), 36.5 ppm of available phosphorous (Olsen method) and pH 7.8. Two bread and two durum wheat varieties were adopted: Bologna and Solehio as bread wheat cvs, Antalis and Saragolla as durum wheat cvs. In each environment and in each crop season a randomized block design with three replicates was adopted with 4 genotypes and 13 fertilization treatments with a combination of 4 N rates (0, 80, 130, 180 kg/ha) and 4 strategies including three double applications (50% at tillering and 50% at stem elongation) of ammonium nitrate (AN split), ammonium sulphate nitrate (ASN split), ammonium sulphate nitrate with nitrification inhibitor (ASNi split), the latter also tested as single application at tillering (ASNi single). A list of agronomic and crop physiologic traits, were evaluated: grain yield (GY) and its components, grain N uptake (GNU), agronomic N efficiency (NAE), apparent recovery efficiency (ARE), partial nutrient balance (PNB), grain protein content (GPC), test weight (TW) and spectral vegetation indexes (VIs including NDVI, WI, EVI, PRI – ASD FieldSpec 2 and Trimble GreenSeeker). Means were separated by least significant difference ($p<0.05$) and analysis of the correlation was performed by JMP (SAS).

Results

The different environments were characterized by differences in thermal and rainfall distribution during crop season (629 mm TO20, 663 mm TO21, 215 mm FG20 and 246 mm FG21). This resulted in a higher mean GY at TO than FG (5.3 t/ha and 8.3 t/ha at TO20 and TO21; 2.7 and 5.5 for FG20 and FG21). Overall, only Solehio in TO resulted in a higher GY, showing a better NAE and ARE. GPC was higher in Bologna and Antalis genotypes. The increase of N rate significantly increase GY and in higher extent GPC. The comparison between the different N fertilization strategies did not impact on GY and NUE, while only ASNI single showed a significant lower GPC. Significant relationships between NDVI and other VIs with GY and, especially, N uptake were observed (Figure 1). The correlation between NDVI and GY was higher at booting and decreasing with development, while in the ripening stages the higher correlation values were observed with GPC. The observed differences in crop productivity, sustainability and grain quality were dependent on the effects of environment, genotype and management.

Table 1. Effect of the genotype, environment and N fertilization on the investigated agronomic traits.

Factor	Level	NDVI			GY	GPC	N uptake	NAE	ARE	PNB
		4.5[a]	6.5	8.3	t/ha	%	kg /ha	kg / kg	%	-
Environment	TO-20	0.76 c	0.80 b	0.31 c	5.2 c	11.7 c	101.9 c	22.7 b	70.6 a	0.89 c
	TO-21	0.84 b	0.79 b	0.32 c	7.7 a	10.6 d	139.0 b	25.2 a	63.0 a	1.17 b
	FG-20	0.73 d	0.88 a	0.45 b	3.1 d	16.6 b	89.9 d	2.3 c	26.4 b	0.81 d
	FG-21	0.90 a	0.87 a	0.49 a	5.4 b	17.1 a	162.4 a	0.4 c	29.4 b	1.43 a
Genotype	Antalis	0.80 b	0.82 bc	0.34 c	5.2 b	14.1 ab	122.8 a	7.4 b	48.2 b	1.07 a
	Bologna	0.80 b	0.85 a	0.44 b	5.4 b	14.8 a	127.6 a	14.6 a	34.2 c	1.11 a
	Saragolla	0.82 a	0.82 c	0.29 d	5.3 b	13.6 b	120.0 a	8.5 b	44.4 bc	1.05 a
	Solehio	0.82 a	0.84 b	0.48 a	5.8 a	13.4 b	122.3 a	15.1 a	65.9 a	1.07 a
N rate (kg//ha)	0	0.71 c	0.73 c	0.33 b	4.0 c	12.2 c	88.9 d	-	-	-
	80	0.79 b	0.82 b	0.36 b	5.1 b	13.3 b	114.4 c	13.0 a	53.9 a	1.43 a
	130	0.81 a	0.82 a	0.40 a	5.5 a	14.1 a	128.0 b	11.2 ab	48.8 ab	0.98 b
	180	0.82 a	0.84 a	0.41 a	5.7 a	14.7 a	137.5 a	9.7 b	40.9 a	0.76 c
N strategy	AN split	0.81 a	0.84 a	0.40 a	5.4 a	14.4 a	129.7 a	11.6 a	52.2 a	1.09 a
	ASN split	0.81 a	0.84 a	0.39 ab	5.4 a	14.1 a	126.7 a	11.1 a	45.8 a	1.06 a
	ASNi split	0.80 a	0.83 a	0.38 ab	5.3 a	14.1 a	124.5 a	10.2 a	44.8 a	1.04 a
	ASNi single	0.80 a	0.83 a	0.37 b	5.3 a	13.8 b	123.1 a	10.0 a	44.1 a	1.03 a

[a] growth phenologic stage according to Zadoks scale: 4.5 = booting; 6.5 = anthesis; 8.3 = ripening.

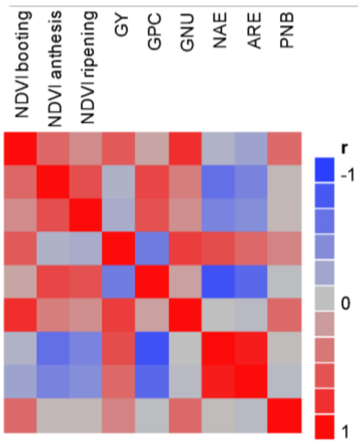

Figure 1 - Matrix of correlation

Conclusions

The spectral phenotyping carried out showed a good correlation between some physiological and yield investigated traits and the main VIs. The timing of phenotyping resulted a critical aspect to predict yield performance and N uptake in grains. Non-destructive spectral measurements assessing phenological and physiological varietal responses to different environmental conditions, can contribute to optimize agronomic management in relation to environmental sustainability, yield and quality. The use of special fertilizer (with nitrification inhibitor and/or S) did not result in a significant yield or qualitative difference, compared to the conventional split application as ammonium nitrate. Furthermore the different fertilization strategies, including the use of nitrification inhibitor, could play a key role in terms of mititgation of GHG emissions. Further analysis on gluten composition and technological quality are in progress.

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POSTERS

Fertilizer Source Affects Crop Yield Under Different Tillage Practices: A Meta-analysis

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Introduction

Farmers are clearly realizing how important sustainable agriculture practices are, to ensure the future of food security while maintaining healthy environment. Organic farming and conservation agriculture are considered as promising alternatives to the conventional managements for crop production taking into consideration the environmental impacts. Organic farming techniques have been extended for more than 6 folds, while conservation agriculture practices have been extended for more than 4 folds, in the last 20 years. The application of mineral fertilizers is extensively adopted to ensure the highest crop productivity, even if their misuse and massive application led to expensive and dangerous circumstances for the environment and human health. On the other side, several studies reported that the use of organic sources of nutrients is considered a suitable strategy for matching the production of safe and healthy foods and enhancing the restoration of soil fertility while mitigating the negative effects of climate change. Accordingly, environmentally friendly practices such as the replacement of chemical or inorganic (M) fertilization with other substitutes, such as mixed inorganic/organic (MO) or sole organic (O) fertilizers should be considered. Furthermore, integrating organic fertilizer application with conservation tillage practices could be a more suitable option for sustainable agriculture. Conservation tillage practices such as reduced tillage (RT) and no-tillage (NT) have advantageous effects over the conventional tillage (CT) regarding time and energy demanding. In addition, they affect soil health positively through improving soil structure, increasing soil organic matter, maintaining soil moisture, as well affecting water and nutrient use efficiency, which consequently influencing crop production. Such practices may prevent further losses, even it can be used to re-establish degraded lands. Several researches reported that under certain farming and environmental conditions, the yields of sustainable and conventional farming practices could be equal, even if the effects of organic fertilization and conservation tillage practices are not well understood, given the wide range of factors affecting agricultural activities. Improving the knowledge concerning the combination of organic nutrient sources under different tillage intensities may represent an important tool to help farmers for decision-making regarding different farming managements. This study focuses on evaluating the effects of organic fertilizers applied alone or in combination with mineral fertilizers compared with conventional fertilized crop, overall assembled studies, and when subjected to different soil tillage regimes.

Materials and Methods

A meta-analysis study was conducted to summarize the results of independent studies that have compared the impact of reducing soil intensities and low-cost nutrient applications, in terms of crop production. The sequential procedure of this study, described in a previous meta-analysis study (Allam et al., 2022). Two datasets were collected to compare the use of sole organic, and mixed O and M fertilizers, both in comparison with sole M application (Figure 1). The appropriate studies were selected using the following criteria: (1) three or more replicates per treatments; (2) comparison between the organic and inorganic fertilizers under the same field management and environmental conditions; (3) report the interaction effect of different fertilization sources under different tillage intensities on crop grain yield. According to these criteria, collected yield pair observations represent 50 studies from 28 publications, and 44 studies from 20 publications for (O vs. M) and (MO vs. M), respectively. The databases represent studies from 12 countries around the world, conducted on 13 different crop species in seven different soil textures. Complete list of references for all included studies are provided in (Allam et al., 2022). A random-effect meta-analysis was performed to compare the response of crop yield to O or MO instead of M. The natural logarithm of the response ratios (RR) was calculated as effect sizes. Subgroup analyses were conducted to assess the effect of different tillage practice on yield response. All statistical analyses were carried out using the R statistical software language.

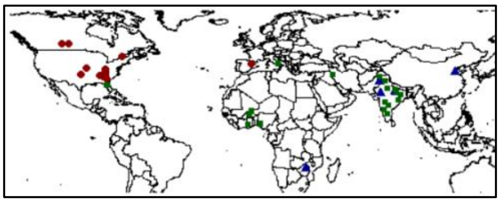
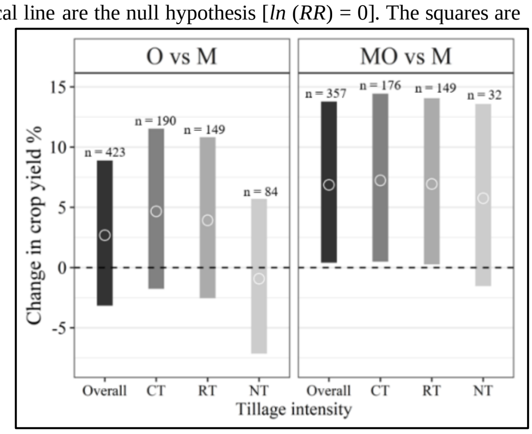


Figure 1. Locations of the studies included in the meta-analysis. Locations of studies evaluated organic (O) versus inorganic (M) nutrient sources, were presented by [■], and [●]. Locations of studies evaluated combined organic and inorganic (MO) versus inorganic (M) nutrient sources, were presented by [▲], and [●].

Results

The impacts of using organic fertilizer (O) or the combination of mineral plus organic fertilizers (MO) instead of mineral fertilizers (M) under different tillage systems on crop production are reported in Figure 2. In this study, the mean additional yield effect of O across all 423 observations is not significant (2.7 % ± 5.8 (95 % C.I.)). At the same time, including tillage practices as a moderator (fixed effect) has not resulted in significant impacts on crop yield when depending only on O fertilizers. However, applying only O sources led to positive impact on crop yield under CT and RT, while negative under NT. This suggests that other factors may be more important on their effect on crop yield. These factors may include site-specific conditions such as soil or climate characteristics. On the other hand, a significant impact was observed overall 357 observations (6.9 % ± 6.5 (95 % C.I.)) when applying MO relative to M fertilizers. Moreover, in comparison with M nutrient sources, crop yield response to MO varied with tillage intensity. MO had a significant positive impact under CT and RT. Positive impact was also detected under NT, but it was not significant. Overall, the effect of MO nutrient sources on crop yield was influenced by tillage intensity than when totally depending on O sources. The study highlighted the beneficial effect of combined application of inorganic and organic fertilizers on crop production, as organic fertilizers could supply crop plants with other nutrients needed, rather than continuously apply N, P and K for several years. In addition, these results confirm that conservation tillage practices such as RT can improve fertilizer use efficiency, as crop production has been enhanced matching the conventional tillage technique when using O or MO nutrient sources.

Figure 2. Crop yield response to organic vs. mineral (O vs. M), and mineral + organic vs. mineral (MO vs. M), represented overall observations, and under conventional (CT), reduced (RT), and no-tillage (NT) practices, expressed as the average effect on crop yield (%). (n) refers to the number of observations for each subgroup. The vertical line are the null hypothesis [*ln* (*RR*) = 0]. The squares are the point estimate of effect size. The horizontal lines are the associated 95% confidence interval for the population parameter.



Conclusions

The combined effects of sustainable farming practices RT with MO can improve soil health conditions which consequently led to higher crop yield production. These managements can greatly improve our environment health by reducing both conventionally farming managements; conventional tillage (plough) and conventional fertilizers (chemical). This analysis also helps to identify optimum farming practices which needed to support the ecosystem services of sustainable agriculture. Further research is necessary to investigate the relationship between MO and soil health properties such as soil organic carbon, especially under conservation tillage practices

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Sicilian Landraces Of Durum Wheat In Conventional And Organic Regime

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Introduction

In Sicily, more than fifty local hard and soft wheat populations have been conserved. Despite presenting low productivity, they highlight some significant agronomic characteristics such as tolerance/resistance to biotic (pathogens and weeds) and abiotic stresses, thanks to the wide adaptability to hot-arid Sicilian environments and droughts as well as to the high height of the plants, which makes them more competitive against weeds, while ensuring high production of the straw by-product (Amato et al., 2017). Several studies have also shown appreciable technological features, sensory, and nutraceutical properties such as high fibre content, antioxidants, vitamins, and minerals (Dinelli et al., 2009; Gallo et al., 2010). The aim of the present work was the agronomic comparison among 12 local Sicilian populations of durum and bread wheat compared to old and new commercial varieties of durum and bread wheat, under organic and conventional farming and under irrigated and dry conditions.

Materials and Methods

Twelve local Sicilian populations of durum wheat (“Bidì”, “Castiglione Glabro”, “Giustalisa”, “Margherito”, “Perciasacchi”, “Realforte”, “Ruscia”, “Russello – Priziusa”, “Russello Ibleo”, “Timilia”, “Tripolino” e “Urria”), one local Sicilian populations of soft wheat (“Maiorca”), one old variety of durum wheat (“Senatore Cappelli”), one commercial variety of durum wheat (“Mongibello”) and one commercial variety of soft wheat (“Bologna”), were cultivated in eastern Sicily, at the experimental farm of the University of Catania (37° 24' N., 15° 03' E., 10 m a.s.l.), in a clay soil. The studied varieties were grown under rainfed and irrigated conditions with organic and conventional cultivation methods. A randomized block experimental design was applied with three replications and plots of 10 m^2. Sowing was carried out on January 13th, 2021. In conventional farming, fertilization was carried out pre-sowing with 54 kg ha^{-1} N (ammonium sulphate) and 138 kg ha^{-1} P_2O_5 (mineral superphosphate) and at stem elongation phase with 26 kg ha^{-1} N (ammonium nitrate), and weeding was carried out using herbicide against dicotyledons (Axial 0.7 l ha^{-1} and Manta gold 3 l ha^{-1}). In the organic regime, organic fertilizer in pellet with 7% of N and 13% P_2O_5 was used by applying an amount to match the same amount of the mineral fertilization. Harvesting was carried out on July 2nd, 2021. Irrigation was carried out by a sprinkler system applying the 100% restoration of ETm from the stem elongation stage.

Results

The length of the period "sowing – earing" resulted in the earliest in the genotypes grown under the rainfed organic farming system (106.5 days), while the genotypes grown under conventional irrigated farming were the latest (108.97 days). The earliest variety resulted in the population "Tripolino", cultivated under irrigated and rainfed organic farming systems (99.5 days); the bread wheat variety "Bologna," grown both under rainfed conventional and irrigated organic farming, was the latest variety (123.5 days). Generally speaking irrigation delayed the earing phase in both farming regimes.

Regarding yield, on average, the highest value was obtained in the varieties grown under conventional rainfed regime (2.03 t ha^{-1}), while the lowest yields have been recorded in varieties grown under irrigated organic farming (1.14 t ha^{-1}).
In irrigated treatments, lodging negatively affected the yields, especially of local populations. On average, the percentage of lodging was 42.2% in the varieties grown under irrigated conventional agriculture and 40% in the varieties grown under irrigated organic agriculture. The lodging in the varieties cultivated under rainfed conditions was equal, on average, to 3.61% under organic farming and to 2.77% under conventional farming.
As far as the individual varieties are concerned, the highest yield was recorded in the commercial variety of durum wheat "Mongibello" cultivated under conventional rainfed farming system (3.91 t ha^{-1}), while among the local populations "Russello Ibleo", cultivated under rainfed farming system, have shown the highest yield (3.07 t ha^{-1}).
The lowest yield in all studied treatments was recorded in the commercial variety of soft wheat "Bologna", very late, dry-grown and organic farming (0.40 t ha^{-1}).

	Sowing-earing interval (gg)			
	Conventional		Organic	
	Dry	Irrigation	Dry	Irrigation
Bidì	108.5	113.0	108.0	108.0
Bologna	122.5	122.5	123.0	123.5
Castiglione G.	109.5	111.0	107.5	107.5
Giustalisa	104.0	106.0	105.0	106.0
Maiorca	110.0	114.0	109.5	112.0
Margherito	104.5	107.0	105.0	108.0
Mongibello	101.0	103.5	100.0	101.5
Perciasacchi	107.0	113.0	107.0	109.0
Realforte	107.0	110.5	109.0	112.5
Ruscia	105.0	105.5	103.0	104.5
Russello	108.5	113.0	108.5	109.5
Russello Ibleo	103.0	104.5	103.5	103.5
Sen. Cappelli	108.0	109.5	107.0	106.0
Timilia	104.0	105.5	104.0	103.5
Tripolino	102.0	102.5	99.5	99.5
Urria	104.5	106.0	104.5	104.5
Average	*106,81*	*109.18*	*106.50*	*107.62*
	Yield (t ha^{-1})			
	Conventional		Organic	
	Dry	Irrigation	Dry	Irrigation
Bidì	2.65	1.63	2.17	1.43
Bologna	0,41	0.63	0.40	0.56
Castiglione G.	1.33	1.75	1.26	0.92
Giustalisa	1.84	1.32	2.10	1.01
Maiorca	1.83	1.47	2.48	1.94
Margherito	2.22	1.85	1.99	1.20
Mongibello	3.24	3.91	1.56	2.02
Perciasacchi	2.19	1.42	1.84	0.78
Realforte	1.82	1.32	1.68	1.49
Ruscia	2.16	0.87	1.68	0.72
Russello	2.31	1.62	1.88	1.14
Russello Ibleo	3.07	1.22	1.90	0.61
Sen. Cappelli	2.28	1.46	2.04	1.49
Timilia	2.02	1.22	2.06	0.82
Tripolino	1.95	1.39	1.50	0.93
Urria	2.54	1.66	1.22	0.61
Average	*2.03*	*1.59*	*1.74*	*1.14*

Conclusions

In conclusion, the bio-agronomic comparison between the local and commercial populations of durum wheat and soft showed high variability in all studied characteristics. While the modern variety Mongibello produced significantly high in conventional farming compared to the organic one, most local populations did not show significant yield differences between the two types of farming. By contrast, the local population, selected in dry farming areas, cannot valorize the high soil water content and are affected by lodging.

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Effects Of Mulching Biofilms And Biostimulants Based On *Trichoderma* and *Ascophyllum nodosum* On Yield Of Industrial Tomato

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Introduction

The European Green Deal aims to reduce the use of synthetic chemical pesticides by 50% by 2030. Thus, novel strategies using low inputs of chemical products are highly desirable. Bioformulates consisting of living beneficial microbes or natural products used to improve crop growth and production or control phytopathogens represent fundamental issues of an Integrated Pest Management (IPM) program. Among the most widely beneficial microbes used in agriculture, there are several species of the fungal genus Trichoderma. In the last decades, increasing attention has been addressed also to plant biostimulants, as valid alternatives to chemical fertilizers. In addition, also the use of biodegradable mulching films drives more sustainable agriculture. The aim of this research was to verify the effect of sustainable agronomic practices on the yield of industrial tomato.

Materials and Methods

The experimental design compared: two biodegradable plastic mulching films (Ecovio® -Eco; Mater-Bi® -MB, and not covered soil – Bare soil), four treatments with biostimulants (not treated – Control; treated with a commercial product based on Trichoderma afroharzianum strain T22 (Trianum P®, Koppert) – Tric; treated with a seaweed extract from Ascophyllum nodosum (Phylgreen®, Trade Corporation International), -Bio, and treated with both products –Tric+Bio. The treatments with Tric were four, the first 3 as soil irrigation, the last as a foliar spray, starting from transplant and, then, by monthly based; the treatments with Bio were three and applied every two weeks, starting from 10 days after the transplant. The test was carried out at a private farm site in Frignano, with loamy soil, with 0.12% total nitrogen, and high content of potassium (1539 ppm), and 1.39% organic matter.
Tomato plants (*Solanum lycopersicum* varietà Heinz 5108) were transplanted on April 11, 2021, and harvested on 23 July. At the harvest, on six plants per treatment and replicates the total fresh weight of marketable fruits (expressed as tons per hectare), the number, and mean weight of marketable and green fruits were determined.
All data were subjected to ANOVA using the SPSS software (version 21.0, IBM, Chicago, Illinois) and the means were separated by the Tukey test.

Results

The marketable yield of tomato plants was significantly affected by the main effect of biostimulant treatments and mulching films (Fig. 1A and 1B). All three treatments with biostimulant enhanced yield without differences between them and with a 23.7% average increase over not treated plants (Fig. 1A). Obviously, the mulching elicited an 18.1% increase over bare soil and without differences between the two biodegradable films (Fig. 1B). As regards the other measured parameters, the number of marketable fruits was significantly affected by the main effects of mulching and biostimulant treatments, instead, the mean weight of marketable fruits and the number of green fruits were statistically affected only by biostimulants treatments (Table 1). As regards the number of marketable fruits, it showed a similar trend to yield, with 22.2% and 15.0% increase in mulching films, and biostimulant treatments over bare soil and not treated plants, respectively (Table 1). The mean weight of marketable fruits were higher in all three biostimulant treatments but the combination of two (Trc+Bio) was not different from Control (Table1). Finally, th number of green fuits was higher in all treated plants but only the plants treated with Trichiderma was significantly different from control (Table 1).

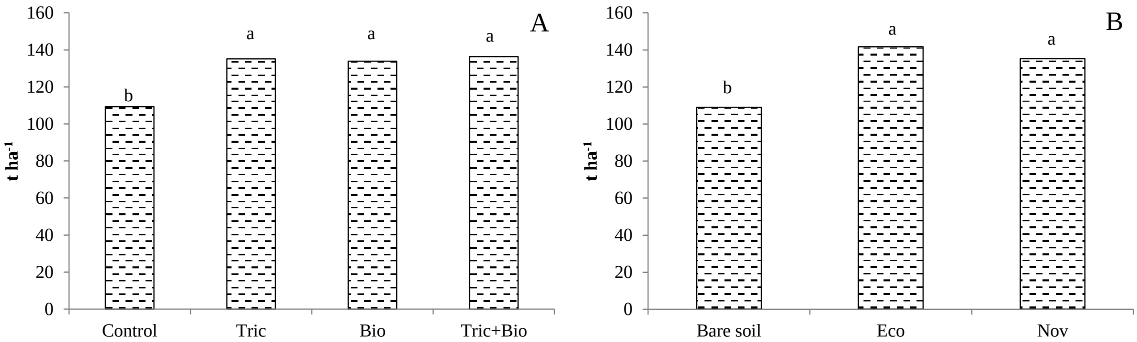

Figure 1. Marketable yield of tomato plants as affected by biostimulant treatments (A) (Control: not treated; Tric: treated with *Trichoderma afroharzianum*; Bio: treated with *Ascophyllum nodosum*; Tric+Bio: combination of the two biostimulans) and mulching films (B) (not covered soil: Bare soil; Eco: soil covered by Ecovio®; MB: covered by Mater-Bi®). Different letters indicate significant differences per $p < 0.01$

Table 1. Height, basal diameter, and number of hemp stems as affected by the main effect of sites, sowing density and genotype.

Factors	**Marketable fruits**		**Green fruits**	
	n° m^{-2}	gr $fruit^{-1}$	n° m^{-2}	gr $fruit^{-1}$
Bare soil	258.3 b	42.5	88.2	32.9
Eco	320.4 a	44.3	73.3	35.8
MB	311.0 a	43.5	72.1	31.0
Control	266.6 b	41.2 b	57.8 b	32.4
Tric	299.1 a	45.3 a	104.4 a	33.8
Bio	298.8 a	45.0 a	66.8 ab	32.3
Tric+Bio	321.7 a	42.3 ab	82.5 ab	34.5
Significance				
Mulching (M)	**	*NS*	*NS*	*NS*
Biostimulant (B)	**	*	*	*NS*
M x B	*NS*	*NS*	*NS*	*NS*

NS, *, and ** refer to not significant or significant at $p < 0.05$, $p < 0.01$ or $p < 0.001$, respectively.

Conclusions

The results highlighted a beneficial effect of both biodegradable mulching films on yield and marketable fruits, as well as of all biostimulant treatments (Trichoderma and seaweed). Other determinations on qualitative parameters of fruits are in progress, in order to evaluate also the possible interaction of the experimental factors.

Optimizing Sowing Date, Soil Tillage And N Nutrition To Improve Yield And Quality Stability Of Barley Grown In Mediterranean Environment

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Introduction

The cultivation of barley (*Hordeum vulgare* L.) is widespread in temperate and Mediterranean environments for livestock feeding and malting purposes, and it is generally adopted in the cropping systems for its good adaptability and lower nitrogen (N) requirements, compared to bread and durum wheat. High N supply can lead to high accumulation of N in grains, while market requirements are in a range comprised of 1.47-1.85% (Cammarano et al., 2020).

A site-specific optimization of agronomic management is strategic in order to improve, on one hand, grain productivity and quality stability and, on the other hand crop sustainability and mitigation. Therefore, the aim of this study is to individuate the best combinations in terms of sowing times, soil tillage and N fertilization associated to the higher stability in terms of grain quality. In order to take into account the large environmental variability that generally occurs under Mediterranean environments, a crop simulation model was adopted.

Materials and Methods

The field study was conducted at the farm level in south Italy, in a site located at Manfredonia (41°25'06.5"N 15°44'11.7"E, Foggia, IT) at 35 m a.s.l. Daily temperature and rainfall data were recorded by a weather station located at about 1 km. The soil texture was clayey according to USDA soil survey, with the following characteristics: 20% sand, 32% silt and 48% clay, 0.138% of total N (Dumas), 7 ppm of available P_2O_5 (Olsen) and 739 ppm of exchangeable K, 2.30% of organic matter (Walkley-Black). Cultivar Arda was adopted as genetic material. Direct sowing (no tillage, NT) was performed at 7/11/2020, with a seed density of 350 seeds / m^2, in a 2 x 5 m plots. The experiments consisted of 4 replicates and 3 N fertilizer rates: 15, 75 and 135 kg/ha of N. At sowing, 15 kg/ha of N and 38 kg/ha of P_2O_5 were applied, respectively as diammonium phosphate (DAP). Further N was applied at tillering (97 das) as urea. Herbicides and fungicides were applied according to the ordinary local agronomic practices. Anthesis and maturity dates (165 and 200 das, respectively) were recorded and grains were harvested. Grain yield (GY) and yield components were measured, and quality analysis was conducted on grains, including moisture and N content (NIR). DSSAT v4.7 (Hoogenboom et al., 2010) was used as a crop model in order to calibrate the genetic coefficients; validation was then performed on the published data reported by Montemurro et al. (2006). Climatic data were obtained by NASAPower database. Seasonal simulation was performed on 35 crop seasons (1984-2019), as refresing initial conditions at the beginning of every year. Simulation included a combination of 2 sowing date (S, S1 at 1/11, S2 at 15/12), 3 soil tillage managements (T, CT conventional tillage with ploughing, MT minimum tillage, NT no tillage) and 8 N fertilization strategies on the basis of the amount of N (kg/ha) applied at sowing and at tillering (N, 0+0, 0+50, 50+0, 100+0, 0+100, 50+50, 75+75, 100+100), as urea. Simulated data of crop phenology, productivity and N uptake were obtained, as for N concentration in grain. For each combination of agronomic a quality index was calculated by assigning a score of 1 if grain N concentration is within 1.47 and 1.85%, and of 0 if outside that range. Means of 35 years of simulation were separated by LSD (5%), in order to individuate the best agronomic combination in terms of quality index.

Results

Climatic data from 1984 to 2019 indicated a mean annual temperature of 17.0 ± 0.6 °C and a rainfall amount of 505.4 ± 99.1 mm. This variability reflected in terms of changes in GY and yield components. As reported in Figure 1, results of the simulation showed a marked effect of the agronomic management in relation to barley grain quality stability; in general, early sowing time and conservative agriculture, including MT and NT, were the most successful in terms of number of years with grain N concentration within the optimal range desired from the malting market (1.47-1.85%). As for N dose 100 kg/ha, both at sowing or split between sowing and tillering, resulted the best rate according to the quality goal, followed by the 0+50 N fertilization at tillering.

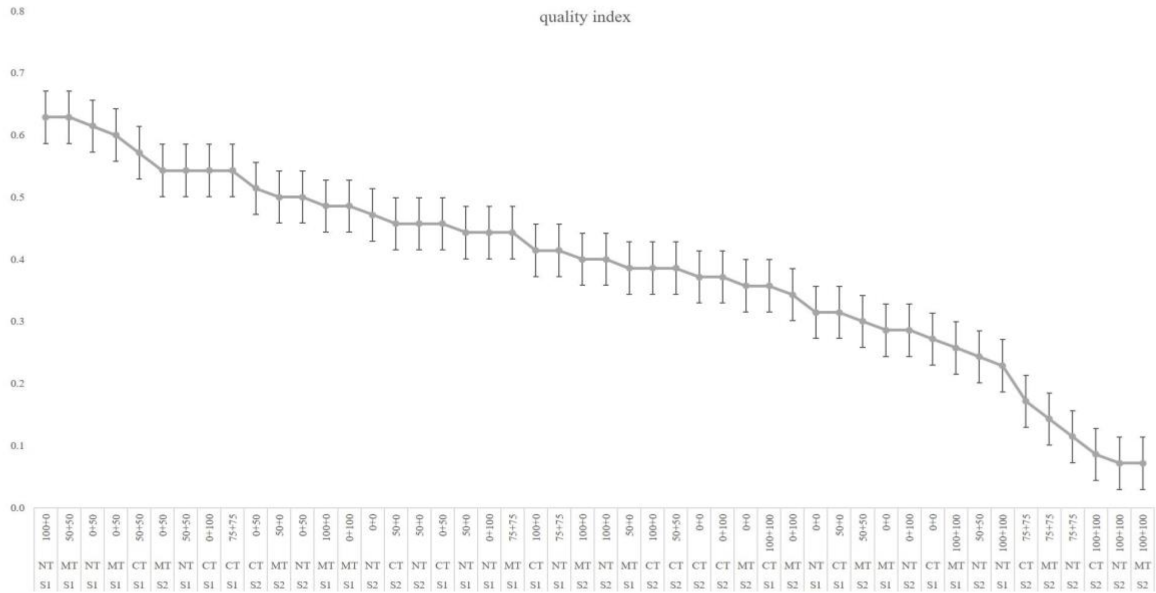

Figure 1. Quality index, expressed as mean ± LSD (5%), of the probability of success of each combination of S, T and N in terms of optimal N grain concentration for malting

Conclusions

Mediterranean environment, such as southern Italy, is characterized by frequent spring water deficit and high temperatures that limit grain filling duration and, then, final production. Most of the uptake of N occurs in the early stages, for winter cereals, when a higher soil water amount generally occurs in the soil. The optimization of agronomic management is critical for barley in these conditions, in particular for N supply since it is necessary a balance in terms of yield and quality, without exceeding with N in grains. The outcome of these studies can give indications in terms of agronomic management, in order to define the best combination of sowing time, tillage system and N fertilization strategy to optimize yield and quality, by also reducing GHGs emissions, with consequent environmental and economic benefits for farmers and along supply chain.

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Relationship Between Hyperspectral Phenotyping And Agronomic Performance Of Two Chickpea Genotypes Grown Under Different Water And Nitrogen Supply

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Introduction

Chickpea (*Cicer arietinum* L.) is a drought-tolerant crop, relevant for its beneficial effects in crop rotations with cereals and the production of seeds with high nutritional properties. Hyperspectral phenotyping by vegetation indexes (VIs) is generally used for cereals while fewer studies are available on chickpea (Zhang et al., 2021), especially in the Mediterranean environment. This study aimed to assess the relationship between the agronomic performance of two largely cultivated chickpea genotypes, Pascià and Sultano and hyperspectral phenotyping by vegetation indexes in two different sites in South Italy. For this purpose, different agronomic conditions were adopted, including two water regimes, three nutrition treatments, including the application of nitrogen and plant biostimulant from seaweed extracts (*Ascophyllum nodosum* L.).

Materials and Methods

Field experiments were conducted, in 2021, in South Italy at the Experimental Agricultural Farm "Pantano of Pignola" (40.5587 N and 15.7587 E, altitude 400 m above sea level) of ALSIA (Agency for the Agricultural Development and Innovation of Lucania), Basilicata Region and at Troia (Apulia 41.3610 N and 15.4218 E, 128 m above sea level), respectively named as Pignola and Troia. Soils were classified (USDA) as silt loam for Pignola and loam for Troia, with 96.6 ppm of available P_2O_5 (Olsen), 317 exchangeable K, 0.40% organic C (Walkley-Black), EC 337 mS/cm at Pignola and with 78.9 ppm of available P_2O_5 (Olsen), 590 exchangeable K, 1.94% organic C (Walkley-Black), EC 360 mS/cm at Troia. As genetic material, two chickpea genotypes were adopted, Pascià and Sultano (ISEA), respectively characterized by large and small seed sizes. Two water regimes were adopted: irrigated with weekly drip irrigation equal to 50% of crop evapotranspiration (minus effective rainfall) and rainfed. Daily weather data were collected, and potential evapotranspiration (PET) was calculated according to the FAO Penman-Monteith. Before sowing, 100 kg/ha of P_2O_5 were applied as triple superphosphate; a combination of three nutrition treatments was adopted: T1 with no N application, T2 with 40 kg/ha of N as urea at sowing and T3 as T2 with a supplemental foliar application of plant biostimulant from seaweed extracts (ANE, *Ascophyllum nodosum* L., Abyss, Sipcam). Chickpeas were sown with a seed density of 70 plants/m^2 at 31/03/2021 and 05/05/2021 at Troia and Pignola, respectively. At maturity, grains were harvested, and grain yield (GY) and yield components were determined. Quality parameters such as water-holding capacity (WHC), and protein content (PC) were also assessed, as reported by De Santis et al. (2020). Agricultural water productivity (AWP) as: AWP = GY / (I + P), where I is total irrigation amount (209.3 mm at Pignola, 181.3 mm at Troia) and P is total rainfall amount during crop cycle. At anthesis (GS 6) and during seed filling (GS 7), expressed as days after sowing (das) and thermal units (°C/d), two hyperspectral measures on canopy were assessed by a field spectroradiometer (Apogee SS-110) and the different vegetation indexes (VIs) were calculated: NDVI, OSAVI, EVI, PRI, CCCI, LAI.

Results

Weather differences between the two environments occurred, with higher rainfall in Pignola than Troia (140.2 mm vs 44.6 mm), resulting in a higher GY. Irrigation treatment allowed for a longer crop cycle in both environments (about 1750 °C/d in rainfed vs 1935 °C/d in irrigated conditions). Thus, a significant higher GY with irrigation supply was observed at Troia. Among all VIs, OSAVI showed the highest correlation with GY and seed weight, in particular during seed filling (GS 7). In particular, in this development stage higher OSAVI values were observed at Pignola than Troia (Figure 1a), indicating a higher crop vigour associated with a higher GY (Figure 1b). Genetic differences were observed with Pascià showing higher GY than Sultano, mostly explained by the higher seed weight and a generally higher AWP. While higher N supply at sowing showed a significant increase in GY and AWP, the application of plant biostimulant did not show an improvement in terms of crop physiological status and grain yield, under both irrigated and rainfed conditions.

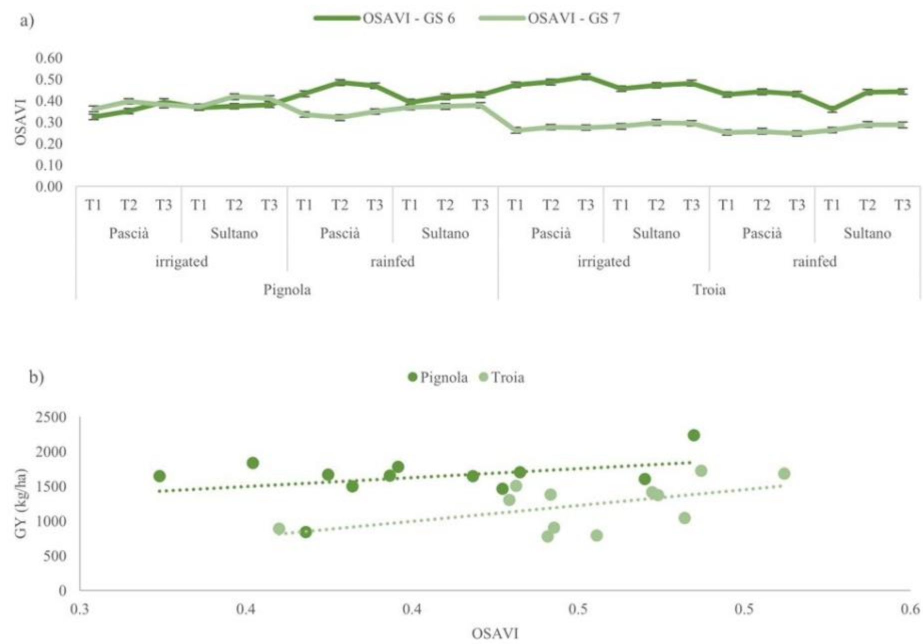

Figure 2. Trend of OSAVI during anthesis (GS 6) and seed filling (GS 7) for Pascià and Sultano chickpea cultivars grown under different irrigation and N regimes at Pignola and Troia, in 2021 (a) and relationship between OSAVI and grain yield (GY) in the two environments (b).

Conclusions

The outcomes of this study give useful data and information on crop phenotyping of key crops for sustainable cropping systems, such as chickpea. OSAVI index showed the best relationship with yield traits, possibly because of the higher impact of soil background in legumes with respect to cereals. The hyperspectral phenotyping carried out gave interesting results, in particular on individuating the optimal timing, grain filling, and vegetation indexes (OSAVI, EVI-LAI) that best describe the physiological status of the two investigated chickpea genotypes. These outcomes can be useful for the scientific community, field technicians and farmers, since little information is actually available on chickpea grown in the Mediterranean basin.

Literature

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Productive Response Of Three Varieties Of Fiber Hemp To Nitrogen Rate And Sowing Density

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Introduction
Industrial hemp (*Cannabis sativa* L.) cultivation is becoming an interesting opportunity for farmers due to the multifunctionality of this crop. It is well known that by adopting an appropriate hemp cultivar it is possible to obtain high-quality fiber. Due to its characteristics, industrial hemp can increase crop diversification and improve the agronomic and economic sustainability of farmers. Agronomic management plays a pivotal role in industrial hemp cultivation affecting both the quality and quantity of fiber hemp. Nutrient availability, as well as crop density, can modulate plant biometrics as well as fiber characteristics depending on the specific pedoclimatic conditions and the employed cultivars. The aim of this research was to assess the effects of different agro- techniques for fiber hemp cultivation on two private farms in the Campania region.

Materials and Methods
The experimental design was a factorial combination of three different hemp cultivars (Felina 32, Futura 75, and Carmaleonte), two sowing densities (150 pt m^{-2} e 300 pt m^{-2}), and three N fertilization regimes (0 kg N ha^{-1}, 60 kg N ha^{-1}, 100 kg N ha^{-1}). The experiment was carried out on two private farms of Campania Plain, in Caserta province, one in Frignano (FR) and the other in Casaluce (CS). Both soils were loamy, with 0.1% total nitrogen, and high content of potassium, but the first had 3.3% organic matter and the second 3.7%. The sowing was made on April 29, 2020, and the harvests were made on a 1 m^2 sample area on 17 and 20 July, in CS and FR, respectively. During the crop cycle, the total rainfall was 104 mm and the mean temperature ranged between about 10 and 14.5°C. At the harvest, the following measurements were made: number, height, basal diameter of stems, and total dry weight (after oven-drying at 60°C until reaching the constant weight) of hemp plants. All data were subjected to ANOVA using the SPSS software (version 21.0, IBM, Chicago, Illinois) and the means were separated by the Tukey test..

Results
The total dry matter of hemp plants was significantly affected only by the interaction between site and genotype (Fig. 1); it was higher in FR than CS, 14.5 and 12.6 t ha^{-1}, respectively. Interestingly, in Frignano the three genotypes showed a different productive response with Futura that reached the highest value (16.6 t ha^{-1}) and was different from all other treatments, also from Felina which showed an intermediate value of dry matter production (15.1 t ha^{-1}). Instead, in Casaluce, no differences were recorded between the genotypes, which were not different also from Carmaleonte-FR. As regards the characteristics of stems, only the main effects of site, sowing density, and genotype were significant (Table 1). At Frignano, the stems were more numerous and higher, but thinner than Casaluce. The sowing density obviously affected the number of plants at the harvest, notably, for both densities, this value was about half of the sowing density. In addition, at higher densities are corresponded stems of lower height and thickness, according to the results of Amaducci et al. (2002) who reported that in the early stages of growth, crops are stimulated to lengthen due to competition for light, producing longer and thinner internodes, then, the excessive competition would seem to limit the plant growth and, as a consequence, to high densities correspond to lower, thinner and with fewer internodes plants. FUT and CAR resulted

hiogher than FEL and, however, different between them; CAR also showed the greater basal diameter but the lowest plant density at the harvest.

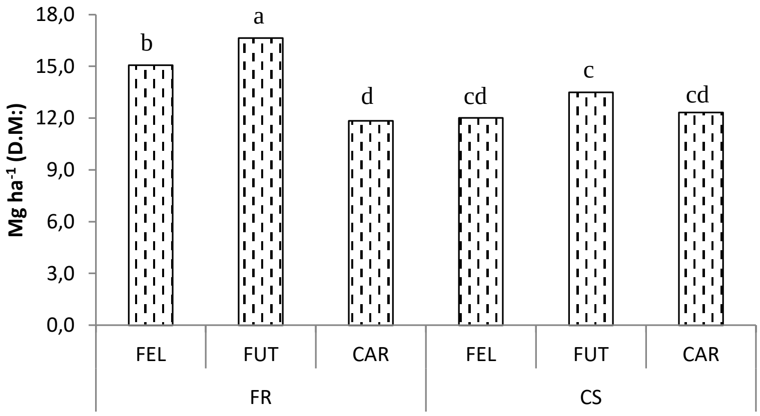

Figure 1. Total dry matter of hemp plants as affected by interaction site (FR: Frignano; CS: Casaluce) and genotypes (FEL: Felina, FUT: Futura, CAR: Carmaleonte). Different letters indicate significant differences per $p < 0.001$

Table 1. Height, basal diameter, and number of hemp stems as affected by the main effect of sites, sowing density and genotype.

Factors		**Stems**	
	Number	**Height**	**Diameter**
	n° m^{-2}	cm	mm
FR	114.5 a	174.5 a	5.2 b
CS	97.5 b	167.7 b	5.6 a
D150	79.6 b	176.2 a	6.0 a
D300	132.0 a	166.4 b	4.8 b
FEL	133.7 a	146.8 c	4.3 c
FUT	104.1 b	194.9 a	5.7 b
CAR	80.2 c	171.6 b	6.2 a
Significance			
Site	*	*	*
Density	**	***	***
Genotype	**	***	***

*, **, *** refer to significant at $p < 0.05$, $p < 0.01$ or $p < 0.001$, respectively.

Conclusions

The high native fertility of the two soils has nullified the response of plants to the N dose; among the varieties, FUT has shown the best performance in terms of dry matter production and stems characteristics, which last ones seem to be negatively affected by higher sowing density.

Literature

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The State Of European Agroforestry And Mixed Farming Policy

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Introduction

Agroecology has been defined by the FAO as “the application of the science of ecology to the study, design, and management of sustainable food systems, the integration of the diverse knowledge systems generated by food system practitioners, and the involvement of the social movements that are promoting the transition to fair, just, and sovereign food systems.” It is a food system approach to restructure the entire system, from the soil to the organisation of human societies. Further, it is dynamic in its nature, as it is a science, a practice and a social movement. Agroecology has the answer to solve many of the world’s most pressing issues, from greenhouse gas emissions to land degradation, biodiversity loss, water pollution, as well as social, economic, political, nutritional and food security issues. (HLPE, 2019; Hernandez-Morcillo et al. 2018). Plenty of food is already produced to feed the world, and agroecology holds the answers to ensure that food is grown with access and cultural sensitivity within territories that respect agricultural traditions and a level of food sovereignty that is needed in order to mitigate the emissions related to the transport (Willett et al., 2019; UNEP, 2016).

On the 25th of June 2021, the EU finalised its negotiations for the new Common Agricultural Policy (CAP) that is set to come into power on the 1 January 2023 and run until 2027. The Horizon 2020 project, Agroecology for Europe (AE4EU), took this opportunity to look at the the inclusion of agroecological Eco-schemes in the draft national strategic plans.

Materials and Methods

The data was collected through through literature reviews, policy document analysis and expert interviews during early 2022. The data was primarily secondary or tertiary, with most information coming from the CAP Strategic Plans themselves, government websites, civil society documents and academic papers. Several interviews with experts, researchers and civil society organisations were conducted to complement the research and fill in gaps in the data.

Results

AE4EU analysed the Eco-schemes that the Commission determined as agroecological. The project found that on average three agroecological Eco-schemes have been included, with five being the highest (Poland) and zero the lowest (Cyprus). The most popular Eco-schemes in the Strategic Plans are extensive grasslands management, use of cover/catch crops and organic farming, while the least are “mixed cropping - multi cropping” and “improved rice cultivation to decrease methane emissions,” with no Eco-schemes found in any of the countries. It is also important to note that these are just numbers and they do not necessarily mean that all are robust or have a high likelihood to succeed in what they set out to do.

While we cannot say just from this list that any country is doing best or worst, there are some interesting examples that can be picked out that show hope for success. The first is countries that have chosen to create multidimensional Eco-schemes (Czech Republic, Estonia, Latvia, Slovakia and the Netherlands) that encourage the implemention of multiple practices at once, as a single practice on its own has little strength in improving sustainability. Rather than a menu of options farmers can choose from, packages should be constructed in a way where complexity and synergy is created. Such Eco-schemes can then also ensure proportionality between the level of payment and the expected environmental benefits with higher subsidies given to farmers who are implementing these packages or several practices at once. Such packages could also include multiple tiers, with different levels of pay for different efforts, rather than flat rates. Secondly, it is important to maintain rigourous conditionality and not pay for practices that are already very common or quite basic. Funding should focus on demanding interventions that maintain fair rewards for farmers who want to make greater efforts to be more sustainable and provide ecosystem services. This would also fulfill the ideal of public money being used for public goods and to reward ecosystem services, for example carbon sequestration in agricultural soils, the development of ecological networks or conservation of semi-natural landscape elements. Lastly, the amount of funding that is devoted to each scheme is vital in the amount of farmers that will eventually take up the scheme. As it stands, the most interesting schemes will be those with low ambition, since they are often more funded than rigorous schemes.

Italy has chosen to include five Eco-schemes in its strategic plan, where three agroecological elements are found: cover crops between permanent crops, crop rotation with leguminous crops, and permanent grassland for biodiversity. Further, three of these Eco-schemes either limit or ban the use of pesticides. The support for organic farming will be through Pillar II, instead of valuing this practice that has proven environmental and economic benefits within the Eco-schemes. While this may seem insignificant since the support is still found, the Eco-schemes have a much larger budget than Pillar II which means they could adequately support farmers for their efforts and support more farmers.

Conclusions

To conclude, most Member States have the skeleton to what could be considered as efficient Eco-schemes but the ambition needs to be significantly increased in order to use the 9 billion euros that are devoted to eco-schemes to truly ecological practices. It is important to ensure that all Eco-schemes have clear environmental reasoning, ambitions, structure, roadmaps, outputs and objectives in order for agroecology to be used as the transformational tool for transition that it is. This can be augmented within the next phase, when the commission responds to each plan.

Increasing the agroecological elements that are found in all Eco-schemes is a vital componenent in order to ensure that the CAP aligns with EU legislations such as the Green Deal, and specifically the Farm to Fork Strategy. Fundamentally, it is a tool that helps us reach food security, better nutrition and an agriculture that supports our ecological systems instead of taking away from them.

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Productivity And Stability Of Two-Year Rotations With Winter Wheat In Long-Term Experiments

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Introduction

Long-term Experiments (LTEs) represent a very important tool to understand long-term effects of agronomic practices (Berti et al., 2016). This paper is based on a randomised LTE in central Italy, which was set-up in 1971 and is still running at present (2022). In this experiment, 13 rotations based on wheat are compared, wherein crop residues are either removed after harvest or buried into the soil at ploughing. In accordance with the original aims of this study, we have previously focused on the productivity and stability of wheat, as well as on the agronomic sustainability of those 'simplified' rotations (Bonciarelli et al., 2016). In this manuscript, we focus on all other ('non-wheat') crops in two-year rotations with wheat; the aims are to: (i) determine long-term productivity and stability, and (ii) try to relate year-to-year yield variations to environmental variables.

Materials and Methods

This experiment is located at the Experimental Farm of the Department of Agricultural, Food and Environmental Sciences (Papiano, PG, 42.96 N, 12.38 E, 163 m a.s.l.) on plain land, loamy soil and under rainfed conditions. It is laid down as a split-plot, with the management of crop residues as the main factor (burial or removal) and the rotation system (13 levels) as the sub-plot factor; all crops in all rotations are contemporarily present in all years; further details can be found in Bonciarelli et al. (2016). We focus on the following crops (in brackets, the years for which observations are available): (i) chickpea (*Cicer arietinum* L.; 1994-95, 1997-98, 2003, 2006-07, 2010-11); (ii) faba bean (*Vicia faba* L. subsp. *minor*; 1983-2012); (iii) grain-sorghum [*Sorghum bicolor* (L.) Moench; 1983-2012]; (iv) maize (*Zea mays L.*; 1974-2012); (v) oilseed rape (*Brassica napus* L.; 1983-91); (vi) pea (*Pisum sativum* L.; 1983-93, 1996, 1999-2002, 2004-05, 2008-09, 2012); (vii) sugarbeet (*Beta vulgaris* L. subsp. *saccharifera;* 1991-2012) and (viii) sunflower (*Helianthus annuus* L.; 1983-2012). All the crops were grown in two-year rainfed rotations with soft winter wheat (*Triticum aestivum* L.). Yield data were analysed by using a heteroscedastic mixed model with random years (Onofri et al., 2016), from where we derived long-term means for all crops and residues management, together with stability indices (i.e.: *environmental variance* and *Shukla's stability variance,* Piepho, 1998). Considering only the removal of crop residues, we also derived the Best Linear Unbiased Predictors (BLUPs) for the 1983-2012 period and for the four crops that occurred in all years (faba bean, grain sorghum, sunflower, and maize). This two-way matrix of yields was submitted to reduced rank regression, in order to elucidate possible effects of environmental variables on the patterns of year-to-year variability.

Results

Long-term yield averages were relatively low for maize, which is explained by the rainfed conditions (Tab. 1). Grain-sorghum and sunflower confirmed to be suitable choices for arid regions, while pea appeared to be, on average, the highest yielding among the legume crops. The year-to-year variability (*environmental variance*) was rather low and equal to, approximately, 10% of the overall mean (the SD across environments is reported in Tab. 1). Maize was the most resilient crop (6%), followed by sunflower (8%); sugarbeet and grain-sorghum showed the most unstable yields. The 'crop x environment' interaction was very big (*stability SDs* in Tab. 1), although small cross-over effects were observed and the ranking among species was approximately constant across years. Burying the residues of the previous wheat crop, on average, produced small and positive effects, ranging from 1.1 (chickpea) to 9.3% (oilseed rape) yield increase. The only exception was faba-bean, where 5.6% yield reduction was observed. It is confirmed that, on average, wheat yield is maximised when this crop is grown after a legume (faba bean or chick-pea), while oilseed rape is not a good previous crop for wheat (Tab. 1).

Table 1. Average yield level and stability traits (BLUPs from a mixed model fit) for eight crops in two-year rotations with wheat, as observed during a LTE in central Italy.

Crop	Yield (t/ha)	Interval (t/ha)	N	Env. SD (t/ha)	Stab. SD (t/ha)	Ranking (min – max)	Burial[d] (t/ ha ± SE)	Wheat[e] (t/ha ± SE)
Chickpea	1.83[a]	1.16 - 2.38	30	0.26	1.38	8 – 8	0.02 ± 0.67	6.18 ± 0.25
Faba bean	2.39[a]	1.69 - 2.91	93	0.27	1.39	5 – 6	-0.14 ± 0.38	6.02 ± 0.12
Grain-sorghum	5.53[a]	2.89 - 8.35	93	0.99	1.20	2 – 4	0.22 ± 0.49	5.92 ± 0.12
Maize	4.31[a]	3.60 - 4.82	120	0.26	1.38	2 – 3	0.08 ± 0.33	5.67 ± 0.10
Oilseed rape	1.94[a]	1.23 – 2.45	24	0.26	1.38	7 – 7	0.18 ± 0.75	5.45 ± 0.15
Pea	3.15[a]	2.47 - 3.99	63	0.31	1.44	3 – 6	0.06 ± 0.47	5.81 ± 0.13
Sugarbeet	45.5[b]	26.6 – 75.8	69	10.2	8.68	1 – 1	1.34 ± 4.49	5.94 ± 0.14
Sunflower	3.09[c]	2.39 - 3.61	93	0.26	1.38	4 – 5	0.06 ± 0.39	5.86 ± 0.12

[a]: 13% moisture content; [b]: fresh weight; [c]: 7% moisture content; [d]: additive effect of burying crop residues, with respect to removing them; [e]: average yield level for wheat, following each of the crops under consideration.

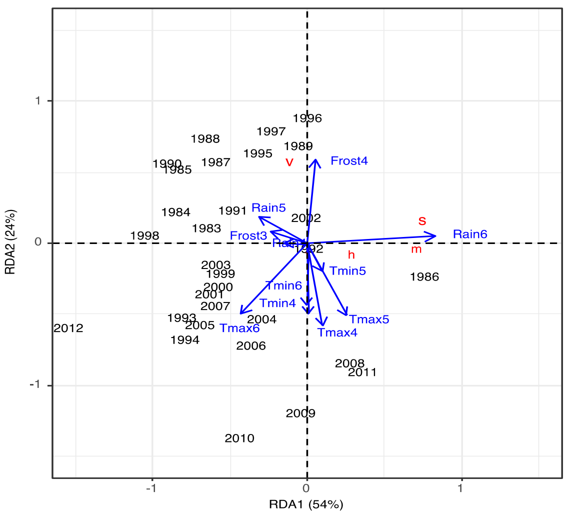

Figure 1. Results of reduced rank regression for four crops in 30 years; v=faba bean; s=grain sorghum; h= sunflower; m=maize. See text for the environmental variables.

Considering the two-way table of yields from 1983 to 2012, a stepwise procedure showed that the environmental variables with the greatest impacts on productivity were maximum and minimum temperatures in April, May and June (Tmin4-6; Tmax4-6), the amount of total rainfall in the same months (Rain4-6) and the number of frost days in March and April (Frost3-4). These environmental variables were able to explain only 36% of yield variability, confirming that other external variables (e.g. pests, cropping techniques, and innovation) may also greatly impact yield vartiability. The 'triplot' (Fig. 1) gave a good representation of the ‘environment by yield’ relationships (78%) and showed that maize and sorghum yields were mainly related the amount of rainfall in June, while faba bean was favoured by mild and rainy weather in April, May and June. Sunflower confirmed to be relatively unaffected by weather conditions, as shown by its positioning close to the origin of axes.

Conclusions

It is reinforced the importance of long-term experiments to obtain relevant and reliable information on productivity and stability of cropping systems and relationship between yield and environmental variables also in a context of climate change.

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Development Of A Cover Crop Frost Damage Simulation Model

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Introduction

The timing of cover crop sowing and termination greatly affects the agro-ecological services provided by the cover crop itself. To maximise cover crop benefits, identifying the correct timing for these operations is crucial. Autumn-winter cover crops, when exposed to sub-zero temperatures exceeding their frost tolerance, can be terminated by frost (winterkill termination). The success of this method relies on a variety of factors: crop frost tolerance, development stage (that influences cold hardening), and weather conditions during winter. The few studies regarding frost tolerance of *Sinapis alba* L. (white mustard) are of local interest. Estimating the frequency of winterkill by applying a simulation model will allow the comparison of crop management options for farms or regions. To the best of our knowledge, no winterkill simulation model is available for cover crops. In addition to modelling, satellite-based remote sensing can be used to monitor the extent and timing of frost damage. Therefore, the aims of this work were to (i) review existing frost damage models, and implement the most promising in a dynamic cropping system model; (ii) perform a sensitivity analysis of the frost model; (iii) calibrate it for white mustard.

Materials and Methods

The model by Byrns et al. (2020) was selected among the other models retrieved from a literature search. This model expresses frost tolerance as the "Lethal Temperature 50" (LT_{50}, °C), defined as the temperature at which 50% of the plants are killed (Bergjord et al. 2008); it simulates the daily change of LT_{50} accounting for the physiological processes of hardening (frost tolerance acquisition) and de-hardening and two stress responses involved in the loss of frost tolerance. This model was implemented in the dynamic cropping system simulation model (ARMOSA, Perego et al. 2013), which simulates crop growth and development, soil water, and nitrogen dynamics at a daily timestep, with the aim to enable the simulation of frost-sensitive crops. An empirical relationship between LT_{50} and soil temperature was used to decrease the aboveground biomass (AGB) when soil temperature < LT_{50}. To select the parameters that need to be calibrated to adapt the model to cover crops, a global sensitivity analysis was performed (based on Saltelli et al. 2010) for each combination of three sowing dates and three sites, during 20 years (autumn 1999 - spring 2020), chosen to represent the variability of European climates and sowing dates. Field measurements of white mustard AGB and visual assessment of frost damage symptoms were performed in six fields (Tab. 1) during the autumn-winter season 2021-2022 to obtain a calibration dataset and to set up a method to estimate frost damage using satellite data. Relationships between ground-measured frost damage and Sentinel-2 vegetation indices (NDRE and NDVI) were developed; then a procedure similar to that developed by Zhao et al. (2020) was applied to identify the timeframes when a decrease in the vegetation index can be accounted for a frost damage event, and the corresponding measured sub-zero temperatures. Finally, we calibrated the most relevant parameters: frost tolerance potential (LT_{50c}, °C), critical photoperiod ($PHOTO_{crit}$, °C), and an empirical coefficient (VRT_{fct2}, unitless).

Results

Winterkill was observed after the severe (T_{min} = - 4.8 °C at 50 cm height) night frost of 30/11/2021 in four sites. Significant ($P < 0.001$) relationships were detected between ground-measured frost damage in the weeks after the frost and the vegetation indices EVI, MMSR, NDRE, and CCCI (R^2 respectively 0.55, 0.69, 0.50, and 0.60). The candidate frost timeframes identified were consistent with field observations (as reported in Tab. 1). After calibration of the frost model parameters, winterkill dates and AGB were correctly simulated (see Fig. 1 for two sites with contrasting sowing dates).

Table 1. Monitoring campaign sites of the white mustard cover crop: observed and simulated dates of the first winterkill event, BBCH before the event, and percent damaged AGB (damaged AGB / total AGB).

Site	Sowing date	Field observed winterkill date	Winterkill timeframe derived from satellite indices	Winterkill date simulated by ARMOSA	BBCH before the event	Damaged AGB (%)
Alfianello (BS)	Sep 5	Nov 30	Nov 28 - Dec 1 (NDRE)	Nov 28	62 (Nov 23)	18.3
Trezzo sull'Adda (MI)	Sep 15	Nov 30	Dec 3 - Dec 23 (NDRE)	Nov 28	50 (Nov 16)	25.5
Fontanella (BG)	Sep 15	Nov 30	Nov 28 - Dec 1 (NDRE, NDVI)	Nov 29	55 (Nov 16)	30.1
Ghedi (BS)	Sep 18	Nov 30	Nov 29 - Dec 1 (NDRE)	Nov 29	51 (Nov 23)	62.2
Castelleone (CR)	Oct 8	no	no	no	17 (Nov 19)	0.0
Tribiano (MI)	Oct 20	no	no	no	13 (Nov 19)	0.0

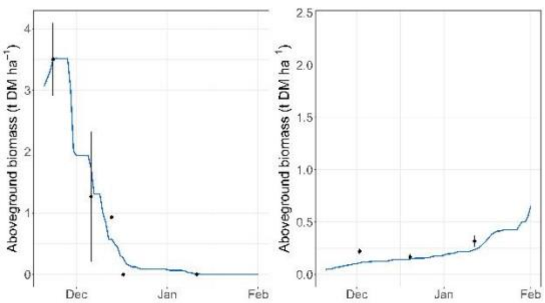

Figure 1. Simulated (continuous lines) and measured (points) non-damaged aboveground biomass in Ghedi (on the left; sowing on Sept 18) and Tribiano (on the right; sowing on Oct 20).

Conclusions

We demonstrated that satellite images can be used to retrieve information regarding white mustard frost damage, thus allowing to extend the calibration dataset to other fields not monitored on the ground. The calibrated model can be extended at a regional level, thus supporting the informed choice of cover crop species and sowing dates adapted to each environment.

Acknowledgements

We gratefully thank Marco Acutis, Marco Botta, and Alessia Perego for their support with ARMOSA model.

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Effect Of Innovative Sowing On Wheat Yield And Weeds Control In Two Internal Area Of Campania Region

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Introduction
Durum wheat (*Triticum durum* Desf.) is the most cultivated crop in many countries of the Mediterranean basin; in the last years, the organic cultivation of wheat is constantly increasing, but weeds control is one of the most limiting factors. Agricultural practices to reduce weeds competition provide for an increase in competitivity of the cultivated crops through an increase in sowing density, a more efficient seeding method, stubble cultivation, and the correct crop rotation. In several studies, it was observed that decreasing the inter-row distance can make crops more competitive against weeds. The aim of the present study was to compare two different types of sowing of the wheat in two areas of the internal hill of the Campania Region, assessing yield and its parameters, and the weeds presence.

Materials and Methods
The experiment was carried out on two private organic farms in the internal hilly area of the Campania Region (Fragneto L'Abate –BN, and Calitri -AV). At each site, two typologies of sowing were tested: sowing with an ordinary seed drill; innovative sowing with "Seminbio", a seed drill that keeps the same seeds density (400 seed m^{-2}) but with a reduced row spacing. The Fragneto soil was a clay-loam with 1.5% organic matter (OM), and 0.1% total nitrogen; the Calitri soil was sandy-clay-loam with 1.9% O.M. and 0.1% total nitrogen. During the growing period (November-July), the mean value of the minimum and maximum temperatures was 8.7°C and 8.2°C, and 18.6°C and 17.0°C, for Fragneto and Calitri. The total rainfalls were 932 and 1020 mm, in Fragneto and Calitri, respectively. At both sites, the sowing with durum wheat "Marco Aurelio" was made on November 6, 2021, and the harvests were made on the second ten-days of July. At the harvest, the following parameters were measured: grain yield, total aboveground biomass, harvest index, culms height, and presence of weeds, expressed as tons per hectare. All data were subjected to analysis of variance by SPSS (SPSS version 22, Chicago, Illinois) and the means were separated according to the Tukey test.

Results
The grain yield was significantly affected by the interaction between site and sowing typologies. The higher production was recorded at Fragneto, with the Seminbio sowing, which was statistically different from all other treatments (Fig. 1). Instead, at Calitri no differences between the two types of sowing were found and the yield was about 1.0 t ha^{-1} on average (Fig. 1). This productive behavior was probably due to the number of spikes per square meter which was 293.1 in Frigneto, and 249.1 in Calitri, on the mean. Also the total aboveground biomass (TAB) was significantly affected by the interaction between site and sowing typologies; it was higher at Fragneto than at Calitri (3.22 vs. 1.69 kg m^{-2}, respectively); once again, the Semibio sowing method showed values significantly higher than the all other treatments, while no differences between the two sowings were recorded in Calitri (Table 1). The HI was not significantly affected by experimental factors, with a mean value of 35.5%. As regards the plant height it was statistically higher in Fragneto but without differences between the sowings; the lowest value (30.7 cm) was recorded at Calitri. Finally, the presence of weeds was statistically higher at Calitri than Fragneto

(5.2 vs 1.4 t ha^{-1}), and in ordinary sowing (3.8 vs 2.7 t ha^{-1}), confirming the positive effect of Seminbio on weeds control.

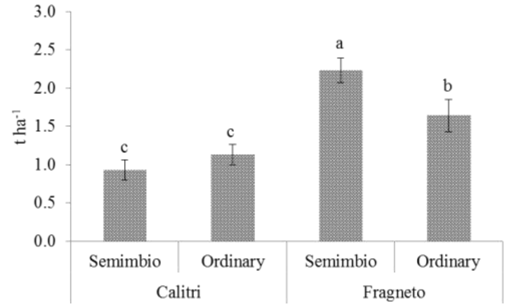

Figure 1. Yield of durum wheat as affected by the interaction of site (Calitri –AV, and Fragneto l'Abate –BN) and typologies of sowing (Ordinary: sowing with an ordinary seed drill; Seminbio: innovative sowing with a new seed drill). Different letters indicate significant differences at $p < 0.01$

Table 1. Total aboveground biomass (TAB), harvest index (HI), plant height, and number of spikes per square meter as affected by interaction of site (Calitri –AV, and Fragneto l'Abate –BN) and typologies of sowing (Ordinary: sowing with an ordinary seed drill; Seminbio: innovative sowing with a new seed drill).

Location	**Sowing**	**TAB** *kg ha^{-1}*	**HI** *%*	**Plant Height** *cm*	**Spikes** *n°m^{-2}*
Calitri	Seminbio	1.55 c	30.0	29.5	204.7 c
	Ordinary	1.83 c	31.5	31.9	249.1 bc
Frigneto	Seminbio	3.77 a	39.2	40.3	348.9 a
	Ordinary	2.68 b	41.1	40.1	293 0 b
Significance					
Location (L)		***	*	***	***
Sowing (S)		ns	ns	ns	ns
L x S		*	ns	ns	**

NS, *, **, and *** refer to not significant or significant at $p < 0.05$, $p < 0.01$ or $p < 0.001$, respectively.

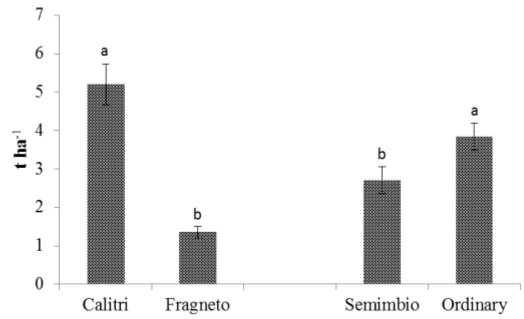

Figure 2. Total biomass of weeds as affected by the main effect of site (Calitri –AV, and Fragneto l'Abate –BN) and typologies of sowing (Ordinary: sowing with an ordinary seed drill; Seminbio: innovative sowing with a new seed drill). Different letters indicate significant differences at $p < 0.01$

Conclusions

The results showed a significant effect of the experimental site both on grain yield and weeds biomass, certainly depending on the different agronomic history of the two locations. In addition, our results highlighted a beneficial effect of the innovative sowing method "Seminbio" on wheat yield and weeds control, in the most productive location.

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Preliminary Suitability Analysis Of *Cv.* “Senatore Cappelli”: Effect Of Soil And Topographic Properties On Yield Variability

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Introduction

The durum wheat (*Triticum durum* Desf.) *cv*. "Senatore Cappelli" was selected by Nazareno Strampelli in 1915 for its adaptability in poor cultivation environments. Despite the very tall plants and low production, the grain of this cultivar is characterised by a high protein content (Pagnani et al., 2020). In the last years this cultivar has met considerable interest from the market for its technological quality and nutraceutical properties. Future European agricultural production will need to be at the same time more productive and more sustainable due to the increasing world population and climate change (Farooq et al., 2019). Understanding interactions between yield and topographical features and soil properties is fundamental knowledge for sustainable agriculture. Remote sensing allows collecting this information cheaply and quickly. Extraction of topographical features from Digital Elevation Model (DEM) is widely used (McBratney et al., 2003) while satellite bare soil images in the suitability analysis have not been extensively investigated. Recent studies have developed new methodologies to obtain bare soil images, such as the Geospatial Soil Sensing System (GEOS3) by Demattê et al. (2018). The objective of this study is: a) to determine how selected topographic information and soil properties can explain yield variability of *cv*. “Senatore Cappelli” at open field scale; b) to assess the ability to predict such variability through remote sensing data.

Materials and Methods

The 12-ha study area is located in the deltaic plain of Po River, near Massa Fiscaglia, FE, (44° 79' N; 11°98' E), in Northern Italy. A 2-year field experiment was carried out during 2020 and 2021 growing seasons. The climate of this area is temperate. In the season 2020, the sowing has been done on January 20^{th} with a density of 250 seeds m^{-2}, and the harvest has been done on July 10^{th}. In the season 2021, the sowing was done on December 15^{th}, 2020, with same density of 250 seeds m^{-2}; and the harvest was done on July 12^{th}, 2021. Each year, a 1 m^2 plot was harvested at each of 122 previously sampled sites. Weather data during the growing period of two seasons were collected by ERA 5 LAND (Hersbach et al. 2020). A soil sampling was carried to determine the predominant soil properties in August 2020. A grid of 122 points, 61 according to a regular grid and 61 chosen randomly, was used to take the sample from topsoil (0-30 cm), measuring soil texture and Organic Carbon. Several topographic indices were calculated by DEM provided by Emilia Romagna Region using QGIS software (Version 3.18.0). A multi-temporal bare soil image named SYSI (Synthetic Soil Images) was obtained by applying the GEOS3 using Sentinel-2 satellite data (Silvero et al. 2021) on the Google Earth Engine platform (GEE). From SYSI, VIS-NIR bands were extracted with a spatial pixel resolution of 10 meters. Principal Component Analysis (PCA) was run to investigate topographic variance and identify important variables (eigenvalues greater than one and loading values more than 0.40) to be used as inputs for suitability analyses. Correlation coefficients were calculated among the selected topographic variables, soil data, and yield. A stepwise regression was used to analyse the combined effects of soil properties and topographic data on crop yield. Finally, stepwise regression was performed again, replacing the soil data with SYSI VIS-NIR bands.

Results

The average yield in the first year was 4.55 t/ha, having a maximum of 6.30 t ha^{-1} and a minimum of 2.43 t ha^{-1}. In the second year, the average yield was 3.74 t ha^{-1}, recording a decrease of about 18% respect the first year. The maximum yield in 2021 was 5.86 t ha^{-1}, while the minimum was 3.74 t ha^{-1}.

The first four Principal Components (PC) were selected with a eigenvalue greater than one and cumulatively explained 90% of the total sample variance. Therefore, the most important topographical features selected by PC are: General curvature, Plan Curvature, Tangential Curvature, Elevation, Hillshade, and Maximal Curvature. Significant correlation ($p \leq 0.10$) between soil properties and topographical features were selected, in particular: Elevation was correlated with all soil properties: it had a strongly positive correlation with Silt (0.45), and a negative correlation with SOC (-0.30), Clay (-0.24), and Sand (-0.24). Moreover, SOC was correlated with Hillshade (0.37), Silt was correlated with Plan Curvature (0.15) and Maximal Curvature (0.24). Considering topographic features, yield and soil properties, yield in season 2020 had a positive correlation with the topographic feature, in particular with Plan Curvature (0.15) and General Curvature (0.31). In the second growing season, yield was negatively correlated with Maximal Curvature (-0.15) and General Curvature (-0.27). Finally, Stepwise Multiple Regression was performed to determine how selected topographic information and soil properties can explain yield variability. The covariates providing significant contribution to regression ($p < 0.10$) were retained in the regression equation. The covariates selected for the two seasons were:

Yield 2020 ~ Silt+Sand+SOC+General Curvature

Yield 2021 ~ Silt+SOC+General Curvature+Elevation

The coefficient of determination from Multiple Linear Regression between yields and soil properties and topographic features was 0.130 in 2020 and 0.135 in 2021. The Stepwise Multiple Regression was performed to assess the ability to predict yield field variability using remote sensing data, in particular replacing soil properties with SYSI. The covariates selected for the two seasons are:

Yield*(rs)2020 ~ Nir Band +General Curvature*

Yield(rs)2021 ~ Red Band+Nir Band+General Curvature

The coefficient of determination from Multiple Linear Regression between yields and SYSI VIS-NIR bands and topographic features was 0.112 in 2020 and 0.118 in 2021.

Conclusions

This study provided a preliminary suitability analysis for the sustainable cultivation of this specific cultivar of durum wheat. The results highlight that soil and topographic properties explain only 13% of within-field yield variability. Additional investigation is needed to study the possible correlation of wheat lodging and yield, this aspect is relevant for the sustainability of management. SYSI alone produced accurate predictions and confirm that it is a good way to quickly obtain information on soil variability and suitability for the cultivation of specific crop or cultivar type.

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Effects Of Different Nitrogen And Phosphorous Fertilization On The Grain Filling Dynamics Of Two Bread Wheat Varieties, Verna And Bolero

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Introduction

Soft wheat (*Triticum aestivum* L.) is one of the most cultivated crops in Italy, with 498.105 hectares and 30.532 billion of tones in 2015 (ISTAT, 2021). In Tuscany the soft wheat represents the first cultivated grain crops for invested area, with 26.855 hectares and with a production of 93.5986 tons in 2021 (ISTAT, 2021). Moreover, the ancient varieties are increased in the last few years thanks to their nutritional characteristics and their low needs for agronomic inputs. Soft wheat growth and development are strongly related to weather and fertilization treatments, especially nitrogen (N) and phosphorus (P). N is a nutrient of high importance for plant growth, development, and grain quality assurance, but it is also one of the most mobile plant nutrients in the soil. Adequate quantity of P in available source is vital for the growth, reproduction, yield and quality of wheat. P is essential for cell division, seed and fruit development. Phosphate and nitrogen fertilization, sowing density and irrigation have an impact in the relationship between amylose and amylopectin present in the starch of the grain. The composition of the starch, as the ratio between amylose and amylopectin, it affects the shelf life of bread as it is high in amylose favouring the permanence of non-free humidity. Some studies have investigated the effects of the fertilization treatments on the accumulation of amylose and amylopectin during the grain filling period considering foliar fertilization treatments (Lv et al., 2021) for the maximization of grain quality, but nobody also comparing ancient and old varieties.

The aim of this study was to understand and compare the biomass accumulation dynamic during the grain filling of two soft wheat varieties Bolero, the modern variety, and Verna, the old variety, considering 4 different combination of fertilization treatments (2 levels of N and P). Moreover, other wheat morphological parameters were analysed, such as the weight and the number of stems, leaves, spikes and gains. The presented results are preliminary for a more detailed analysis regarding the evaluation of the amylose and amylopectin accumulation during the grain filling period under different levels of fertilization treatments considering a modern and ancient varieties.

Materials and Methods

Two soft wheat varieties, Bolero the modern variety and Verna the ancient variety, were sowing for two years 2018/19 and 2019/20 in Asciano (SI), at Baccoleno farm. The experimental trials were carried out during the Regional project (PSR 2014-20) Pane + Days. The field trials, for both years, was organized in a randomized block scheme in which 3 levels of nitrogen (N1=45, N2=90, N3=145 kg N ha^{-1}) and 2 levels of phosphorus (P1=46 and P2=92 kg P ha^{-1}) have been tested in 3 randomized block (A, B, C). The varieties were sown on the 3rd of January 2019 and the 10th of January 2020. The phosphorous treatments have been done at sowing, while the nitrogen fertilization treatments have been done the 4th of March (50%) and the 3rd of April (50%) for the growing season 2018/19 and the 27th of February (50%) and the 15th of April for the 2019/20.

For both years, 5 samples have been carried out during the grain filling period for the combined thesis P1N1, P1N3, P2N1, P2N3. The samples' dates have been for 2018/19: 31 May, 13 June, 21 June and 5 July; for 2019/20: 26 May, 9 June, 26 June and 3 July. For each block and variety, 5 plants (replicates) have been collected. After 5 days at 70 °C, the material was weighted as total biomass, and then divided in stems, leaves, ear, husks, grain and also the number of the different biomass components (i.e. n° of stems, leaves, grains). Differences in agronomic performances among plants grown with different fertilisation treatments were assessed using a general linear mixed model (GLMM) fitted using R software v3.6 (R core team 2013) with R/lme4 (Bates et al., 2015) and considering blocks as random factors and varieties and fertilisation level as fixed. Then a post-hoc Tukey test for multiple comparisons among different fertilisation levels within the same variety was carried out using the same software.

Results

The outcomes of GLMM model indicated that blocks not differed significantly ($p < 0.05$). Fertilization combination of phosphorus and nitrogen significantly influence growing parameters on both varieties (Figures1 and 2): single plant dry weight significantly varied ($p < 0.05$) only among the different fertilization levels in Verna, with the lower value recorded for the higher fertilization dose (Figure1a).

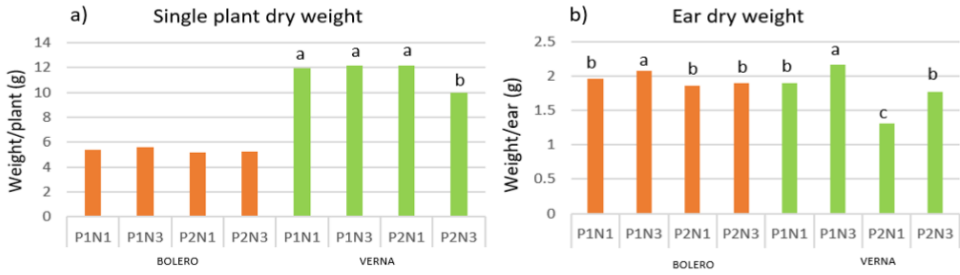

Figure 1. Single plant (a) and ear dry weight (b) for Bolero and Verna varieties under P1N1, P1N3, P2N1, P2N3 treatments.

The number of stems and ears didn't change according to the fertilisation rate within varieties, while n° of grains/ears ($P<0.005$) and leaves/plant ($P<0.005$) changed with different rate of P and N and with wheat varieties (Figure 2). In both varieties the low number of leaves and the higher number of grain/ears were produced by plants with P1N3 fertilisation. The higher ear dry weight was found for the P1N3 fertilisation.

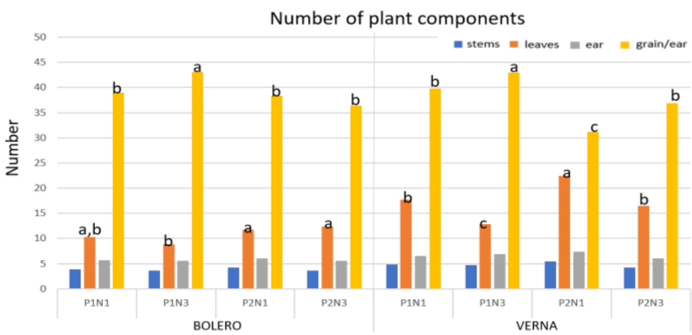

Figure 2. Number of plant components (e.i. stems, leaves, ear, grain/ear) for Bolero and Verna varieties under P1N1, P1N3, P2N1, P2N3 treatments

Conclusions

The presented results are preliminary, we are analysing the amylose and amylopectin accumulation in the grain samples collected during the grain filling period to assess the effects of fertilisation combination. These information with the presented agronomic performance data will allow us to better understand what happen during the starch accumulation phase in these two bread wheat varieties with different fertilisation. At higher N rate usually correspond higher morphological and productive parameter, but in combination with high P level this effects seemed to be reduced probably for the N-P interaction.

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Knowledge The research was founded by "G.O. Pane+Days" project financed by PSR- Regione Toscana and with the support of SYSTEMIC project ERA-NET ERA-HDHL (n° 696295).

Seeding Time And Rate Effects On Dhurrin Content And Yield Of *Sorghum bicolor* (L.) Moench

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Introduction

In recent years, the use of sorghum (*Sorghum bicolor* (L.) Moench) has been gaining popularity in agriculture as a heat and drought tolerant crop (Bean et al., 2013; Sarfraz et al., 2012). It is used for human food, animal feed, or as a cover crop to enhance soil physicochemical and control weeds and pests such as nematodes. Sorghum contains the cyanogenic glucoside p-hydroxy-(S)-mandelonitrile-β- D-glucoside (dhurrin) which can degrade into hydrogen cyanide (HCN) that can cause cellular asphyxiation and eventually ruminants death (Hoveland and Monson, 1980). High differences in dhurrin content were observed among cultivars (De Nicola et al., 2011) and with plant growth. It has been widely demonstrated that the highest concentration occurred in plants with 5 leaves or less (<100 cm height) (Martin et al., 1938; Vinutha et al., 2017). Furthermore, the content of dhurrin increases when plants grow under drought stress (Martin et al., 1938). No information exists regarding the effects of seeding rate on the content of dhurring. Our hypothesis is that seeding time and rates may affect yield and dhurrin content with effects on sorghum use.

Materials and Methods

A plot trial was established on 31st May 2021at the Experimental Agricultural Farm of Padova University in Legnaro, northeastern Italy (45°20′ N, 11°57′ E, and elevation 8 m). The location has a humid subtropical climate, with an annual rainfall of 820 mm mostly distributed from April to November and a mean annual temperature of 12.6°C. Sorghum 'Pampa Triunfo' was seeded in a strip-plot design with three replications at two seeding rates: 20 and 40 g m^{-2}. The soil at the site was a silty loam with a pH of 8.1. Plots of 11.04 m^{-2} were split into subplots where five plants were randomly collected at 60 and 100 cm height and immediately frozen. Subsequently, plants were freeze-dried and grounded to determine the dhurrin content using the method introduced by De Nicola et al. (2011). Furthermore, the aboveground biomass fresh weight of each subplot was measured and a subsample of 0.5 kg was collected and dried for 36 h in a drying oven at 105°C to determine DM yield. The dhurrin production per hectare was calculated based on dhurrin content and DM yield. The experiment was repeated by seeding a new trial on 15th July 2021. The plots were irrigated only during establishment by applying 5 mm d^{-1} of water. Dry matter yield, dhurrin content, and dhurrin production were subjected to ANOVA using R 4.0.2 (R Core Team, 2020).

Results

Dry matter yield was affected by seeding rate and plant height, while dhurrin content by the interaction between seeding rate, seeding date, and plant height (Table 1).

The dry matter yield was higher for sorghum seeded at 40 g m^{-2} (4.41 vs 3.47 t ha^{-1}) and for plants cut at 100 cm height (4.63 vs 3.25 t ha^{-1}). The only significant difference in dhurrin content was found between plants seeded in May and cut at 100 cm for both seeding rates, and plants seeded in July at a rate of 40 g m^{-2} and cut at 60 cm (Table 2). As reported by other authors (De Nicola et al., 2011; Martin et al., 1938), we found a tendency for the dhurrin content to be higher in young plants (60 cm height). However, this tendency was not found in the sorghum seeded in July with the lowest seeding rate. It seems that intraspecific competition did not have a deterrent effect on dhurrin accumulation as no significant differences in dhurrin content were found between seeding rates at the same cutting height.

Table 1. Results of the analysis of variance testing the effects of dry matter yield, dhurrin content, and dhurrin production of sorghum 'Pampa Triunfo' established with two seeding rates (20 and 40 g m^{-2}) on 31th May and 15th July 2021 at the Experimental Agricultural Farm of University of Padova in Legnaro, northeastern Italy (45°20' N, 11°57' E; elevation 8 m).

	Dry Matter	Dhurrin %	Dhurrin/ha
Seeding rate (Sr)	**	ns	ns
Seeding date (Sd)	ns	ns	ns
Plant height (Ph)	*	ns	ns
Sr x Sd	ns	ns	ns
Sr x Ph	ns	ns	ns
Sd x Ph	ns	ns	ns
Sr x Sd x Ph	ns	*	ns

Table 2. Seeding date effect on dhurrin content (%) of sorghum'Pampa Triunfo' seeded at two seeding rates (20 and 40 g m^{-2}) and cut at 60 and 100 cm height.

Seeding date	20		40	
	60 cm	100 cm	60 cm	100 cm
31th May	0.26 ab	0.15 b	0.22 ab	0.15 b
15th July	0.24 ab	0.26 ab	0.36 a	0.20 ab

Conclusions

Our study showed that the dhurrin content in sorghum 'Pampa Triunfo' was not affected by seeding rate nor by seeding time. Increasing the seeding rate from 20 to 40 g m^{-2} increased DM yield, but the dhurrin per hectare did not increase due to a slight dhurrin depletion in plants cut at 100 high compared with those cut at 60 cm high. These results suggest that feeding ruminants with sorghum harvested at 100 or 60 cm high causes the same negative effect regardless of the seeding rate used. On the other hand, increasing the seeding rate from 20 to 40 g m^{-2} and reducing the cutting height from 100 to 60 cm do not increase the efficacy of sorghum in soil pests control.

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Broad Bean Productivity Under Conservation Agriculture

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Introduction

Conservation Agriculture is a farming system that promotes minimum soil disturbance (i.e. no- or minimum-tillage), maintenance of a permanent soil cover, and diversification of plant species (Hobbs et al., 2007; Rinaldi et al., 2022). It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increase water and nutrient use efficiencies and to improve and sustain crop production.

Broad or faba bean (*Vicia faba* var. *minor* L.) is a grain legume that improves soil fertility and for this has an important role in rainfed crop rotations and in sustainable cereal crops production. It can be also planted as cover crops and green manures, for its N fixation capability: in fact, many studies showed that substantial savings (up to 100–200 kg of N ha^{-1}) in the amount of fertilizer N required to maximize the following crop yield can be obtained using broad bean in rotation (López-Bellido et al., 1998).

The aim of the reasearch is to verify how conservation (No-Tillage) and conventional (Minimum-Tillage) agriculture systems could affect the quality and yield of broad bean.

Materials and Methods

The field experiment was established in 2013 in Foggia (South of Italy) in a rainfed area. The experimental design consisted of the comparison of conservation (NT, no-tillage) and conventional (MT, minimum-tillage) agriculture systems, arranged in a randomized block design with five replications. Elementary plot size was 120m × 80m.

The cropping system was a 2-year rotation of durum wheat with legumes or fallow. The MT treatment consisted of 2-3 passes of field disk cultivator (15 cm depth). In the 2020-21 growing season a non-selective herbicide (1.5 L 36% glyphosate per ha) was applied before sowing in the NT treatment. The sowing of broad bean o 23rd December 2020 (cv Vesuvio) was carried out with a no-till seeder equipped with disk type furrow openers. No fertilization was applied. Crop residues were removed in MT, and chopped and left on soil surface in NT treatment.

During broad bean growth cycle the following measurements were carried out: Leaf Area Index (in three dates) with LICOR LAI 2200; soil moisture at 0-30 cm (gravimetric method) at sowing and at harvest dates; seed yield and aboveground plant biomass at harvest (25th June 2021). Statistical analysis (ANOVA) was carried out according to the experimental design, and t-test as mean separation test.

Results

The crop development showed a LAI higher in MT than in NT in 2 out 3 measurement dates (Fig. 1). The final seed yield did not significantly differ between the two tillage treatments (1.06 vs 0.99 t ha^{-1}, respectively for NT and MT), while a greater 1000 seeds weight was observed in NT (Fig. 2): this highlights a plant health condition in seed ripening phase more favorable in NT than in MT. The total plant biomass (Fig. 3) did not significantly differ between the two treatments, and this produced an harvest index greater in NT than in MT (0.28 vs 0.25). The water balance indicated a larger soil water content at sowing and, consequently a capability of broad bean to extract more water in NT than in MT (Tab. 1); the WUE, both for seed and biomass, resulted similar between the two treatments.

Conclusions

The two tillage practices - NT and MT- experimented on broad bean did not influenced significantly seed and total aboveground biomass yields. The soil moisture content, and in particular the amount of depleted water from sowing to harvest, higher in NT than in MT, influenced positively the seed repening in the final part of growing season. This also confirms the positive effects reported in literature of conservation agriculture and in particular of NT, in environments where water availability is main yield limiting factor.

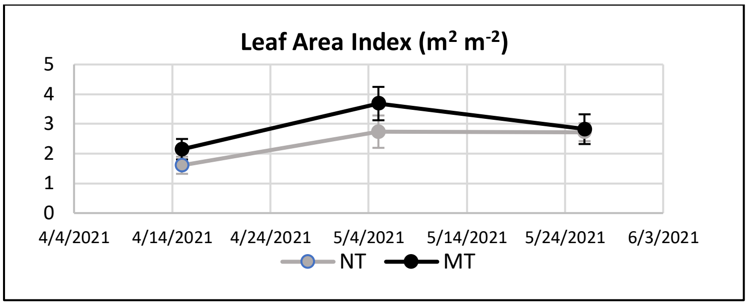

Figure 1. Leaf Area Index of broad bean, measured in 3 sampling dates. The bars indicate the standard deviations.

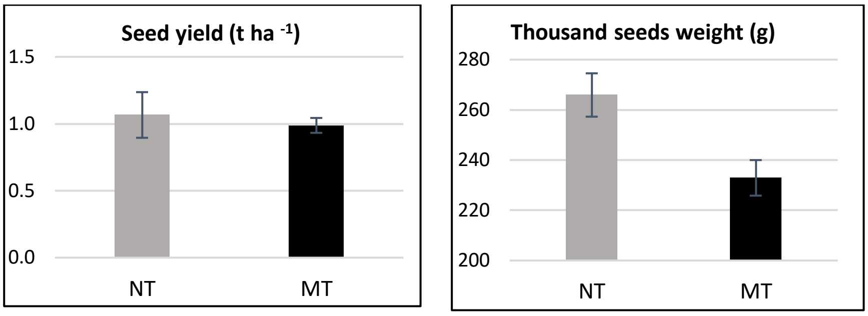

Figure 2. Seed yield and thousand seeds weight of broad bean in the two tillage treatments. The bars indicate the standard deviations.

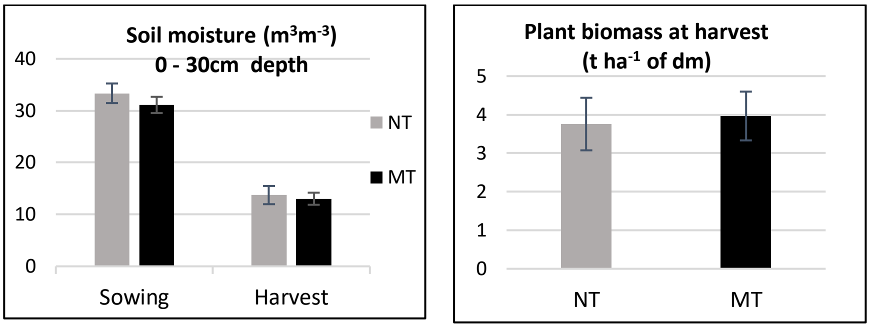

Figure 3. Soil moisture at 0-30 cm depth measured with gravimetric method at sowing and at harvest times and total broad bean biomass yield at harvest. The bars indicate the standard deviations.

Table 1. Water use and Water Use Efficiencies of broad bean (different letters indicate different values at P<0.05, t-test).

	Soil Water Depletion (sowing-harvest) in 0.6m (mm)	Seasonal Water Use (mm)	WUE_seed (kg ha^{-1} mm^{-1})	WUE_biomass (kg ha^{-1} mm^{-1})
No-Tillage	66.59±21.78 a	302.59±21	3.51±0.42	12.55±1.81
Minimum-Tillage	48.82±16.29 b	284.82±16	3.48±0.36	13.96±1.68

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Linseed As Opportunity For Increasing Cropping System Diversification and Resilience: The Sic-Oleat Project Experience

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Introduction

The use of suitable crop species and varieties and the diversification of cropping systems are key adaptive actions in response to weather challenges (Hufnagel et al., 2020). In this context, minor oilseed crops have been making their way into our diets and production systems, representing a reasonable choice in helping farmers to increase the efficiency of their food systems and to cope with challenging climate adversities and economic risks. The SIC-OLEAT project aimed to assess the adaptability of linseed (*Linum usitatissimum* L.), as source of vegetable oil and protein, to the pedo-climatic conditions of Tuscany Region (Central Italy), with a site-specific approach. Consequently, a 2-years field trial has been carried out in two contrasting environments, representative of the northern and southern coastal areas, respectively, comparing five commercial linseed varieties with the aim to hypothesize production path for the inclusion of this new crop within traditional rainfed cereal-based cropping systems.

Materials and Methods

Open-field trials were performed in 2020 and 2021 growing seasons, at the Experimental Center of DiSAAA-a, located in the lower Arno River plain (San Piero a Grado – SPG, Pisa province, 43°40’29’’, 10°18’47’’) and at the Tuscany Region Agricultural Center (TeReTo), located at Alberese (ALB, Grosseto province, 42°41’38’’, 10°08’29’’). In both sites, five linseed commercial varieties (Galaad, Libra, Sideral, Szafir, Kaolin) were compared in spring (07 April and 13 February 2020, in SPG and ALB rispectively) and autumn sowings (10 October and 11 November 2020, in SPG and ALB rispectively) within an organic system. In each site, plots of the different genotypes were arranged in a randomized complete block design with four replications with sowing time and cultivar as variability factors. The plot area was 18 m^2 (6 × 3 m) and a seed rate of 45 kg ha^{-1} has been adopted. Commercial organic fertilizer (2,8% N; 2,5% P_2O_5; 3% K_2O) was applied in each plot at 700 kg ha^{-1} rate. Harvests were performed on 20/07/2020 and 26/06/2020 for spring crops at SPG and ALB respectively, and on 30/06/2021 and 21/06/2021 for autumn crops at SPG and ALB. Daily metereological data (rainfall + temperature) were obtained by automatic stations located near each experimental site. Growing Degree Days (GDD) were calculated for each growing season with a 5° C T_{base}, and phenological development has been monitored according to Smith and Froment (1998). In both sites and growing seasons, soil physical and chemical characteristics were evaluated at a 30 cm depth at the beginning of the experiment. In both environments, soils used for spring sowing were sandy loam, while for autumn sowing, loam soils were used. At seeds maturity, sample areas of 1 m^2 for each plot have been manually harvested, collecting all above-ground plant biomass. Seeds and vegetative biomass dry matter yields were quantified on unit area. Afterwards Harvest Index (HI) and Thousand Seeds Weight (TSW) were obtained. Seeds oil content was determined by a FOSS-NIRS DA1659 analyser (FOSS, Hillerød, Denmark) and expressed on dry matter basis. Results were subjected to 3 way ANOVA (Cultivar x Sowing Date x Location), while comparison among means was performed using Tukey’s HSD test when the ANOVA F-test was significant at the 0.05 probability level.

Results

Costal site of southern Tuscany (ALB) was characterized by dryer climate compared to norther area (SPG); this is confirmed by higher cumulative rainfall observed in SPG in both year (Table 1). At the same time, a shorter crop cycle length has been observed in SPG compared to ALB (Table 1.). As reported in Table 2, linseed better performed in SPG respect to ALB, in terms of SY (2.1 vs 1.3 Mg ha^{-1}), HI (33.7 vs 32.6%) TSW (7.1 vs 6.8 g) and oil percentage (47.5 vs 46.0%). The best performance of linseed at SPG was mainly due to the higher rainfall amount registered in both growing seasons.

Table 1. Total rainfall, crop cycle lenght and GDD (mean value across cultivars) for each experimental site during the two years of trials.

	Total rainfall (mm)	Cycle lenght (days)	avgGDD (°C d)
SPG_2020	194	100	1377
SPG_2021	798	219	1463
ALB_2020	128	135	1245
ALB_2021	384	223	1656

Compared to spring sowing, autumn sowing reached higher SY (2.1 vs 1.2 Mg ha^{-1}), TSW (7.5 vs 6.6, g) and oil content (47.1 vs 46.5%), but a lower HI (29.8 vs 37.4%) was recorded in autumn crop than in spring one, probably due to longer vegetative development wich provided a more consistent translocation of photosynthetates and, in turn, a higher biomass production. Seed yield resulted genotype-dependent: Kaolin (1.9 Mg ha^{-1}) = Szafir (1.7 Mg ha^{-1}) = Galaad (1.7 Mg ha^{-1}) ≥ Sideral (1.6 Mg ha^{-1}) ≥ Libra (1.3 Mg ha^{-1}). A similar pattern was observed for HI: Galaad (36.6%) = Kaolin (35.1%) = Szafir (34.5%) > Libra (31.5%) = Sideral (30.4%). Likewise, TSW significantly varied depending on genotype, with the following trend: Galaad (8.0 g) > Szafir (7.5 g) > Kaolin (7.4 g) > Libra (6.5 g) > Sideral (6.0 g). The highest oil content was observed in Kaolin (48.1%) and Libra (49.3%), while Sideral (43.7%) showed the lowest value. Galaad (46.2%) and Szafir (46.5%) reached intermediate value. All productive parameters showed first-order interactions, while HI and TSW showed also second-order interaction (Table 2.). A detailed explanation of these interactions should take into account variations on each yield component such as tillering, number of capsule per stem, number of seeds per capsule, and water stress contrains during the vegetative development and grain filling.

Table 2. Results of three-factorial ANOVA for Seed Yield (SY), Harvest Index (HI), Thousand Seed Weight (TSW) and Oil content (Oil) on dry matter basis.

	SY	HI	TSW	Oil
Genotype	***	***	***	***
Sowing Date	***	***	***	*
Location	***	***	***	***
G x SD	n.s.	n.s.	*	*
G x L	**	***	***	n.s.
SD x L	***	***	***	***
G x SD x L	n.s.	**	*	n.s.

Conclusions

Although a remarkable variability has been observed depending on cultivar, sowing date and cultivation site, linseed showed good agronomic traits that make it suitable to be introduced in the tested environment, contributing to the local production of vegetable oil and to provide protein-rich meals/cakes for livestock. In general, autumn sowing coupled with milder and wetter conditions, like those observed at SPG, seemed to be more favorable for linseed cultivation. Among the tested varieties, Kaolin seems to have the highest production stability, while Libra, despite a good oil content, seems to have poor adaptation to the test areas. Aside from different development length, both "Sowing Date" and "Location" are meteoclimatic-related factors, and the presence of interaction of these with the factor "Genotype" reinforces the need for a site-specific approach for choosing the most suitable variety for each pedoclimatic context.

Acknowledgements

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High-throughput Plant Phenotyping: A Comparison of 2D- and 3D-imaging Strategies for Extracting Architectural Traits

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Introduction

The accurate and quick analysis of quantitative phenotypes (e.g., canopy size and space occupation) related to agriculturally important morpho-physiological processes has the potential to boost production in the fastest way. Image-based high-throughput phenotyping (HTP) enables the non-destructive monitoring of such traits, which may assist in selecting genotypes with increased yield potential and adaptability in a changing climate (Danzi et al. 2019; Li et al. 2021). In this contest, optical RGB sensors mounted on automatic phenotyping platforms have been widely applied to provide morphometric measurements in two- (2D) and three-dimension (3D) at an affordable price. However, these imaging techniques exhibit different performances in evaluating crop phenotypic traits depending on the geometry of the modelled canopy architecture. In our best knowledge, no previous study has focused on the comparison between the 2D and 3D plant phenotyping acquisition techniques, therefore, the aim of this work is the evaluation of the most suitable data acquisition method for the extraction of the main architectural traits from individuals with variable canopy structures.

Materials and Methods

The experiments were conducted at the ALSIA *Metapontum Agrobios* Research Center (Metaponto, Italy) on 20 maize (*Zea mays* L.) and 20 tomato (*Solanum Lycopersicum* L.) plants grown in 2 L single-pots under greenhouse conditions. From 26 to 61 Days After Sowing (DAS), maize and tomato plants were scanned at 2-day intervals using two imaging stations: (a) a LemnaTec Scanalyzer 3D System equipped with two 2-megapixel Visible light cameras (Briglia et al. 2019) and (b) a 36.3-megapixel commercial photographic camera mounted on the low-cost phenotyping platform of Rossi et al. (2020). Specifically, three images at 1:1 scale were acquired for each plant (top-view, 0° and 90° side-view; Danzi et al. 2019) into the Scanalyzer 3D unit. Then, 2D-image analyses were performed using the PlantCV package (Python) to segment the non-plant background. Next, the main morphological traits plant's height (*PH*), shoot area (*SA*) and convex hull volume (*CH*) were extracted (Marko et al. 2018). Parallelly, 45 RGB-images were collected over each sample (mounted on a 360º rotating plate delimited by 4 Rubik's cubes of 3cm edge) using a digital RGB camera for plant scanning and scaling. In this context, the 2D-image sequences were segmented and processed according to Rossi et al. (2020) to derive a 3D-dense point cloud of each plant for the extraction of *PH*, *SA* and *CH* via a Multi View Stereo-Structure from Motion (MVS-SfM) approach. The observed phenotypic traits were obtained through manual (i.e., *PH* and *CH*; Thorne et al. 2002) and destructive samplings (i.e., *SA*; Moriondo et al. 2016) on 3 (DAS: 26, 33, 40, 47, 54) or 5 (DAS: 61) randomly selected. Finally, the R^2, the rRMSE and the AIC were computed between image-derived and observed data for assessing phenotyping performance of the tested technologies.

Results

Results highlighted the effectiveness of the tested phenotyping methods (i.e., 2D image analysis and MVS-SfM 3D-reconstruction) in accurately reproducing the main determinants of shoot architecture over the time (Figure 1). In particular, both 2D- and 3D-imagery resulted adequate in estimating traits that are clearly visible from the boundary of the canopy (e.g., *PH*), while they showed different performances in handling inner plant targets (e.g., *SA* and *CH*) depending on their penetration ability within the surface of canopies with varying complexity.

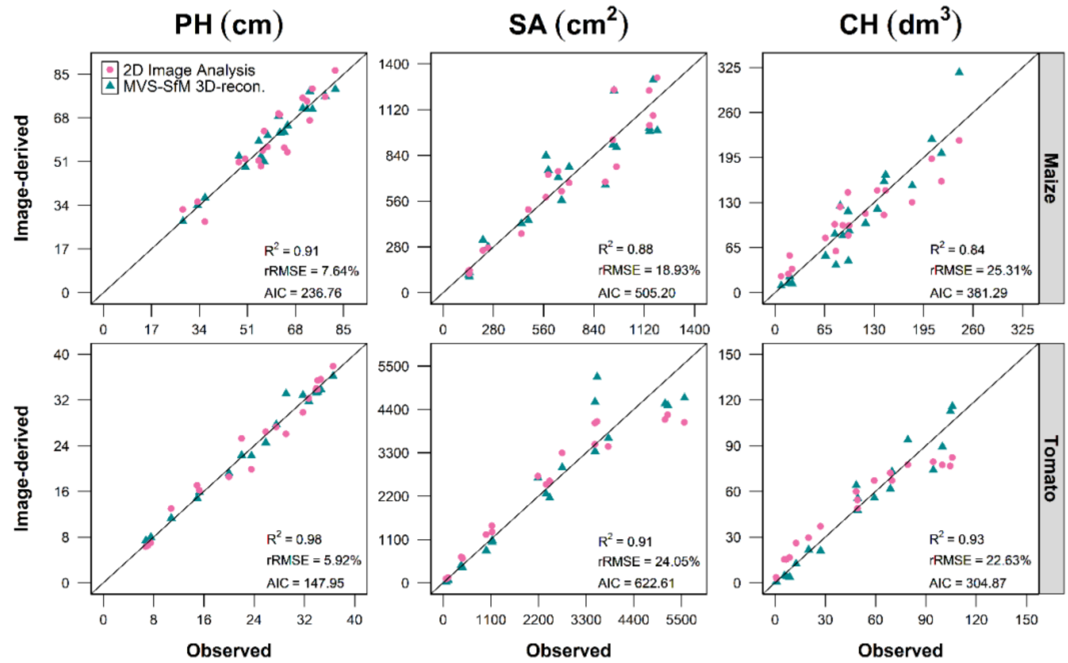

Figure 3. Plot image-derived and observed data for maize and tomato *PH*, *SA* and *CH* collected at the destructive sampling dates (DAS: 26, 33, 40, 47, 54, 61). The black lines represent 1:1 agreement.

Conclusions

Plant 2D- and 3D-imaging techniques were tested to evaluate the most suitable HTP strategy for maize and tomato. The results highlighted how 2D image analysis is advantageous to characterize non-complex canopies (e.g., maize), while MVS-SfM 3D-reconstruction offers better performance in disclosing phenotypic traits of plants with more complex architectures (e.g., tomato). Such evidences could help accelerate the use of image-derived phenotypic traits as input parameters driving the modelling of daily morpho-physiological processes (e.g., biomass accumulation, photosynthesis and transpiration) involved in crop yield potential, which benefits from high data accuracy.

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Evaluation Of Nand Phosphorus Response On Yield Traits Of Common Wheat (*Triticum aestivum* L) Under Different Agro-climatic Zone Of Afghanistan

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Introduction

Common wheat (*Triticum aestivum* L.) serves as a staple food crop for Afghanistan, followed by rice, barley, and maize. It contributes to about 60% of the total calories of the population diet; their annual per capita consumption reaches 181 kg (MAIL and FAO, 2013). Therefore, achieving sufficient wheat production will ensure food and economic security for Afghanistan (Soofizada et al., 2018). Nowadays, various improved varieties with high yield potential have been used, but still wheat production does not meet the national requirement (Sharma, 2019). Some opportunities in the wheat sector of Afghanistan are represented by proper crop management, the wide use of good quality seeds, and the use of fertilizers (Dreisigacker et al., 2019). In particular, nitrogen and phosphorus supply can play a vital role in plant development and optimal grain yield (Mussarat et al., 2021).

Materials and Methods

The experimental field was set up in Afghanistan at four contrast predominant wheat cultivation zones, from September 2016 to July 2018 (2 growing seasons, GS) under irrigation condition on alkaline soil (table 1).

Table 1. Site characteristics

Soil information	**Locations**			
	Baghlan	Balkh	Helmand	Herat
pH	7.50	8.12	7.91	7.60
Organic matter (%)	1.50	1.01	0.63	0.82
Available P (PPM)	8.50	5.41	6.12	7.54
Available K (PPM)	120	117	107	115
Total N (g kg^{-1})	1.00	0.61	0.70	0.85
Soil texture	Loam	Silty loam	Silty loam	Sandy loam

Sixteen treatments were planned, comprising 4 nitrogen fertilization rates (NL) (35.28, 65, 95 and 120 kg N ha^{-1}, namely NL35.28, NL65, NL95 and NL120, respectively) and 4 phosphorus fertilization rates (PL) (0, 50, 70 and 90 kg P_2O_5 ha^{-1}, namely, PL0, PL50, PL70 and PL90, respectively). One improved winter wheat variety (*Triticum aestivum* L.) was used for this study. Thus, 120 kg ha^{-1} seed was applied as uniform to all locations (L). The trail was arranged in split plot design (SPD) with three replications, NL was arranged in the main plot and PL was placed in the sub plot. The plot size was 1.5x5m (7.5m^2), each plot contained six row with a pacing of 0.25 m. Four middle rows with net experimental unite size 4 m^2 were considered for investigation. Analyses of data run by Rstudio version (R. 4. 1. 1).

Results

The main factors GS, L, NL, and PL significantly affected all the agronomic traits with the exception of the effect of NL and GS on SY (Table 2). Specifically, GY was been strongly influenced by NL as statistically different values were recorded at different nitrogen rates; therefore, the increases of GY for NL65, NL95, and NL120 was been of 10%, 17%, and 22% respectively compared to the minimum NL (NL35.28). Similarly, the highest HI was reported at NL120, but similar values were obtained at NL90 and NL120.

Table 2. Mean of grain yield (GY), straw yield (SY), and harvest index (HI) parameters, considering nitrogen level (NL), phosphorus level (PL), location (L), and growing season (GS) as factors. Lowercase letters show the Tukey HSD post-hoc test results, while the values inside parentheses represent standard error.

Treatments		**GY ($t\ ha^{-1}$)**	**SY ($t\ ha^{-1}$)**	**HI (%)**
NL ($kg\ ha^{-1}$)	35.28	3.89 (0.14) d	7.06 (0.24)	0.36 (0.06) c
	65	4.28 (0.15) c	7.18 (0.24)	0.38 (0.07) b
	95	4.56 (0.15) b	7.21 (0.23)	0.39 (0.07) a
	120	4.76 (0.16) a	7.33 (0.22)	0.39 (0.07) a
PL ($kg\ ha^{-1}$)	0	3.62 (0.13) d	6.26 (0.21) b	0.37 (0.08) b
	50	4.41 (0.15) c	7.30 (0.23) a	0.38 (0.07) b
	70	4.60 (0.16) b	7.56 (0.23) a	0.38 (0.07) b
	90	4.86 (0.15) a	7.64 (0.24) a	0.39 (0.05) a
L	BGL	5.95 (0.09) a	8.09 (0.13) b	0.43 (0.06) a
	BLK	2.95 (0.09) d	4.18 (0.12) c	0.41 (0.03) b
	HLM	3.41 (0.07) c	7.94 (0.16) b	0.30 (0.06) d
	HRT	5.18 (0.12) b	8.56 (0.18) a	0.38 (0.03) c
GS	1^{st} GS	4.67 (0.11) a	7.16 (0.15)	0.40 (0.07) a
	2^{nd} GS	4.07 (0.11) b	7.22 (0.18)	0.36 (0.06) b

In addition, the results showed that the addition of PL90 had significantly increased GY, SY and HI; in particular, the surge of GY at PL90 was of 34% with respect to the control (PL0). No significant differences were obtained between PLs with the exception of PL0, which resulted stiastically lower than other PLs. On the contrary, no significant differences of HI were detected between PLs, excluding PL90 which highlighted the highest HI compared to the other PLs. Moreover, result showed that GY, SY, and HI were completely distinctive for each location; the highest average GY and HI were recorded in BGL, while the lowest obtained in BLK and HLM, respectively. On the other hand, the highest value of SY was obtained in HRT, followed by BGL and HLM, while BLK showed the lowest SY. This result was confirmed by soil test and climate report. Location with the poorest N and P concentration in soil along higher pH content, recorded the lowest GY. Eventually, data showed that GY highly influenced by GS, therefore the 1^{st} GS demonstrated higher GY, as compared to the 2^{nd}. This suggests that probably due to the higher average of precipitation and lower temperature values in the 1^{st} GY.

Conclusions

It is concluded that in Afghanistan the NL and PL fertilization significantly increased GY as well as HI. Regarding SY, no significant effect was displayed by NL, which was in contrast with the significant effect demonstrated by PL. In addition, this study observed a huge difference result among the locations as well as growing season, because of site-soil variability and climate fluctuations. However, this study recommended a combined application of NL120/PL90 for farmer of BGL, BLK, HLM and HRT locations to achieve sustainably production, but further investigations in this regard also strongly recommended.

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Long-Term Experiment In Durum Wheat: Effect Of Residues Management And Nitrogen Nutrition Under Different Rotation Systems

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Introduction

Among cereals, winter durum wheat (*Triticum durum*, Desf.) represents a preeminent crop in Mediterranean countries, and southern Italy in particular, where the cultivation is practised on more than 1.21 Mha cultivated in 2021 and the productions are almost 4 MTons, used for the durum wheat industrial chain. In the last 50 years, wheat productivity has increased from 1.49 t ha^{-1} in 1970 to more than 3,0 t ha^{-1} in 2010. Different components have contributed to the increasing yields: soil management, rotation, plant protection and nutrition, crop technology, genetics and breeding. In particular, nitrogen application significantly affect wheat yield and grain quality (Tedone et al., 2015). In this last period, problems related to the need to reduce chemical application are emerging due to fertilizer prices increasing and the impact on the environment that nitrogen fertilizer causes. This creates huge pressure on farmers and the food industry to provide sustainable products and on scientists to offer significant knowledge to support and increase the sustainability of cultivations (Bowles et al, 2020). Long-term field experiments represent a very important source of information that can provide knowledge about the long-term effects of different fertilizers, crop rotations and climate conditions on the yield and quality of arable crops (Bonciarelli et al., 2016). With this note, we report the results of a 50-years long-term experiment on durum wheat.

Materials and Methods

The long-term experiment, which is still ongoing, was carried out at the Didactic Experimental Centre "E. Pantanelli" of University of Bari Aldo Moro, in the Policoro area (MT). The experiments were started in 1972 on a deep silty-clay soil, rich in organic matter, deep, and whit high fertility.

Three different crop rotations whit durum wheat as the main crops are compared:

- Rotation 1: Wheat monoculture, (Fc)
- Rotation 2: Wheat + catch crop (corn FAO class 200)
- Rotation 3: Triennial rotation (chickpea - wheat + catch crop (silagecorn FAO class 200) - wheat)

Two crop residue managements are compared (burn and soil incorporation of straw) and 3 combinations of N were compared :

- For wheat 3 N levels (0, 50, 100 kg ha^{-1}), for corn 3 N levels (0, 100, 200 kg ha^{-1}).

The experimental design was a split-split plot, considering the crop rotation as the main factor, the crop residue management as the sub-plot and the fertilization formula as the sub-sub-plot. The reported data refer to the period 2015-2020 and, we report the effect of crop residue managementand and nitrogen levels in the three different rotations. On the grain yield analysis of variance was realised, carried out for all the data and the homogeneity of error variance for the different years was studied using the Bartlett test. The structure of the combined analysis of variance over years was determined on the basis of Gomez and Gomez (1984). Means were compared according Duncan's multiple range test for multiple comparisons of paired means of treatments

Results

A synthesis of results of 2015-2020 period is here reported. The anova effect showed high significance (*** P< 0.01) of the year effect, same results related the nitrogen application rate (*** P< 0.01), while not significat was the effect of residue management. Between interaction, year x nitrogen application

Figure 2. Rotation 2: Productive response of durum wheat and silage corn according different nitrogen application Different letters indicate differences at p<0.05 (Duncan's test)

presented a significant at 0.1 P level. The lower yield was observed in the rotation where durum was rotated annually with catch crop silage corn, whit an average response of 2,51 t ha^{-1}. Continuous wheat presented an average production of 2,96 t ha^{-1}. The response of wheat in the triennial rotation was higher, whit an average production of 3,66 t ha^{-1} in the first year

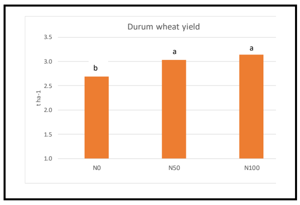

Figure 1. Rotation 1: Productive response of durum wheat according different nitrogen application Different letters indicate differences at p<0.05 (Duncan's test)

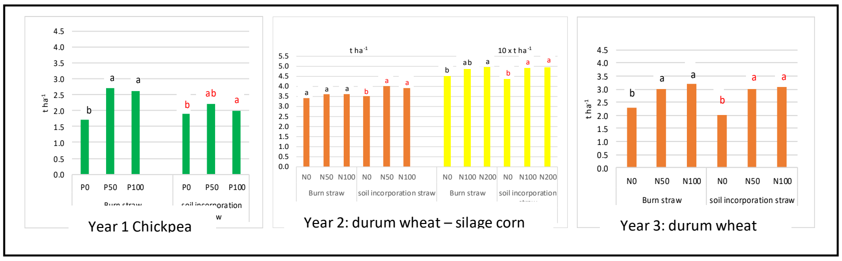

Figure 3. Rotation 2: Productive response of chickpea, durum wheat and silage corn according different nitrogen application Different letters indicate differences at p<0.05 (Duncan's test)

of wheat after chickpea and 2,79 t ha^{-1} in the second year and after silage corn catch crop. The average production of silage corn was 46,51 t ha^{-1} in the continuous rotation wheat-corn catch crop and 47,64 t ha^{-1} in the first year of wheat in triennial rotation. The production of chickpea was, on average, 2,34 t ha^{-1}. Concerning the long-term effect of nitrogen, the results present a high impact on this kind of nutrient on yield response: as a general average of all wheat production, we found an increase of yield from 2,35 t ha^{-1} in the treatments N0 to 3,05 t ha^{-1} in the treatment N50 and 3,3 t ha^{-1} in N100 treatments. The same behaviour was observed on catch crop silage corn, where we found an increase in biomass production from 43,39 t ha^{-1} in N0 to 48,41 t ha^{-1} in N100 and 49,39 t ha^{-1} in N200. In chickpea, the P effect presented differences between T0 plots, 1,79 t ha^{-1} and P feritilised, respectively 2,46 and 2,32 t ha^{-1}, showing no significant differences between the fertilized treatments. Straw management did not present significant differences between treatments, both in durum wheat and catch corn (2,76 t ha^{-1} in burned straw plots vs 2,72 t ha^{-1} in soil incorporated plots.

Conclusions

Long-term experiments are critical to evaluate the effect of management over the years on agronomical variables on the response of cultivation in a different rotation systems. The reported data give some interesting information relating to the effect of residue management on yield in a continuous cropping system of winter durum wheat. The effect of straw incorporation did not seem to increase productivity with respect to burning straw. Instead, the effect of rotation, including legumes such as chickpea, has a beneficial effect on wheat productivity. Also, nitrogen in all combinations gives a productive improvement in wheat and silage corn.

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Modelling Parametrization Of A Long Term Experiment Based On Wheat Cultivation In Southern Italy

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Introduction

Global warming (GW) causes the rise of the average temperature, reduces rainfall, and increases the frequency of extreme weather events, for instance frosts and heat waves, periods of dryness and storms. Consequently, it is necessary to provide agronomical practices and strategies to adapt and mitigate the effects of GW on crop yield and product quality. Adaptation strategies aim to minimize the negative effects of GW on agricultural production. On the other hand, mitigation strategies aim to reduce greenhouse gas emissions, maintaining or increasing the organic carbon content in soil. Therefore, integrated analyses are necessary to redesign and to adapt the cropping systems to the new climate conditions, in areas with homogeneous agronomic, pedological and climatic characteristics, such as the Mediterranean zone. ARMOSA is a process-based cropping system model that has been proved to be suitable for field crops and for simulating different soil-management practices under several environmental conditions (Puig-Sirera et al., 2022).

The purpose of this work, funded by PSR-Puglia SFOF, AGROMODELLI, SYSTEMIC and PON-W4AF projects, was the calibration of ARMOSA model, by using a Long Term Experiment (LTE) dataset, based on a durum wheat in continuous cropping system, cultivated in Foggia, Southern Italy, since 1977 to date. Subsequently, the validation of the obtained results, will be carried out by means of another independent LTE dataset collected under the same area, with the application of conservative agricultural practices. The last phase of the work will consist of scenario analysis on a farm scale, concerning durum wheat subjected to conventional and conservative agronomic practices.

Materials and Methods

LTE dataset used to calibrate the ARMOSA parameters, consists of winter durum wheat cropped, since 1977, under three managements based on soil incorporation of crop residues without (T2) and with N fertilization (T5) and irrigation (T8), applied on straw before ploughing. Data reported in this work, refer to T2 treatment.

The experimental design was a randomized complete block design with five replications. All the experimental field was located in Podere 124 experimental station, located at Foggia, Southern Italy.

The soil has a clay-loam texture of alluvial origin. The climate is classified as “accentuated thermomediterranean”, characterized by an annual average of 550 mm of rainfall, mostly concentrated in winter (Ventrella et al., 2016). The parameterization of the model was performed for eight varieties cultivated over the years: Valgeraldo 1978-1982, Appulo 1983-1987, Latino 1988-1992, Appio 1993-1996, Simeto 1997-2000 and 2007-2013, Ofanto 2001-2006, Claudio 2014-2018, Saragolla 2019-2021. Calibration was carried out using phenological phase durations (doy), biomass produced (kg ha^{-1}), grain yield (kg ha^{-1}) and total organic carbon (TOC, kg ha^{-1}), comparing the simulated values with the observed ones, taking into account the value of relative root-mean-square error (RRMSE, the lower the value, the better the fitting) and model efficiency (EF, 0 worst value, 1 the best one).

Results

As indicated by the statystical indicators, calibration of ARMOSA model proved to be quite good for all crop management. The model applied under the considered area showed to be a good predictor for the durum wheat in terms of yield (kg ha^{-1}) and biomass (kg ha^{-1}), as well as the phenological phases (doy), and TOC (kg ha^{-1}) and consequently to evaluate the effects of different soil management. It hould be noted that the number of observed data was unbalanced among cultivars. Namely, Simeto was the cultivar with the highest number of observed data, Saragolla the one with the lowest. The former showed an RRMSE of 2, 5.7, and 5.3 for emergency, flowering and physiological maturation, respectively.

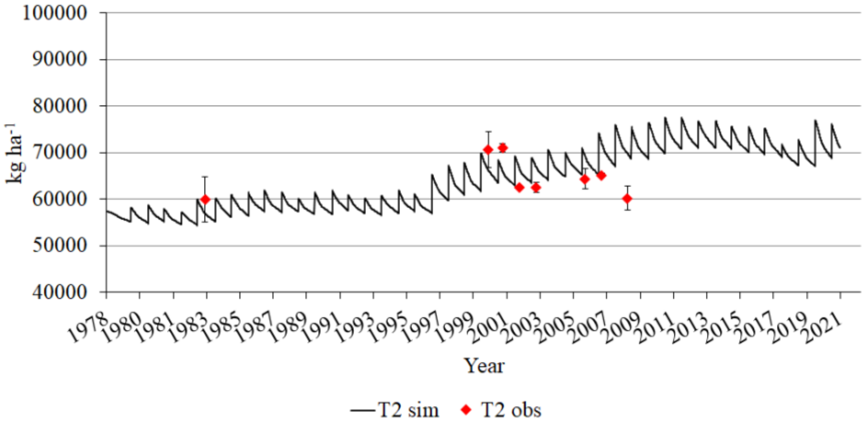

Figure 1. Simulated vs observed data of TOC trend at 0-40 cm depth under T2 management.

Concerning yield and biomass, RRMSE resulted 35.7 and 14.9, while EF was 0 and 0.63, respectively. ARMOSA also performed very well the trend of TOC at 0-40 cm (Fig. 1).
Linear regression between simulated and observed data for all cultivars over the growing periods showed a good fitting for what concerns biomass, more tricky resulted the calibration for yield, even if some cultivars performed better compared to others (Fig. 2). Finally, RRMSE of 56.5 and 34.9 resulted for yield and biomass, respectively.

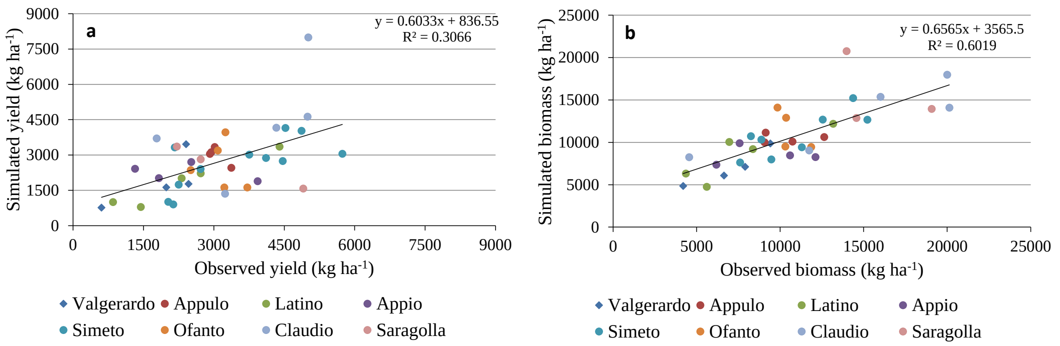

Figure 2. Linear regression between simulated and observed data for yield (a) and biomass (b) for all cultivars over the growing periods.

Conclusions

Calibration of ARMOSA indicated that this model is suitable to predict the performance of durum wheat under continuous cropping systems in Mediterranean environment. A further step to verify the goodness of ARMOSA, will be assessed under different LTE dataset (validation phase). Finally, ARMOSA will be applied to evaluate several scenarios in order to assess and screen mitigation and adaptation strategies.

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Session 2

2050 perspective: what to produce?

ORAL PRESENTATIONS

Strategies To Reduce Acrylamide Content In Wheat Products: Possible Effects Of Genotype And Fertilization

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Introduction

The presence of acrylamide in food was announced for the first time in April 2002 by the Swedish National Food Agency (Tareke et al., 2002), but the critical issues related to this substance were already known since 1994, when it was classified as neurotoxic and probably carcinogenic to humans by the US Environmental Protection Agency and the International Agency on Research on Cancer (Douny et al., 2012). It is now generally accepted that acrylamide is formed naturally in the Maillard reaction from reducing sugars and certain amino acids, such as asparagine, during thermal processes (Mottram et al., 2002). Researches on acrylamide primarily examines potato due to its higher acrylamide content in chips or French fries (EFSA, 2015). However, limited data are available on less contaminated but more prevalent foods such as grain products, which could be a significant source of daily acrylamide intake. Strategies to decrease acrylamide content in grain-based foods include identifying raw materials with low concentrations of acrylamide precursors and identifying proper agronomic management. For these reasons, the main objectives of the study were: *i) to* compare 20 Italian common wheat (*Triticum aestivum* L.) varieties to identify those with a low content of asparagine and reducing sugar; *ii)* to evaluate the effect of the fertilization plan on acrylamide precursors and indirectly on acrylamide formation.

Table 1. Protein and acrylamide content in different Italian wheat varieties.

	Protein content (g/100g)	**Acrylamide content (mg/kg)**
Genotypes	**	***
Aleppo	10.42 (ab)	25.87 (e)
Aquilante	10.70 (ab)	30.93 (abcde)
Bologna	11.97 (ab)	28.91 (cde)
Falcone	10.87 (ab)	30.67 (bcde)
Frassineto	11.92 (ab)	32.24 (abcde)
Funo	10.85 (ab)	32.53 (abcd)
Funone	12.00 (ab)	33.90 (abcd)
Inalettabile	11.85 (ab)	32.19 (abcde)
Gentil Rosso	12.65 (ab)	37.10 (a)
Ginger	10.15 (b)	27.69 (de)
Metropolis	11.82 (ab)	27.80 (de)
Rebelde	12.17 (ab)	29.68 (cde)
San Pastore	11.97 (ab)	33.28 (abcd)
Soana	11.30 (ab)	33.00 (abcd)
Solehio	10.05 (b)	28.39 (de)
Teorema	12.50 (ab)	32.26 (abcd)
Terminillo	12.25 (ab)	37.13 (a)
Terramare	10.90 (b)	29.51 (cde)
Verna	12.55 (ab)	35.16 (abc)
Villa Glori	12.90 (a)	36.28 (ab)
Year	***	***
2019/20	9.77 (b)	27.98 (b)
2020/21	13.42 (a)	35.47 (a)
V*Y	**ns**	***

Materials and Methods

Field trials were carried out at the CO.NA.SE experimental fields in Conselice (RA, Italy), for 2 growing seasons (2019/20 and 2020/21). The field scheme was organized in replicated plots of 8.5 m^2, arranged in a randomized block design with 2 blocks, with a sowing density of 300 seeds/m^2. The influence of variety was studied using 20 Italian wheat varieties, while the effect of fertilization plan was carried out using 2 cultivars (San Pastore and Terramare) each with 0, 30, 90, 140 N kg/ha with ammonium nitrate. Additionally, both the inflluence of nitrogen fertilizer enriched with sulfur (90 N kg/ha), and the influence of 600 kg/ha of Natural bio N (SCAM) allowed in organic farming were studied. At harvest, data on yield and quality production (protein and gluten content) were evaluated. Analysis to evaluate acrylamide content and its precursors were carried out using wholemeal flour. Reducing sugars in flour were determined by enzymatic assay using the sucrose/d-fructose and d/glucose Megazyme kit. Asparagine in flour was determined by LC-MS, following the method described by Nielsen et al. (2006). For this purpose, 1 g of flour extracted twice with 45% ethanol for 10 min into an ultrasonic water bath. After centrifugation for 10 min at 5,000 rpm at 5°C, 1 mL of supernatan was cleanup with SPE cartridges and than filtered through a 0.20 µL nylon filter. Finally, to determine the potential of acrylamide formation in flour, 2.5 g was heated at 180°C for 20 min in a 100 mL beker. Samples of 1 g of heated flour was extracted twice with 10 mL of water in ultrasonic water bath for 10 min. The supernatant was frozen to -18°C for 30 min, and then after centrifugation for 10 min at 5,000 rpm, the sample was cleanup with SPE-cartridges and filtered trought 0.45 µL cellulose filter. Acrylamide was quantifyied as above. All analyses were performed in duplicate. General Linear Model (GLM) was used to assess the variance significance for the fixed (varieties; nitrogen fertilization) and random (year) factors for all measured variables.

Table 2. Protein and acrylamide content in the fertilization trial.

	Protein content (g/100g)	Acrylamide content (mg/kg)
Genotypes	***	**
San Pastore	12.03 (a)	31.42 (a)
Terramare	10.89 (b)	29.57 (b)
N dose	***	***
N0	10.57 (c)	26.86 (c)
N30	10.63(c)	28.43 (bc)
N Organic	10.51 (c)	29.60 (bc)
N90	12.22 (ab)	31.67 (b)
N90 + S	12.01 (b)	31.40 (b)
N140	12.80 (a)	35.02 (a)
Year	***	***
2019/20	10.03 (b)	28.74 (b)
2020/21	12.88 (a)	32.26 (a)
G*N dose	**ns**	**ns**
G*Y	**ns**	**ns**
N dose *Y	**ns**	*

Results

Among the 2 investigated cropping years, the samples of 2020/21 showed significantly higher levels of protein and acrylamide than sample of 2019/20. In particular, grain protein ranged from 10.05 (cv. Solehio) to 12.90 g/100g (Villa Glori), while acrylamide content varied from 25.87 (cv. Aleppo) to 37.13 mg/kg (cv. Terminillo) (Table 1). A close linear correlation between protein and acrylamide content (r=0.850, P<0.001) could be observed, demonstrating that protein content significantly influenced acrylamide formation in heated flour. This correlation was previously observed by Claus et al. (2006). Finally, it is important to note that some varieties (e.g., Bologna, Funone, Teorema) maintained stable acrylamide levels while showing highly variable protein levels over the 2 years. In the fertilization trials, fertilization had a strong impact on protein and acrylamide content, while the inflluence of sulfur (90 N + S) did not show a relevant effect (Table 2). Finally, the content of protein was highly correlated with the acrylamide in the heated flour (r=0.707; P<0.01).

Conclusions

Analyses related to acrylamide precursors are in progress. Data collected will be useful in identifying varieties and agronomic strategies to reduce acrylamide content in cereal foods.

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Elicitation Effect Of Salinity On Phenolic Compounds, Glucosinolates And Antioxidant Activity Of *Camelina sativa* (L.) Crantz Sprouts

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Introduction

Studies carried out by our group have demonstrated that camelina (*Camelina sativa* (L.) Crantz) sprouts are a rich source of phenolic compounds, glucosinolates and antioxidants (Falcinelli et al., 2022). It is known that these compounds are secondary metabolites and can be increased by stressing conditions, which actually work as elicitors (Benincasa et al., 2019; Galieni et al., 2020; Liu et al., 2019). Among abiotic elicitors, salinity applied during germination has been reported to be an easy and effective tool to increase the phytochemical content and the antioxidant activity in sprouts of many plant species (Galieni et al., 2020; Liu et al., 2019), including *Brassicaeae* ones (Falcinelli et al., 2017; Benincasa et al., 2021). The effect of salt stress on germination and growth parameters of camelina seedlings is well known, and reported to vary among genotypes (Luo et al., 2021). On the other hand, there is no information about the effect of salinity on the phytochemical content of camelina sprouts. Therefore, the aim of this work was to study the effect of increasing NaCl concentrations on the phytochemical content and the antioxidant activity on sprouts of five camelina genotypes.

Materials and Methods

Seeds of five camelina genotypes (Alba, Cceμ3, CO46, Joelle, Vera) were incubated on filter paper laid over sterile cotton contained in plastic trays (1.5 g of seeds per tray) and wetted with 75 mL of NaCl solutionts 0, 25, 50 and 100 mM. The trays were placed in a growth chamber (T= 20±1°C and RH= 70±5%) under photon flux density (PFD) of 200 μmol m^{-2} s^{-1} and light/dark photoperiod of 16/8 hours. A completely randomized design with three replicates (trays) was applied. In parallel, a germination test at the same NaCl concentrations was also conducted with three randomized reps. Sprouts were harvested at the stage of fully-expanded cotyledons (achieved 6 DAS for treatments up to 50 mM and 7 DAS for 100 mM), collecting the whole seedlings (i.e., both shoot and root). The total fresh sprout biomass was recorded for each replicate. Fresh and oven dry weights, and the lengths of shoots and roots were measured on a subsample of 10 individuals per replicate. Samples were stored at -20°C until analytical determinations. Free and bound phenolic fractions were extracted according to Stagnari et al. (2017). The contents of polyphenols (P), and the antioxidant activity (DPPH, FRAP and ABTS tests) were measured according to Singleton and Rossi (1965) and Thaipong et al. (2006), respectively. Free and bound fractions of phenolic acids (PAs) were measured according to Bravi et al. (2021). Total P, PAs, DPPH, FRAP and ABTS were calculated as the sum of free and bound fractions. Glucosinolates (GLS) were extracted in the same way of free phenolic fraction (Stagnari et al., 2017) and quantified using a validated UHPLC method.

Results

The germination and seedlings growth of camelina in the unsalted control varied among genotypes. Germination ranged from 88% for Alba to 98% for Cceμ3 and Joello, and the fresh biomass production per tray (i.e. the single replicate) ranged from 7 g (Alba) to 15 g (Cceμ3). Salinity slightly affected these performances, even at the highest concentration (100 mM NaCl), without relevant differences among treatments (data not shown). Just to give an idea, at 100 mM of NaCl, on average over all genotypes, germination decreased to 88% (*vs* 95% at 0 mM) and the total fresh biomass production to 11 g per tray (*vs* 14 g at 0 mM).

On the other hand, the effect of salinity on the phytochemical content and the antioxidant activity of camelina sprouts was relevant and differed among genotypes (Table 1). The results of the free and bound fraction are not shown in Table 1, however the bound fraction represented a much smaller portion compared to the free fraction, thus total values reported in Table 1 substantially reflect the trends of the free fractions. In the unsalted control the highest values of GLS were recorded in sprouts of Alba, while the highest values of P, PAs and ABTS and DPPH were recorded in Csceμ3 and Joelle, and only FRAP was the highest in CO46 and Joelle (data not shown). Moderate salinity, up to 50 mM, generally increased P, PAs, GLS and antioxidant activity in all genotypes (apart for Joelle at 25 mM), while 100 mM generally depressed the benefit, except for Alba where a further increase was observed.

Table 1. Significant increase (+), decrease (-) or invariance (≈) of total phenols (P), phenolic acids (PAs), glucosinolates (GLS) and antioxidant activity (DPPH, FRAP, ABTS tests) in sprouts of camelina obtained at increasing NaCl concentrations (25, 50, 100 mM NaCl) in the germination substrate, as compared to the unsalted control. A number before + or – means a n-fold increase.

Total values (free + bound)	Cultivars and NaCl concentrations (mM)														
	Alba			Cceμ3			CO46			Joelle			Vera		
	25	50	100	25	50	100	25	50	100	25	50	100	25	50	100
P	+	2+	2+	≈	+	-	+	2+	-	≈	+	-	2+	2+	+
ΣPAs	2+	2+	2+	+	2+	3-	+	2+	≈	-	2+	-	≈	2+	+
GLS	+	+	3+	+	+	-	+	3+	2+	≈	2+	-	2+	2+	2+
DPPH	2+	2+	2+	-	+	-	+	2+	-	-	+	-	+	+	+
FRAP	2+	2+	2+	+	2+	2+	+	2+	≈	-	≈	2-	2+	2+	+
ABTS	2+	2+	2+	≈	+	-	+	3+	+	-	+	-	2+	2+	+

Conclusions

Salinity increased the phytochemical content and antioxidant activity of camelina sprouts. In four out of five genotypes the best results were obtained with 50 mM NaCl, which increased, and in many cases doubled, the values of most parameters while causing negligible decrease of biomass yield. In these four genotypes, 100 mM reduced the benefit on antioxidant contents and depressed germination and sprout growth. Only Alba showed a further increase of GLS at 100 mM, but this was counteracted by the lower germination and sprout growth. Overall, moderate salinity (~50 mM NaCl) represents the best compromise to maximize the phytochemical yield and antioxidant activity in all camelina genotypes.

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Nitrogen And Sulfur Fertilization Effect On Yield And Asparagine Content In ‘Old’ Common Wheat Varieties

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Introduction

In the past decades, ‘old’ common wheats varieties have been reintroduced, and many local micro-economies have been developed around them. Numerous studies have highlighted the positive effects on health of wholegrain bakery products made from ‘old’ common wheat (Triticum aestivum L.) varieties. However, ‘old’ common wheat varieties display poor rheological properties and there is limited information on their free asparagine (ASN) content, which is the predominant precursor of acrylamide formation in wholegrain bakery products. The aim of the work is to quantify the effects of 2 agronomic treatments, nitrogen fertilization, sulfur fertilization and their interaction, operated on 14 ‘old’ varieties of common wheat, on the rheological characteristics of the doughs and on the free ASN content.

Materials and Methods

The experiment was conducted at the demo-farm “Tenuta di Cesa” in Marciano della Chiana, Tuscany (Lat. 43.3095; Lon. 11.8264; 246 m asl) from September 2017 to July 2019 under rainfed conditions on an alkaline clay-loam soil. The soil was characterized by good available nitrogen (N; 19 N mg kg^{-1}), while was both phosphorous- and sulfur-deficient (available P and S less than 10 mg kg^{-1}). A total of 14 ‘old’ common wheat cultivars (Triticum aestivum L.) were investigated: Acciaio [AC], Andriolo [AN], Autonomia A [AU_A], Autonomia B [AU_B], Bianco Nostrale [BI], Frassineto 405 [FR], Gentil Bianco [GB], Gentil Rosso [GR], Gentil Rosso Aristato [GR_A], Gentil Rosso Mutico [GR_M], Inallettabile [IN], Mentana [ME], Sieve [SI], and Verna [VE]. Results from one “modern” genotipes (Bologna [BO]) are reported for comparison but not statistically analysed with the other ‘old’ varieties. The genotipes (GEN) were evaluated with 6 fertilization treatments comprising 3 nitrogen levels (NL; 35,80 and 135 kg N ha^{-1}) and 2 sulphur levels (SL; 0 and 6.4 kg S ha^{-1}) each replicated 3 times. Nitrogen was distributed 20% at seeding, 40% at tillering and 40% at the beginning of the stem elongation. Sulfur was distributed at booting by spraying a solution containing 20 g L^{-1} of wettable sulfur powder (80% a.i.; Thiovit Jet 80WG®, Syngenta). The experiment was established as a strip-plot design with three replicate blocks per year (plot dimension of 14.4 m^2). After harvesting, the kernel yield was measured (GY; t ha^{-1}) and then milled (0.5 mm screen) to obtain wholemeal flour samples as reported in Guerrini et al. (2020). The total protein percentage (PC; %) was determined by means of CHNS analyzer (total nitrogen percentage multiplyied by 5.7). The protein yield (PY; t ha^{-1}) was calculated (GY x PC). The ASN concentration in wholegrain flour (ASN, micromoles g^{-1}) was determined using an enzymatic method as reported by Lecart et al. (2018). Dough W (10^{-4} J) was determined according to ISO 27971 (2015).

Results

The highest average GY was measured in AU_A, followed by AU_B and SI, while the lowest average GY values were measured in AC. N fertilization significantly affect the GY in BO, while it do not significantly affect the GY in ‘old’ varieties. This is problably related to the base soil N fertility that was sufficient to satisfy the N requirements of ‘old’ varieties. The highest average PY was measured in AU_A followed by AU_B, while the lowest value was measured in FR. Results indicated that the SL6.4 treatment increased GY by 8.2% and 18.5% compared to SL0, for ‘old’ varieties and BO, respectively. Sulfur application (SL6.4) increased PY by 9.4% and 18.3% with respect to SL0, for ‘old’ varieties and BO, respectively. Furthermore, the PY significantly increased by 8.8% and 32.9%, from NL35 to NL135, for ‘old’ varieties and BO, respectively. The highest W was measured in SI, followed by GB and FR, while the lowest values were measured in AN. In ‘old’ varieties, the W value significantly increased by 84.4% and 15.9% with the NL treatment (from N35 to N135) and the SL treatment, respectively. In BO, the NL treatment increased the W by 210% from N35 to N135, while the SL did not significantly affect the W. The highest free ASN concentration was measured in GR_A, followed by GR_M, GB, and GR, while the lowest values were measured in SI. It was observed a significant negative correlation (R^2 = 0.69, $p < 0.01$) beetwhen the ASN content and the release year of these ‘old’ varieties. The ASN content significantly increased by 111% from NL35 to NL135, while decreased by 85.1% with the SL treatment.

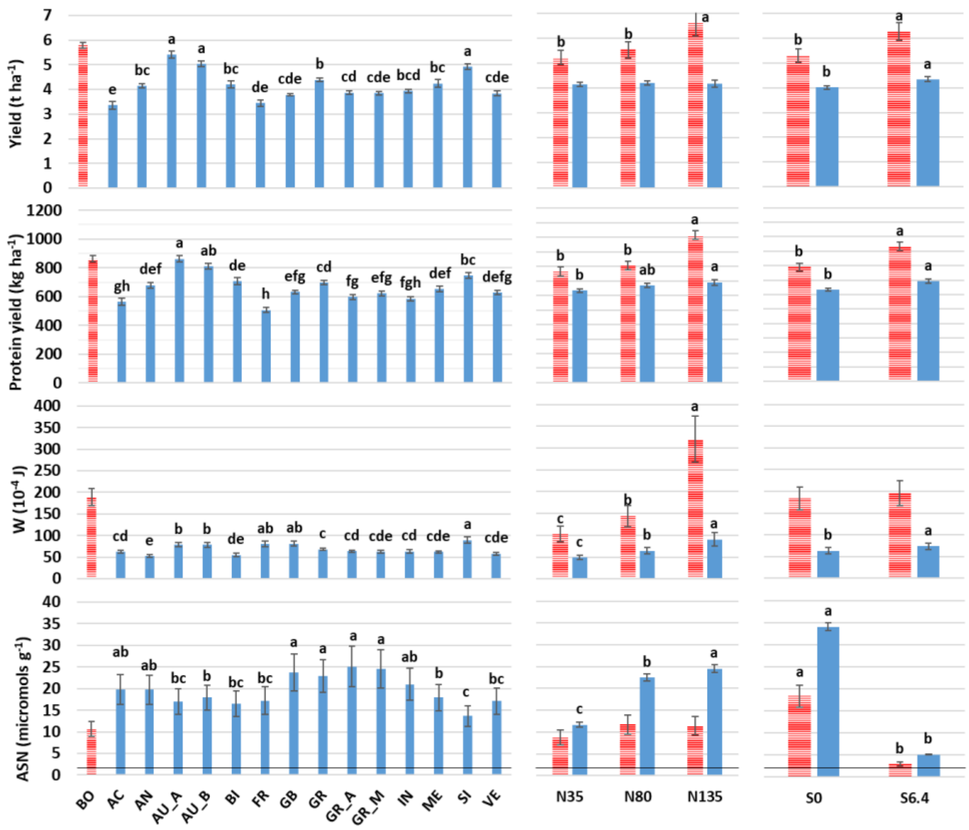

Figure 1. Grain quality parameter mean values of 14 ‘old’ common wheat varieties as a function of genotype (Gen), nitrogen (NL) and sulfur fertilization (SL). Grain yield, protein yield, dough strength (W), and asparagine (ASN) content in kernels are reported.

Conclusions

The rheological characteristics, and consequently the technological properties of “Tipo 2” flour from “Old varieties” can be significantly improved thanks to careful management of N and S fertilizers. At the same time, the free ASN content in grain was found to be strongly linked to the sulfur availability, which favors the inclusion of ASN within proteins.

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The Legume Choice Determines Crop Production, Nitrogen Dynamics, Weed Control And Economic Viability Of Relay Intercropping In A Mediterranean Cereal Based Low-Input Cropping System

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Introduction

The relay intercropping of subsidiary legumes with durum wheat (living mulch) can be a valuable agroecological practice to supports nutrient availability and non-chemical weed control at crop rotation level without negative impacts on crop productivity (Tosti et al., 2016; Hiltbrunner et al., 2007). This study aimed to investigate the long-term agronomical and economical sustainability of eight different legumes among perennial, annual and annual self-seeding species tested in relay intercropping with durum wheat in a Mediterranean low-input cereal-based cropping system. In particular we evaluated the impact of each legume on 1) intercropped wheat, through the evaluation of N uptake, grain yield and protein content, 2) the subsequent forage sorghum taking into account the residual effects of the legumes on the following summer crop through the evaluation of biomass production and N uptake, 3) the effects of legume on weeds community composition and biomass before and after wheat harvest and in the subsequent cash crop. Finally we performed an economic assessment to test if costs due to the relay intercropping are balanced by the ecosystem services it provides at crop rotation level taking into account the impact of the legumes on the co-cultivated wheat and on the following forage sorghum.

Materials and Methods

A two-year wheat-sorghum rotation was repeated twice at the Centre for Agri-Environmental Research "Enrico Avanzi" of the University of Pisa (Italy). Durum wheat was sown in 18 cm spaced-rows at a rate of 350 viable seeds m^{-2} on fields previously ploughed at 25 cm depth and refined with rotary harrow. Legumes used in this experiment include *Medicago sativa*, *Trifolium repens*, *Hedysarum coronarium*, *Medicago lupulina, Trifolium incarnatum, Trifolium resupinatum, Trifolium subterraneum* and *Medicago polymorpha*. Legumes were seeded before the wheat elongation phase in the wheat inter-row space. A control treatment was also implemented with wheat grown as the sole crop to evaluate the incidence of undersown legumes on wheat yield performance. Each treatment was repeated in four randomized blocks. Durum wheat was mechanically harvested. After wheat harvest, legumes persisted in the field during the summer as dead mulch (annual and self-reseeding legumes) or working as cover crops (perennial legumes). In the autumn, self-seeding legumes re-germinated from the seeds disseminated in summer and behaved as cover crops until the sowing of the following crop. Legume biomass was incorporated into the soil in spring and sorghum for forage production was sown at a rate of 150 viable seeds m^{-2} in 30 cm wide inter-rows following the legume plots. In the control, after the wheat harvest bare soil with spontaneous vegetation was maintained until the sorghum sowing.

Results

Wheat grain production was on average 3.2 t/ha. Living mulches did not have any negative effects on the durum wheat yield compared with the control for any of the species used in this experiment. We hypothesized instead a beneficial effects of undersown legumes on wheat in terms of N uptake and grain protein content. However, results of this study showed that relay establishment of living mulches had no significant effect on wheat grain yield and quality, but only on the subsequent forage sorghum. The quantity of N accumulated in wheat straw was 48.5 kg N/ha on average and grain protein content was

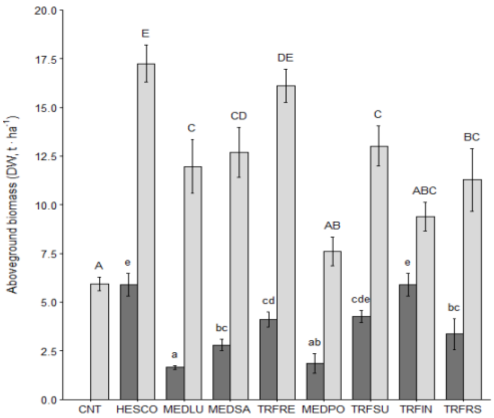

Figure 1 - Legume biomass at spring (dark grey bars) and subsequent sorghum biomass at harvest time (early grey bars) during the second repetition of the experiment.

14.5%. Relay intercropping of legumes proved to be an effective solution to control weeds before and after the wheat harvest, provided suitable legumes species are chosen. Leumes such as *H. coronarim*, *M. sativa*, *T. repens* and *T. subterraneum* reduced the weed biomass up to the 90% during the intercropping (e.g. *M. sativa* 2.03±0.57 vs 23.47±6.60 g/m^2 weed dry biomass) and up to 96% in the following spring (e.g. *H. coronarium* 8.81 ± 2.15 vs 223.21 ± 53.6 g/m^2 weed dry biomass) with respect to the control (wheat sole stand crop). The annual legume *T. resupinatum* reduced weed biomass during the intercropping period however, residues of this legume in the following spring (2017-19 growing season) supported weed growth compared with the control (278 ± 30 vs 129 ± 18 g/m^2 weed dry biomass). Legumes were maintained after wheat harvest and then used as green manure by plowing them under in the following spring when forage sorghum was sown.

Nitrogen inputs from legumes was estimated by the determination of the nitrogen content in the legume biomass before their termination and incorporation into the soil in spring. Nitrogen input from legume residues vary considerably according to the legume species and seasonal conditions and it ranged from 1.22 to 182 kg/ha. Nitrogen provided by legumes was not totally available for the subsequent crop and sorghum nitrogen uptake ranged from 0.9 to 138 kg/ha. During both repetitions of the experiment *H. coronarium* and T. *repens* and *T. subterraneum* had the highest level of nitrogen content compared with the other legume species. In particular nitrogen input from these legumes was respectively up to 182, 157 and 113 kg/ha. Sorghum dry biomass production in the control plot was on average 4 t/ha. Without the use of external nitrogen, biomass production of sorghum preceded by *H. coronarium*, *T. subterraneum*, *T. repens* and *M. sativa* was 11 t/ha on average (Figure 1), in line with the productive level of the same sorghum grown under conventional conditions. In sorghum, the effect of legume residues mainly affected dicotyledonous weeds whereas residues of *T. resupinatum* and *T. incarnatum* promoted monocotyledonous weeds growth. The economic assessment conducted in this study reveals that relay intercropping reduces profitability of the co-cultivated durum wheat due to the cost for inter-seeding. Instead, the gross income of sorghum (production value – costs) preceded by *H. coronarium*, *T. repens*, *T. subterraneum* and *M. sativa* was up to 955 €/ha. Overall, the use of *H. coronarium* maximised the cumulative gross income (wheat+sorghum) in this cereal-based low-input crop rotation (1381 vs 639.5 €/ha in the control).

Conclusions

Our study highlights the importance of the selection of suitable legumes for relay intercropping with wheat to support nutrient availability and weed control at crop rotation level. Relay establishment of legume living mulches proved to be a viable option to limit the competition with wheat and maintain adequate levels of grain production. However, relay intercropping with legumes did not affect N uptake and grain protein content in wheat. On the other hand a positive effect on the subsequent cash crop was demonstrated. According to the overall agronomic and economic evaluation of legumes throughout the entire growth cycle, *H. coronarium* was identified as the most suitable legume species to be used in relay intercropping with durum wheat in low-input Mediterranean cereal-based cropping system.

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POSTERS

Exploring Agronomic Traits In *Camelina sativa* (L.) Crantz Lines Included In The UNTWIST Project Core Collection

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Introduction

Camelina [*Camelina sativa* (L.) Crantz] is an oilseed crop characterized by a short growing cycle and low input requirements (Berti et al., 2016; Zanetti et al., 2021). These traits, together with the high polyunsaturated fatty acid (PUFA) content of its oil, make camelina a valuable option for the European agricultural sector, as the crop can be introduced into existing rotation systems (Righini et al., 2016; Zanetti et al., 2021). Many camelina cultivars and natural accessions are available, however an improved knowledge about their performance is desirable. Quantitative assessment of field performance would facilitate a data-driven selection of the best-performing varieties in terms of agronomical characteristics such as seed yield and seed weight. In this context, the UNTWIST project (EU H2020) investigated 54 different camelina varieties to evaluate their agronomic performance in the north Mediterranean climate.

Materials and Methods

The field trial was conducted at the experimental farm of Bologna University at Cadriano (44° 33' N, 11° 23'E, 32 m a.s.l.), during the 2020-2021 growing season. Cadriano is characterized by a cumulative mean annual precipitation of 712 mm and a mean temperature of 13°C. The soil of the trial was a silty-clay-loam (29% sand, 26% clay, 45% silt). Fifty four camelina lines, included in the UNTWIST project's Core Collection, supplied by the different partners and collaborators were grown. The trial was sown on October 29th, 2020 by means of a plot seeder. Sowing rate was 500 seeds m^{-2} with 0.13 m row distance. The plot size was 1 m^2; the experimental design was completely randomized blocks (*n*=4). Fertilization was manually supplied at stem elongation at a 50 kg N ha^{-1} rate as urea. Weed control was performed manually, and the trial was rainfed. Camelina was harvested in mid-June 2021. Plants were manually cut at soil level and then threshed to separate seeds and straw. Seed samples were collected from each plot and analyzed to determine 1000-seed weight (TKW).

Results

One-way ANOVA was performed considering cultivar as a factor. The results showed that plant density, seed yield, and TKW were significantly ($P \leq 0.05$) influenced by cultivar. The mean plant density at harvest was 258 plants/m^2, with values ranging from 39 to 633 plants/m^2. Previous trials conducted at the same location demonstrated that the optimal plant density for camelina in the site is approximatively 200 plants/m^2. In the present experiment, 19 out of 54 cultivars displayed a final plant density lower than 200 plants/m^2, thus not representing suitable lines for the considered location.

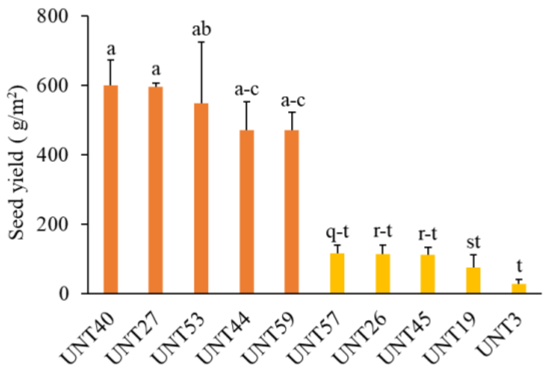

Figure 4. Effect of cultivar on seed yield. Different letters: significant different values (P<0.05). Vertical bars: standard error.

Mean seed yield was 281.3 g/m^2, with values ranging between 27.3 and 599.4 g/m^2. The five most productive cultivars were UNT40, UNT27, UNT53, UNT44, and UNT59. The least productive lines were UNT57, UNT26, UNT45, UNT19, and UNT3 (Figure 1). These results underline the diversity existing among camelina cultivars. Mean TKW was 1.17 g, with values ranging from 0.9 g to 1.55 g, in line with those reported by Alberghini et al. (2022) in the same experimental site.

A correlation test was performed, showing a significant positive correlation between final plant density and seed yield (r=0.58, $P \leq 0.05$). This result is further corroborated by looking at the plant density of the ten above mentioned cultivars (Figure 2). UNT53, UNT40, UNT27, and UNT59, which were among the most productive lines, display the highest plant densities. On the other hand, UNT45, UNT3 and UNT19 showed both the lowest seed production and plant density. Finally, UNT44 and UNT26, that were among the most productive and the least productive lines, respectively, performed both on average when plant density was considered (238 plants/m^2 and 264 plants/m^2, respectively). Final plant density was also found to be negatively correlated with TKW (r=-0.34, $P \leq 0.05$), as previously reported by Vollmann et al., 2007. UNT53, UNT40, UNT27, UNT26 and UNT59 reported TKW between 0.9 and 1.21 g.

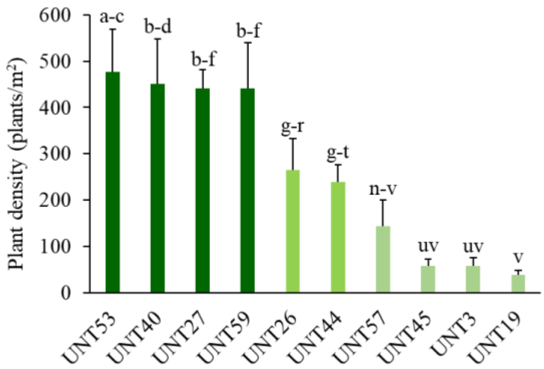

Figure 5. Effect of cultivar on plant density. Different letters: significant different values (P<0.05). Vertical bars: standard error.

Conclusions

The obtained results highlighted the considerable diversity in terms of agronomic traits existing among different camelina varieties. Some of the lines included in the UNTWIST core collection demonstrated an ability to the environmental conditions. UNT53, UNT40, UNT27, UNT26 and UNT59 were identified as the best cultivars due to their performances in terms of plant density and seed yield. Sowing rate should be adjusted to obtain a final plant density ensuring both optimal seed production and satisfactory seed weight.

Acknowledgments

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Effects Of Seed Pre-Germination On Free Nutraceutical Compounds In Old Italian Open-Pollinated Maize Varieties

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Introduction

Maize-based food is one of the main human dietary component, although with high phytates contents, one of the highest among plants (8,300-22,200 mg kg^{-1}) (Kerovuo, 1998). Phytic acid (i.e., myo-inositol hexaphosphate) is the major component of plant origin containing phosporous. About 75% of the total phosphorus in cereals and legumes is present in the form of phytate, i.e., phytic acid salt, not readily available by monogastric (poultry, pigs and humans) (Wodzinski and Ullah, 1988).

During the processes of transformation and digestion of foods, phytic acid can be partially dephosphorylated to produce products of degradation, such as penta-, tetra- and tri-phosphates, through the action of endogenous phytase, which are found in most of the seeds of higher plants (Sandberg and Anderson, 1998).

Phytic acid is present as a salt of mono and divalent cations (e.g., potassium, calcium and magnesium). It accumulates rapidly in the aleurone layers of the seeds during the period of maturation and is generally considered to be the primary source of inositol and reserve of phosphorus in the seeds of plants used in animal and human nutrition (flour of seeds, cereal grains and legumes) (Maga, 1982).

Within the PSR project GO-SEEDS on pre-germinated seeds for the food industry, financed by the Veneto Region, the contents of phytic acid and free phosporous as well as free phenolic acids before and after seed pre-germination were investigated in various old open-pollinated maize varieties, in order to evaluate the possible variation of bioavailable nutraceutical compounds.

Materials and Methods

Four open-pollinated maize varieties, i.e., Corvino, Marano, Sponcio, Vinaiolo and Rosso Rostrato, were cultivated during the 2021 growing season in open field at the experimental farm of the University of Padova at Legnaro (Padova, NE Italy) at a density of 7 plants m^{-2}. At harvest, the ears were manually harvested and shelled by a stationary plot combine harvester.

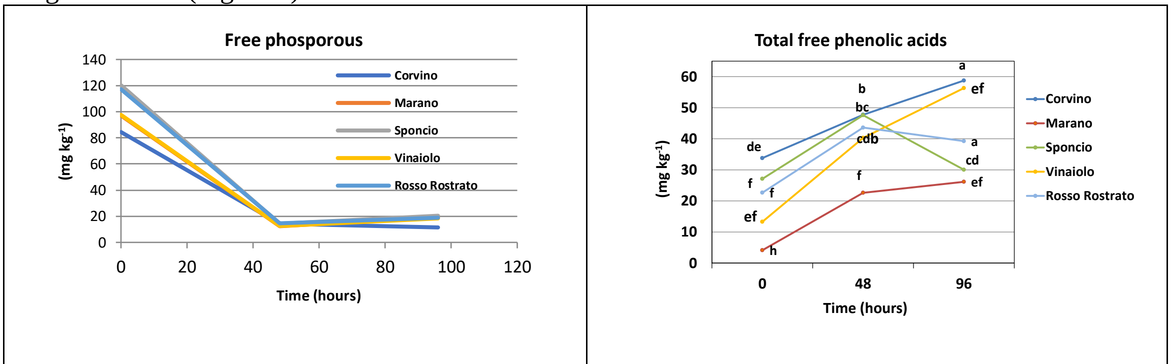
The kernels were used to set-up a pre-germination protocol, which consisted in preliminary water soaking (24 hours) and successive germination for 72 hours at 22°C and 90% air humidity within a climatic chamber. In this way the process complessively lasted 96 hours, at the end of which the kernels showed the primary radicle of ~1 cm and the sprout of ~0.5 cm of length.

The content of free phosphorus was determined in non germinated kernels and 48 and 96 hours from the beginning of soaking. Free phosphorus was extracted by 12.5% TCA in $MgCl_2$ (25 mM) for 18 hours; the supernatant collected after centrifugation was further treated with the Chen's reagent and measurements were done at 660 nm wavelength.

Free phenolic acids, such as *p*-coumaric acid, caffeic acid, syringic acid, vanillic acid, and *t*-ferulic acid were extracted with 80% v/v chilled acetonitrile (ACN) after 5 min shaking, and centrifugation. The supernatant was analysed by HPLC using an Ultra Tech sphere C18 column (1.5 µm, 33 mm × 4.6 mm; CIL Cluzeau, Sainte-Foy-La-Grande, France) Photodiode Array Detector at 282 nm wavelength.

Results

The total content of phosphorus in non germinated kernels was quite high with similar values among maize varieties (average 3,268 mg kg^{-1}, with maximum of 3,531 mg kg^{-1} in var. Marano, and minimum of 2,976 mg kg^{-1} in var. Rosso Rostrato), whereas the content of free phosphorus varied largely, it ranging from 84 mg kg^{-1} in var. Corvino and ~120 mg kg^{-1} of varieties Rosso Rostrato and Sponcio.
During germination, while the content of phytic acid remained stable, free P decreased rapidly within 48 hours and remained stable during the rest of the processs, with no differences among varieties (finale average of 13.6 mg kg^{-1}) (Figure 1). As regards the content of free phenolic acids, it increased over time during pre-germination, the hierarchy among varieties remaining rather stable: the richest variety was Corvino, and the poorest Marano (Figure 1). The most aboundant phenol was ferulic acid in var. Corvino and Rosso Rostrato, and syringic acid in var. Sponcio. Caffeic acid increased largely in all varieties with the germination (Figure 1).



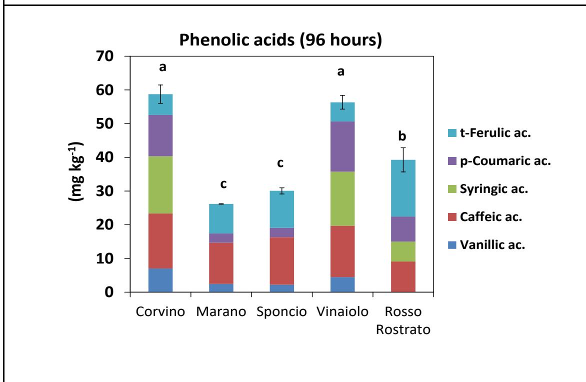


Figure 1. Dynamics of free phosphorous and total free phenolic acids during seed germination (above), and phenolic acids patterns at the end of the process (left) in old maize varieties. Letters: statistical multiple comparisons (above) and variety differences (left) (Student Newman-Keuls test, $P \leq 0.05$).

Conclusions

Old maize varieties represent an important source of genetic variability that can be valorized in the seed pre-germination process for the food chains thanks to their attractive kernels colour and nutraceutical value. Indeed, during the germination process the content of free phosphorous decreased markedly, probably due to its utilization by the growing sprout, an effect that can reduce the potential renal acid load (PRAL), while the content of phenolic acids often doubled. Seed pre-germination has proved in the past to increase microelement bioavailability at intestinal level, particularly iron, and these results also proved its efficacy in improving the content of antioxidant compounds.

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Valorisation Of Heritage Wheat And Other Underutilised Crops In Piedmont For Sustainable Food Systems

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Introduction

Wheat is the first most cultivated cereal globally as an energy source for human nutrition, followed by rice and corn. World wheat production hits a record 775 million tons in the 2021 (FAO, 2022). The EU is the first on volumes with 152 million tons (France, Germany, Poland, Spain) and increasing production, followed by China 137 million tons, India 100 million tons and the Russian Federation 86 million tons. Italy is in 20th place with 3M hectares of cereals. The most spread common wheat varieties in Italy (*T. aestivum L.*), according to certified seed data in order of importance, are: Bologna, Rebelde, Giorgione, Solehio, PR 22R58, Altamira, Bandera, Illico, Adhoc, LG Ayrton, that alone represent the 47% of the total quantity of certified seed in Italy.

The FAO international treaty for plant genetic resources for food and agriculture (ITPGRFA) stresses the importance of the conservation and sustainable use of all plant genetic resources for food and agriculture and the equitable sharing of the benefits deriving from their use, in harmony with the Convention on Biological Diversity (1992) for sustainable agriculture and food security.

But what is the role of dynamic value chains using biodiverse and underutilised crops to improve food system resilience and deliver foods with good nutritional and health properties while ensuring low environmental impacts, and resilient ecosystem functions?

UC can be defined as “a neglected, but valuable species, landrace, variety, or cultivar that has limited current use in a given geographic, social, and economic context and that holds great promise to diversify agricultural systems, create resilient agroecosystems, diversify diets, and create economically viable dynamic value chains for feed, food, and non-food uses (FAO, 2019)”.

Underutilised crops and in particular heritage varieties of wheat are at the core of two projects that enhance participatory plant breeding strategies for local wheat varieties; build local as well as cross-country networks between farmers, organisations and institutions implicated in the valorisation of underutilised crops, and increase the public and market awareness about underutilised crops in particular bread wheat varieties.

Materials and Methods

The GER.MONTE project “Recovery, characterization and conservation of the germplasm of local species and varieties of Piedmont" https://www.unisg.it/ricerca/germonte-3/ funded by the Piedmont Region (under Law 194/2015 Biodiversity Fund), it started in 2017 and is in its third edition. It provides for the implementation of dissemination activities aimed at spreading the values of biodiversity and enhancing the conservation actors of local Piedmonts varieties with ex situ and in situ strategies. The final goal is the exchange of genetic material, experiences and information between partners of the regional biodiversity network and the enhancement of agrobiodiversity through the dissemination of knowledge on local varieties to the consumer.

The European Horizon 2020 RADIANT - “Realizing dynamic value chains for under utilised crop” https://www.radiantproject.eu/ is 4 year project (2021-2024) that implements a suite of strategic and fully inclusive multi-actor engagement methods to co-develop solutions and tools to ensure that agrobiodiversity in the form of underutilised crops (UCs) is realised via Dynamic Value Chains (DVCs). Our activities are carried out in several farms of Piedmont and include:

I. identify, collect and multiply the local genetic resources of wheat
II. screening wheat collections for adaptation to different pedoclimatic conditions, sources of resistance to stress

III. participatory breeding approaches to adapt to climate change (Bocci et al. 2020)
IV. valorisation of locally grown wheat landraces and development of improved landraces and new varieties.

Results

The projects GER.MONTE and RADIANT include both agronomic research as well as dissemination actions and networking activities.
The following results have been achieved in 2021/22:

- 10 local varieties of wheat have been enrolled in the national catalogue of conservation varieties;
- animation and dissemination of the regional network of biodiversity of agricultural and food;
- 10 catalogue fields with plots and educational gardens;
- 11 technical meetings in the field and meetings with consumers;
- a publication and 4 videos illustrating 3 genetic resources (wheat, corn and horticulture crops)
- a cycle of 10 lectures at high schools on agrobiodiversity to sensitive the young generation
- a public event aimed at celebrating the biodiversity day of agricultural and food interest and at animating the regional biodiversity network: a conference, a farmer's markets with 25 producers, a lunch with gastronomic preparation using local varieties and products and others events.

The results of a questionnaire show (Roatta et al. 2021) that around 20 local varieties of wheat are cultivated by 40 different small farmers in Piedmont (fig 1):

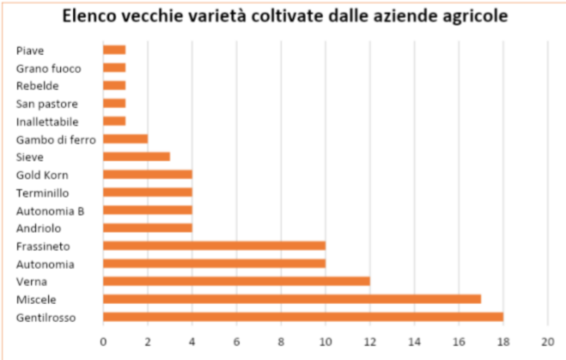

Figure 1. List of local wheat varieties cultivated in Piedmont in 2020

Conclusions

The two projects present a model of how a multi-stakeholder and multi-level approach is fundamental to be applied in order to revive the cultivation as well as the value chain of underutilised crops such as wheat. A wheat production rooted in local communities and territories is a pillar for food sovereignty, sustainable and local food chains as well as local biocultural diversity

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Effects Of *Bradyrhizobium inoculum* And Plant Density On The Productive Characteristics Of A Sweet Cultivar Of *Lupinus albus L.*

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Introduction

The inclusion of lupin in crop rotation has numerous agronomic and environmental advantages (López-Bellido, 1994), including growing on less fertile, acidic and sandy soils where other crops produce lower yield (Pospišil and Pospišil, 2015), and as legumes, a high symbiotic nitrogen fixation rate (Georgieva et al., 2018). Characteristics particularly relevant in organic agricultural production, due to its low input requirements and positive impact on subsequent crops yield, as wheat (+45% according to López-Bellido, 1994). The white lupin (*Lupinus albus* L.), a fabacea with a high protein content (about 40%), had played a marginal role in animal nutrition and so in cultivation systems, because of the presence of high levels of toxic and bitter quinolizidine alkaloids in seed. The selection of new bitter alkaloids free blue and white lupine genotypes is opening new prospects for the use of these grain legume, already successfully introduced in central Italy, where the sweet lupines have joined the protein pea as grain legumes ~~i~~n the feeding livestock, but are still absent in Sicilian agroecosistems.

Moreover, the lacking of lupin cultivation and its poor ability to grow in sub-alkaline soils determined, the absence in the soil of the specific *Bradyrhizobium* genus. Thus, the inoculation of *Bradyrhizobium* strains adapted to the various pedo-climatic conditions may play an important role in expanding lupin cultivation area. In the framework of the Crealup project, with the aim to introducing lupin cultivation in a Sicilian farms, two different studies were performed on sweet *Lupinus albus* cv. Tennis. The first one evaluated the effects of a commercial strain inoculation *of Bradyrhizobium* on the agronomic characteristics in sub-alkaline soils. The second study evaluated the effects of plant density on the lupin productive characteristics when cultivated in the most suitable (acidic pH) soils.

Materials and Methods

The trials, adopting a full randomised block design with three replicates, were undertaken in semi-arid Mediterranean climate conditions with the highest air temperature (37.7 °C) in May, the lowest (-0.60 °C) one in February, and a total precipitation of 260 mm (Servizio Informativo Agrometereologico Siciliano). The first trial was carried out in two farms "Villa Cesarea" (37°7'5,005''N - 15°4'49,846''E , soil pH 7.4) and 'Musso'(37°00'57.8"N - 14°54'27.4"E, soil pH 7.5), characterised by subalkaline soils. The studied treatments were: control vs nitrogen fixing bacteria inoculum (I). The *Bradyrhizobium* strains used for the trial were: *B. japonicum* AGF 542, *B. lupini* AGF 543, *B.* AGF 544 (Agrifutur srl, Alfianello-BS, Italia). The biofertilizer was applied at sowing (400 g ha^{-1}).

The second trial was carried out in the farm "Zocco Antonino" (37°02'22.2"N - 15°05'37.6"E, soil pH 6.26). The "Tennis" was sown on 23 October 2020 at two plant densities: 25 and 35 plants m^{-2}. The chemical-physical soil characteristics were determined according to the "Official methods of soil analysis" (MIPA, 1999). The soils are classified as loamy clay soil (International Society of Soil Science-SISS). Phenological phases were monitored and at harvest plant height, total biomass, and seed yield were evaluated. The data were submitted to ANOVA analysis.

Results

No significant differences were observed in the phenological stages among the studied treatments.

First trial. The effects of the inoculum on plant density were not univocal. Two months after sowing, on "Villa Cesarea' farm a significative higher plant number (16 vs 14 plants m^{-2}) was obtained in control, whereas the opposite was true in the Musso farm where inoculum determined a double plant number 16 per m^{-2}. However, plants were weak and whatever the treatment died before flowering.

Second trial. Plant density significantly influenced plant height, total biomass and grain yield. Plant height was increased by 19% by the highest density as compared to the lowest one (103,6 cm) (Fig. 1a). Total biomass was doubled by increasing the number of plants per m^{-2} from 25 to 35 (Fig. 1b), as the grain yield which rised from 0,49 Mg ha^{-1} to 0,90 Mg ha^{-1} (Fig. 1c).

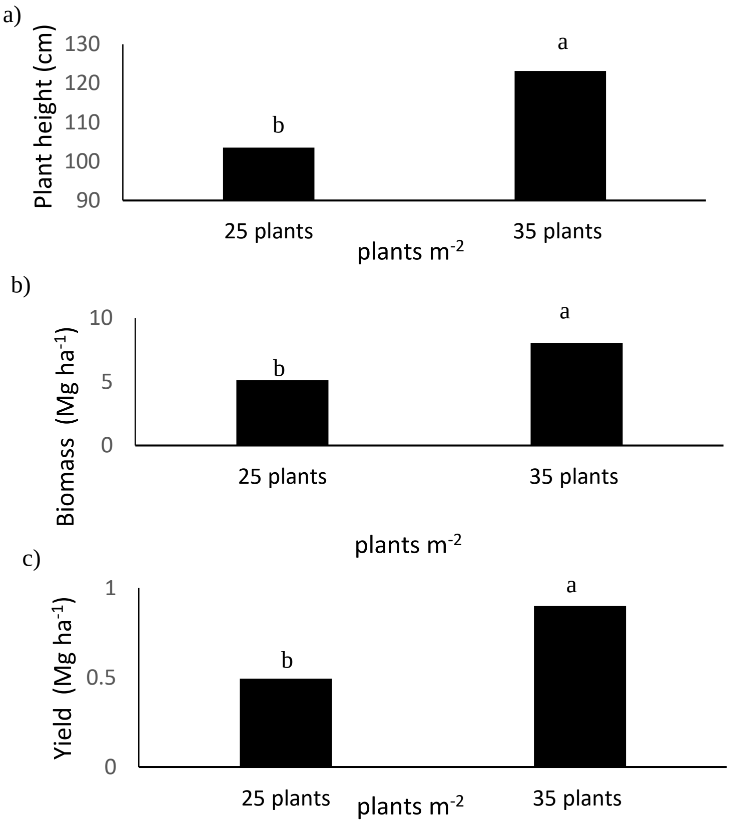

Figure 1. Plant height (a), biomass yield (b) and grain yield in relation to the studied densities (c).

Conclusions

These first results indicated that:

-inoculum was not able to permit the development of lupin in subalkaline soils. This result calls for the selection of rhizobium strains more suitable for subalkaline soils, conditions that should also be alleviated with specific agrononomic interventions.

-sowing density significantly influenced the yield of white lupin. Rising the number of plants for square meter increased significantly seed yield. These results agree with the results obtained by Mülayim et al. (2002) who stated that seed yield was increasing with sowing density up to 74 plants/m^2.

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Effects Of Wheat Crop Nitrogen Availability On The Phenolic Content, Pigment Content And Antioxidant Activity Of Wheatgrass Obtained From Offspring Grains

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Introduction

The rate and timing of N fertilization is known to affect wheat growth and yield, and the grain protein content. However, little research has dealt with the effect of N fertilization on the phytochemical content and antioxidant activity of offspring grains and no study specifically investigated the effects of the rate and timing of N supply to maternal crops on offspring wheatgrass, despite this novel food is trendy due to its benefits in human health. This study was carried out for evaluating the effect of the N fertilization schedule on wheatgrass phenolic and pigment contents and antioxidant activity.

Materials and methods

Wheat (*Triticum aestivum* L.) grains were harvested in June 2018 from a field experiment at the experimental station of the Department of Agricultural, Food and Environmental Sciences of the University of Perugia. Two bread wheat cultivars were used, having different kernel weight: Bora (BR, 28-32 mg) and Bologna (BL, 45-50 mg). Both cultivars were subjected to six different N fertilization schedules, according to a split-plot design with four replicates (randomized blocks), with the cultivar in the main plot and the N treatment in the sub-plot. For this sprouting experiment we used grains from the four following N treatments: 1) constantly well N fed (N300), i.e., fertilized with 300 kg N ha^{-1}, split into five applications of 60 kg N ha^{-1} each throughout the growth cycle; 2) N fed only very early (N60-0), i.e., fertilized with 60 kg N ha^{-1} on December, 16th (one month after sowing); 3) N fed only late (0+120), i.e., fertilized with 120 kg N ha^{-1} on March, 15th (initial shoot elongation); 4) unfertilized control (N0). The four fertilization treatments had been effective and differences among them were very marked for both cultivars in terms of crop growth indices, leaf greenness, biomass accumulation, grain yield and quality.

The grains obtained from each of the eight treatments (2 cultivars × 4 N) were used for sprouting according to the methodology of Benincasa et al. (2015), i.e., they were incubated on plastic trays with distilled water. Treatments were laid down according to a completely randomized block design with four replicates (trays). Each tray contained 15 g of seeds. In each tray, seeds were positioned on filter paper laid over cotton wetted with distilled water, to guarantee constant water availability while preventing anoxia. Distilled water was periodically added to trays to restore initial tray weight, assuming that weight change was mainly due to water evaporation. The trays were placed at 20°C, and a light/dark regime of 16/8 h, with a light intensity of 200 µmol photons m^{-2} s^{-1}. Wheatgrass was harvested 10 days after sowing, collecting only the shoots. Grains and wheatgrass were extracted and analysed with an HPLC-MS/MS system for their individual phenolic compounds according to Oliva et al. (2021). Moreover, they were analysed for their leaf chlorophyll and carotenoid contents (ChlA, ChlB, and Car, respectively) following the method described by Lichtenthaler and Buschmann (2001). The antioxidant activity was measured with a gold nanoparticles (AuNPs) photometric assay according to Della Pelle et al. (2018). Statistical analysis was performed by a two-way ANOVA.

Results

In ungerminated seeds, the differences among cultivars and N treatments for all the measured parameters were significant but little (data not shown). The increase of phenolic compounds and antioxidant activity passing from seeds to wheatgrass was very high, around 15-fold for the total amount of phenolic compounds (TPC) and 3-fold for AuNPS, on average over cultivars and N treatments (data not shown). In wheatgrass, the differences between cultivars for all the parameters were significant, but not much relevant and somehow expected (Table 1). Also differences among N treatments in wheatgrass chlorophyll and carotenoid contents and in antioxidant activity, although significant, were little and did not reveal any meaningful trend (Table 1). On the contrary, differences among N treatments for TPC were significant and very high. In particular, in both cultivars, TPC was much higher in the treatment N60-0 than in the average of other treatments (+57% in BL, + 92% in BR). The most represented phenolic compounds in wheatgrass were flavonoids, especially orientin (accounting for around 2/3 of TPC) and rutin, and some phenolic acids like, the protocatechuic, chlorogenic, 4-OH-benzoic, and vanillic acid (data not shown).

Table 1. Contents of total phenolic compounds (TPC), chlorophylls (ChlA + ChlB) and carotenoids (Car), and antioxidant activity of wheatgrass as affected by cultivars (CV) and N fertilization treatments. See text for labels.

N treatment	TPC (μg g^{-1} DW)			Chl TOT (μg g^{-1} FW)			Car (μg g^{-1} FW)			AuNPS (μg/g GAE)		
	BL	**BR**	*Mean*	**BL**	**BR**	*Mean*	**BL**	**BR**	*Mean*	**BL**	**BR**	*Mean*
N0	8548	5876	*7212*	1817	1967	*1892*	240	237	*239*	1614	1499	*1556*
N300	5602	6022	*5812*	2475	1929	*2202*	291	192	*242*	1437	1396	*1416*
N60+0	11011	12170	*11591*	2186	1985	*2086*	298	239	*269*	1412	1676	*1544*
N0+120	6835	7094	*6965*	2021	1465	*1743*	247	161	*204*	1255	1436	*1346*
Mean	*7999*	*7790*		*2125*	*1836*		*269*	*207*		*1430*	*1502*	
CV	*** (36.8)*			*** (179.2)*			*** (25.9)*			*** (25.9)*		
N	*** (52.1)*			** (253.5)*			** (36.7)*			*** (36.6)*		
CV x N	*** (73.7)*			** (358.5)*			*n.s. (51.9)*			*** (51.7)*		

** $p < 0.05$; ** $p < 0.01$; n.s. = not significant; LSD at P=0.05 in brackets. DW=dry weight; FW=fresh weight*

Conclusions

Our results demonstrate that N fertilization schedule can greatly affect wheatgrass phenols content. In both cultivars, grains obtained from crops subjected to late N deficiency produced wheatgrass with higher phenols content. Thus, we conclude that late N deficiency is a stressing condition which elicits the production of phenols. Of course, such an imbalance in crop nutrition is not desired but cannot be excluded *a priori*, in light of the need to reduce economic and environmental costs of fertilization and due to climate changes, which can result in unusual but possible heavy rainfall in spring.

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Effect Of Foliar Application Of Fertilizers And Biostimulants On The Growth And Seed Production Of A Male-Sterile Inbred Line Of Maize

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Introduction

Inbred maize lines are highly specialized crops cultivated to obtain hybrid seeds. Soil fertilization is the most widespread method to supply nutrients to the crop. However, plants can uptake mineral nutrients also by leaves whean applied at appropriate concentration (Fageria et al., 2009). Foliar fertilization aims at providing nutrients under limiting soil nutrient availability and to sustain the plants during critical phases for nutrients requirement (Fernández et al., 2013). Foliar fertilization has many advantages, such as the possibility to provide small nutrients quantity, satisfy specific plant needs in different growth stages, and stimulate roots to absorb nutrients from the soil solution by systemic internal signals. Although foliar fertilization cannot replace soil fertilization, it can be used as a supplement/complement in sustainable production systems (Kannan, 2010). There are many factors affecting the dynamics of foliar nutrient absorption, such as leaf size, shape and age, the presence of trichomes, the chemical composition of cuticle and foliar waxes, as well as some environmental factors, like temperature, relative humidity and wind speed, and intrinsic characteristics of the commercial products such as nutrient concentration, solubility, pH, point of deliquescence (POD) and molecular weight of dissolved compounds (Fernández et al., 2013). While foliar fertilization has been initially developed for horticulture, it is becoming important for cereals such wheat and maize. In this study, various fertilizers/biostimulants were applied in open field to a female imbred maize line at early stages by foliar application in order to verify whether plant growth and seed production were improved, for better sustainability.

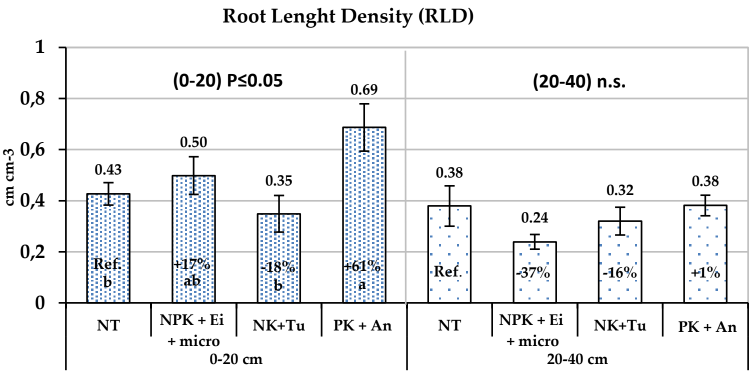
Materials and Methods

The trial was conducted at the Ca' Corniani farm in Caorle (Venice, NE Italy, 2 m a.s.l.) during the 2020 growing season. The field trial considered an inbred female male-sterile line of maize for a FAO-700 hybrid seed production. The experimental set-up consisted of a latin-square with four replicates (n=4). Each plot was 4,5 m wide (6 rows of seedbearing plants) and 10 m length (45 m^2). Among the plots, there were two rows of male line that are spaced out 0,50 m each one. The foliar treatment was carried out on 16 June in the middle of the day at V5 stage (5 true leaves extended). The organic-mineral fertilizers applied by foliar spraying are commercial products, consisted of at least two macro-nutrients with organic carbon deriving from different matrices: a) Organic-mineral fertilizer 10.5.7 hydrolyzed animal epithelium and micro-elements (NPK + Ei + micro); b) Organic-mineral fertilizer in suspension 13.0.5 with humified peat (NK + Tu); c) Organic-mineral fertilizer 0.13.5 together with brown algae *Ascophyllum nodosum* extracts (PK + An). The investigated parameters regarded both physiological (SPAD, Net CO_2 assimilation), and morphological (plant height, root growth) traits, and productive/qualitative traits for commercial purposes (grain dry weight and number of bags per Gross hectare – field surface divided into 84% and 16% of female and male lines, respectively – kernel caliber, waste kernels, germination rate, etc.). Statistical analysis was carried out with Costat software (Cohort software, Manugistics, Rockville, MD-USA; ver. 6.204). Separation of means was set at $P \leq 0,05$ with the Newman-Keuls test.

Results

As regards plant physiology, foliar fertilization did not lead to benefits on shoot growth of maize and leaf chlorophyll content (SPAD), while at stage V10-V11 the root system was improved mainly in the shallow soil layers (0-20 cm) by the PK + An treatment (and somewhat by the NPK+Ei), as referred to diameter, root length and root area densities (Figure 1). The root dry biomass was also increased by PK + An. As regards the qualitative parameters of the grains, the application of these products allowed slight improvements compared to controls (NT) in terms increased number of kernels per spike and reduced percentage of waste kernels. The production of seed commercial bags (80 k seeds each) was not significantaly affected by foliar application, although slight improvements were recorded for all the treatments (Figure 1). On average, the proportion of kernels with medium caliber was higher than the larger one.

Germination was not affected by any foliar fertilization.



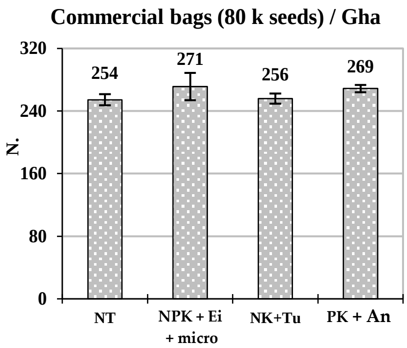


Figure 6. Root Lenght Density (RLD) in two soil layers (0-20 and 20-40 cm) (left) and number of commercial bags product per Gross hectare (right) in a male-sterile seedbearing line under different foliar

Conclusions

This study demonstrates that it is essential to pursue a research and development model aimed to strengthening agronomic knowledge on the impacts of foliar fertilization on crops such as seed maize, with the aim at tuning the agronomic technique and developing increasingly productive and sustainable practices. In addition to greater economic sustainability for the seed company, producing more seeds on a smaller surface allows to obtain more basic material for future crops, in line with current needs of a constantly growing population. It can be concluded that foliar fertilization with specific fertilizers and biostimulants is agronomically interesting in seed maize production, even if further studies are necessary in order to consider different doses and application timing (possibly later, at the 7-8-leaf stage, at the spike differentiation).

Literature

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Biomass Yield And Morphology Of Giant Reed Clones From Mutagenesis

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Introduction

Arundo donax L., common name Giant reed, is a C3 warm-season, lignocellulosic rhizomatous perennial energy grass, belonging to the *Gramineae* family (*Poaceae*) (Lewandowski et al., 2003).
Arundo donax L. has a high photosynthetic capacity which is different from other C3 species, indeed, it is very similar to the C4 species. This high photosynthetic capacity is related to the lack of saturation in the absorption of CO_2 and in the transport of electrons through the photosystem II (Haworth et al., 2019; Cosentino et al., 2016).
It has a high biomass yield, the ability to use water efficiently and satisfactory biomass quality; and therefore, hold a great promise for biomass production in drought affected areas (Cosentino et al., 2016; Cosentino et al., 2014). Even though *Arundo donax* L. produces flowers, the seeds are not viable (Boose et al., 1999). Consequently, its propagation and diffusion are carried out mainly by agamic propagation. Due to vegetative reproduction, low genetic variability has been observed among Giant reed plants (Touchell et al., 2016).
In this regard, the University of Bologna (Italy) has applied the γ-irradiation of in vitro cell cultures to obtain mutagenesis and produce numerous clones. Twelve of these clones, in the framework of the PRIN 2017 project from the Italian Ministry of University and Research "Technical and biotechnology innovations in perennial lignocellulosic crops for the production of bioenergy, green building and furniture panels" were studied in Sicily by the University of Catania in order to verify their biomass yield and drought resistance.

Materials and Methods

Twelve mutated clones, developed at the University of Bologna (Italy) from mutagenesis γ-irradiation of in vitro cell cultures compared with a native clone from University of Catania (ARCT) were established under optimal water conditions in a randomized block design. The rhizomes of the studied clones were transplanted in May 2019 at the Experimental Farm of the University of Catania. A randomised block field experiment replicated three times was applied. Each plot measured 6×10 m.
No fertilization was supplied and weeds were manually controlled twice during the growing season. The irrigation was provided by a drip irrigation system. During the growing season, all plots received the restoration of 100% of maximum crop evapotranspiration.
The harvest was performed in February 2020. Within each plot was inside harvested (4×8 m) cutting the stems by a grass trimmer. In order to estimate dry yield, the fresh biomass collected in each plot was weighted and a sample of biomass was then put in oven at 105°C in order to determine the percentage of humidity. Within the harvested biomass, samples were then randomly collected and morphological, biometric and productive traits were determined in laboratory.

Results

Figure 1 shows the yield in above ground dry biomass, subdivided in dry leaves and stems for each clone. Clone 6F had the highest yield (6.28 Mg ha^{-1}) followed by clones 44C and 7F (5.71 and 5.69 Mg ha^{-1}) which produced more than ARCT clone (4.82 Mg ha^{-1}). The lowest yields were observed in 36B, 9F, 7D, 70I, 1 and 8F (4.24; 3.63; 3.26; 2.65; 2.43; 1.83 Mg ha^{-1}, respectively).

Within the mutated clones the percentage of dry stems yield compared to total dry yield ranged from a minimum of 43% of clone 95M to a maximum of 75% in 7F, whereas in ARCT more than 88% of the aerial biomass was represented by stems.

Indeed, the highest stem yield of the mutated clones resulted similar to that of ARCT clone (4.30 Mg ha^{-1} in 7F compared to 4.26 Mg ha^{-1} in ARCT). The other most producing clones in stem yield were 44C, 36G and 6F with 3.97, 3.29 and 3.19 Mg ha^{-1}.

The biomass leaf-to-stem ratio showed large differences among clones, ranging from 1.3 to 0.3 g g^{-1} (Fig. 2).

Clones 6F, 70I, 1 and 8F had a similar trend with 0.94, 0.58, 0.83 and 0.70 g g^{-1}. Clones 95M and 21G had the highest values, 1.3 and 1.2 g g^{-1} respectively, showing leaf dry matter higher than the stem dry matter.

To sum up, clones 95M and 21G not only have a high leaf to stem ratio but also present a good yield with an average of 5.22 Mg ha^{-1} and 4.51 Mg ha^{-1}, respectively. Indeed, clones with a low leaf to stem ratio and a good yield are 44C and 7F with an average of 5.71 Mg ha^{-1} and 5.69 Mg ha^{-1}, respectively.

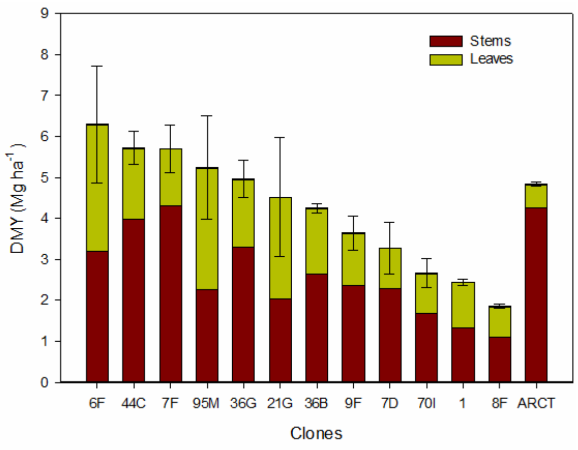

Figure 7. Above ground yield (Mg ha^{-1}) subdivided in stems and leaves in the studied clones.

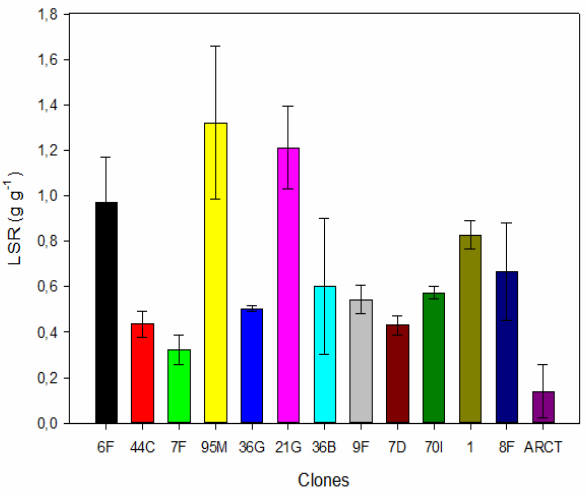

Figure 8. Leaf-to-stem biomass ratio (g g^{-1}) in the studied clones.

Conclusions

The field trial is still ongoing to assess the productivity and variability of important traits for specific end uses of *Arundo donax* clones obtained from mutagenesis suitable to warm-temperate and hot summer areas.

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Mater-Bi® Mulching And Drip Fertigation Increase Yield And Quality Of Flue-cured Tobacco In The Tiber Valley

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Introduction

Mulching is useful to suppress weeds, rise the top-soil temperature, reduce evaporation and protect soil structure, with beneficial effects on physical and chemical conditions of the soil and on crops growth and yield. Tobacco mulching is not usual in Italy, but frequent in some tobacco districts (Chida, 2015; Xiaoheng, 2020). Here we report on a comparison of mulching and drip fertigation vs no mulching, ordinary fertilization and sprinkler irrigation on flue cured tobacco in a trial conducted in the Tiber valley growing district.

Materials and Methods

The trial was conducted in the year 2021 at Città di Castello (PG). For the mulching with drip fertigation treatment (Mulch-Drip) a black, biodegradable film (N1-F04 grade MATERBI) 0.7 m wide, covering a 0.4 m width across the ridge, and a T-Tape micro-fertigation system were used. The control treatment was fertilized as usual and sprikler irrigated. The treatments were replicated three times in plots of 50 m^2 with 144 plants. Tobacco plants cv ITB6178 (Bergerac Seed & Breeding) were transplanted on May 29 on a sandy loam with high permeability, low in organic matter and NP nutrients. All plots were fertilized pre-planting with 40 Kg/ha N and 90 kg/ha P. Control plots received also 52 kg/ha N at the earthing up and 13 kg/ha N and 46 kg/ha P at the end of July. Mulched plots were fertigated thrice, receiving in total 53 kg/ha N and 46 kg/ha P. Plants were topped when 2/3 of them in the plot showed flower buds and treated with n-decanol suckercide. The harvest was completed with three reapings, conducted respectively on August 26, September 13 and October 1 for mulched plots. September 10 and 22 and October 8 for the control. Cured tobacco was graded by color, ripeness, structure and texture and priced accordingly. Gross returns were obtained multiplying yield by price. For inference purposes normal distributions were attributed to the outcomes, with parameters for the means estimated with a linear model using the R environment (R Core Team, 2022). Average (means) and observable (predictions for new trials) treatment effects for the trial conditions, expressed as percent differences, were computed from posterior distributions of the model parameters.

Results

The test treatment allowed to finish the harvesting ten days earlier, a notable benefit considering that the last reaping may be compromised in the district by the early onset of the cold season (Miele et al., 2003*)*. Average observed values for the Mulch+Drip and the control treatments were, respectively, 4 and 3.2 MT/ha for cured yield, EUR 3.07 k/MT and 2.39 k/MT for unit price, and EUR 12.24 k/ha and 7.48 k/ha for gross return (Table 1).

Table 1. Ranges and medians of yield, price and gross returns per treatment.

Treatment	Cured yield, MT/ha			Price, EUR k/MT			Gross return, EUR k/ha		
Mulch+Drip	3.8	**4.0**	4.2	3.04	**3.07**	3.10	11.58	**12.24**	12.80
NoMulch+Sprinkler	2.9	**3.2**	3.3	2.36	**2.39**	2.42	7.08	**7.48**	7.87

Inferential distributions of plausible values for expected values (long-term averages) and observable (predictions for a new trial) treatment effects are represented in Figure 1. With 90% probability, in the condition of the trial, the Mulch+Drip treatment expected increases above the NoMulch-Sprinkler may range between 14% and 42% for cured yield, 25% and 31% for price, 46% and 80% for gross returns per hectare. Corresponding intervals for observable increases range between -7% and 75% for cured yield, 23% and 34% for price, 32% and 100% for gross returns per hectare. Values in the middle of the ranges are relatively more probable.

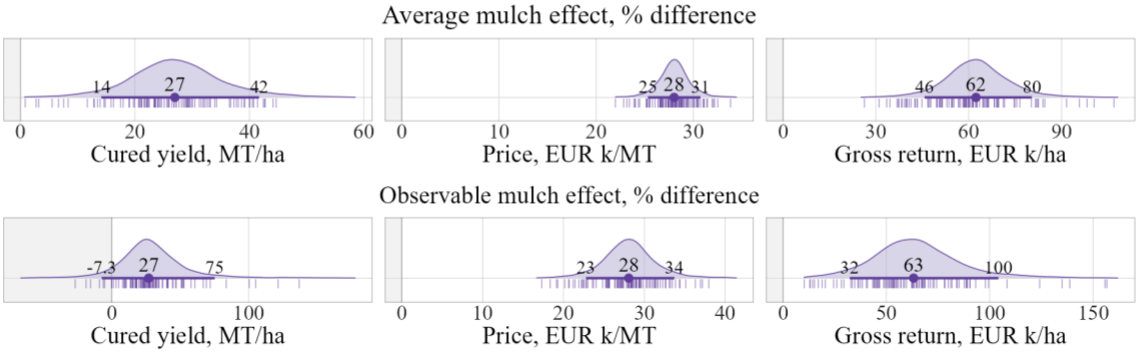

Figure 1. Distributions of average treatment effects (means) and observable effects (predictions for a new trial) for the trial conditions, with central values and 90% intervals. Ticks below the curves represent a sample of 100 values).

Conclusions

Mulching with drip fertigation showed large positive effects in this preliminary trial. The package of biodegradable mulching plus micro-fertigation appears promising for a sustainable, high intensity, tobacco cultivation.

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Influence Of Fertilization Programs On The Antioxidant Content Of Processing Tomato Fruits

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Introduction

The fruit of tomato (*Solanum lycopersicum* L.) is considered a functional food, because of the high content of vitamins, minerals and antioxidants (carotenoids and phenolic compounds) believed useful for prevention of chronic and degenerative diseases. Lycopene is the main carotenoid hydrocarbon of tomato fruits. Agronomic practices are among the factors influencing the nutraceutical profile of the tomato fruit. Here we report the effect of some fertilization programs on the antioxidant content of processing tomato fruits.

Materials and Methods

Three fertilization programmes for processing tomato, F1 'Coronel' (ISI Sementi, Parma) with large oval fruits, were evaluated in the year 2019 at Portici (NA), on a sandy clay loam soil low in organic matter and nitrogen but well endowed with phosphorus, for their effect on antioxidants: i) Mineral at the rate of 180 kg/ha nitrogen and 30 kg/ha phosphate (Mineral); ii) compost at the rate of 10 MT/ha (Compost); iii) compost at the rate of 5 MT/ha complemented by 90 kg/ha nitrogen (Compo-Min). The treatments were assigned to plots of 10 m^2 (32 plants) replicated thrice in randomized blocks. Tomato was transplanted on May 10, 2019, at the density of 32,467 plants/ha in paired rows on ridges mulched with a yellow photoselective and photoreflecting 25-μm thick film (Ginegar Plastic). The compost and phospate were applied all at ridging, nitrogen split 30% at ridging and the balance as topdressing by drip fertigation with a T-tape device. The crop was irrigated weekly, balancing the amount of water lost with evapotranspiration (Hargreaves), up to ten days before harvesting. Fruits were all harvested when 80% of them per plot were ripe. Samples of 15 marketable fruits per plot were analysed for the content of phenols, flavonoids, lycopene, ascorbic acid, dry matter and total antioxidant activity by the methods reported in Cozzolino *et al*. (2021). For inference purposes normal distributions were attributed to the outcomes, with mean parameters dependent on experimental factors, estimated with a linear model using the R environment (R Core Team, 2022). Average (means) and observable (predictions for new trials) treatment effects for the trial conditions, expressed as percent differences, were computed from posterior distributions of the model parameters.

Results

Observed average values by treatment were higher with Compost compared to Mineral for all the responses, in agreement with findings of Ana *et al* (2014), and, except for ascorbate, also compared to Compo-Min, which showed roughly intermediate values (Fig. 2). The higher values of the compost treatments could have been favoured by a moderate stress incurred by the plants, resulting in lower yields of fruits higher in soluble solids and compounds contributing to the nutritional quality of the fruit (Oliveira *et al*, 2013).

Inferential distributions of plausible values for average treatment effects are represented in Figure 1. With 90% probability, in the condition of the trial, the Compost treatment average increases above the Mineral may range between 2% and 18% for phenols, 1% and 50% for flavonoids, 15% and 49% for lycopene, 19% and 32% for antioxidant activity, 5% and 21% for ascorbic acid, 1% and 59% for dry matter, the probability of the expected values increasing toward the centre of the distributions. Compared to Mineral the average increases with Compo-Min are expected with 90% probability in the ranges: 1% and 17% for phenols, 1% and 32% for flavonoids, 0.5% and 30% for lycopene, 14% and 26% for antioxidant activity, 10% and 26% for ascorbic acid, -19% and 41% for dry matter.

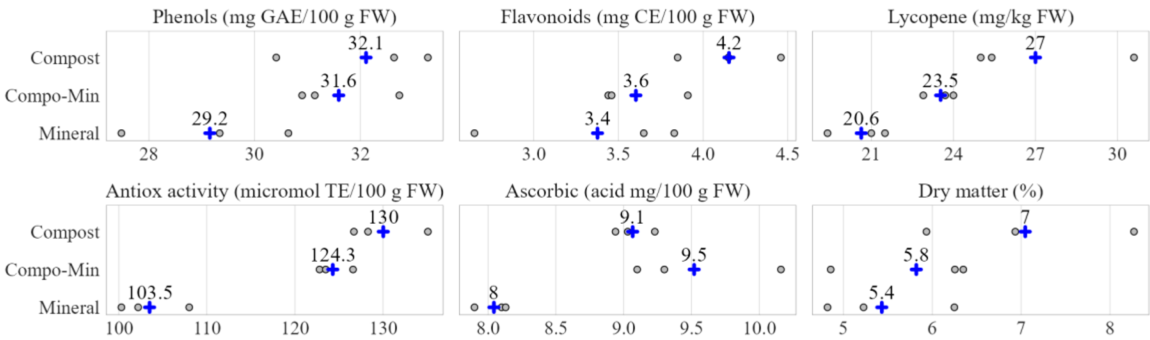

Figure 1. Observed values of dry matter and antioxidant compounds of tomato fruits by treatment (o), with marks (+) and values of means.

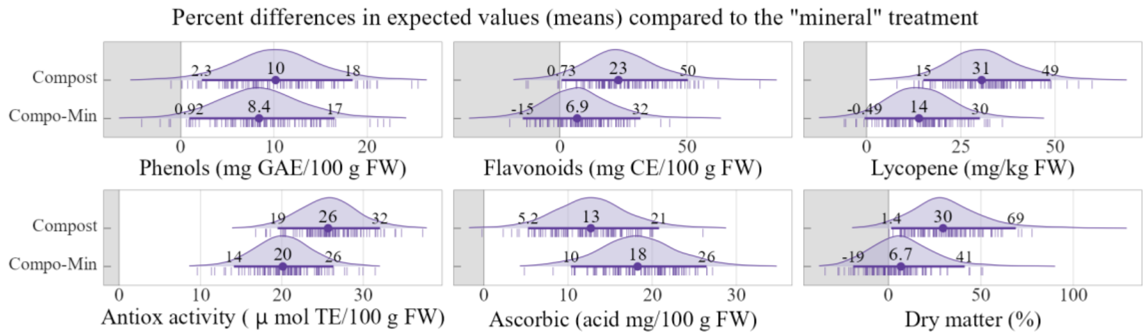

Figure 2. Distributions densities of average treatment effects (population means) for the trial conditions, with central values and 90% interval values. The ticks below the curves represent samples of 100 values.

Conclusions

In a sandy clay loam soil low in nitrogen content, fertilization programs with only compost (10 MT/ha) and with compost complemented with mineral nitrogen (5 MT/ha and 90 kg/ha N, respectively), compared with only mineral nitrogen program (180 kg/ha), increased the content of nutraceutical substances in processing tomato fruits, particularly of phenols and lycopene, in proportion of the compost rate, enhancing average antioxidant activity by 26% and 20% respectively.

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Seed Productivity Of Different Hemp Cultivars As New Nutritional Resources Under Mediterranean Climate

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Introduction

Hemp (*Cannabis sativa* L.), belonging to family *Cannabaceae*, is an important plant since times immemorial. It is a source of durable fibers, nutritious seeds and psychoactive metabolites.

Hemp seeds contain about 25-35% oil, 20-25% protein, 20-30% carbohydrates, 10-15% insoluble fibers, 5% ash, vitamins and minerals (Callaway, 2004). Its oil is rich of polyunsaturated fatty acids (over 80%) containing linoleic acid (18:2 *omega*-6, 55–60%), α-linolenic acid (18:3 *omega*-3, 15–20%), γ-linolenic acid (~5%) and stearidonic acid (~1%) (Galasso et al., 2016; Leizer et al., 2000). The o*mega*-6 to *omega*-3 ratio (n6/n3) in hemp seed oil is normally between 2:1 and 3:1, which is considered to be optimal for human health. Hemp seed oil is a complete nutritional source for its properties and it will have an appeal to a variety of potential markets and consumers (Leizer et al., 2000).

The aim of this research was to evaluate different hemp cultivars for seed yield in Apulian Region.

Materials and Methods

Cultivation: A field experiement was carried out between spring and summer 2021 at the "M. E. Venezian Scarascia" farm, belonging to Council for Agricultural Research and Economics - Research Center for Agriculture and Environment (CREA-AA) in Rutigliano (Bari) (Lat: 40° 59' 33.80'' N; Long: 17° 01' 53.82'' E; Alt: 147 m a.s.l.), in Southern Italy.

The local climate is Mediterranean, with long and hot-dry summer, mild winter and average annual rainfall of 500 mm, mostly concentrated from autumn to early spring. The soil is clay-loamy.

Seven hemp cultivars: 5 dioecious (Carmagnola, Carmagnola Selezionata, Eletta Campana, Fibranova, Fibrante) and 2 monoecious (Codimono, Carmaleonte) were sown at the end of April 2021 with 25 Kg seed ha^{-1}. The fertiliser used in the trial was granular ammonium nitrate (26% N) with a dose of 120 Kg N ha^{-1} and was applied one month after sowing.

Two irrigation treatments were compared: high irrigation (High Irr) and low irrigation (Low Irr). During the cultivation cycle, the plants were irrigated for high irrigation treatment, restoring completely the water lost by evapotranspiration, and for low irrigation treatment, intervening in periods of succor.

Determinations: The plants were harvested when 75% of seeds were ripe, between September and October 2021 and were divided in male and female. The female infiorescences were dried in a ventilated oven and then residual infiorescences and seeds were separated. The following parameters were determinated: number of male and female plants, seed yield (t ha^{-1}), thousand seed weight (g).

Results

The highest values of seed yield were observed in high irrigation treatment (average 1.38 t ha^{-1}) and in dioecious cultivars (average 1.53 t ha^{-1}) (Table 1). The highest seed yield was observed in Eletta Campana (2.14 t ha^{-1}) in high irrigation treatment and the lowest value was shown in Codimono (0.37 t ha^{-1}) in low irrigation treatment (Table 1).

The thousand seed weight was higher in high irrigation treatment (18.8 g) than in low irrigation treatment (16.9 g) and was higher in dioecious cultivars (19.6 g and 17.5 g) than monoecious cultivars (17.0 g and 15.3 g) (Table 1).

Figure 1 shows the percentage (%) of number of male and female plants for each hemp cultivar. In the average of two treatments, the male and female plants were 46% and 54% respectively in dioecious cultivars and 100% female (seedbearing) plants were in monoecious cultivars.

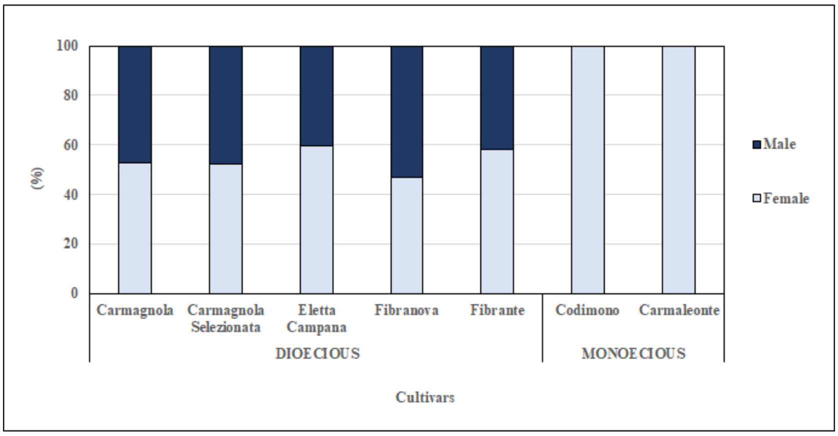
Conclusions

This research confirmed that irrigation is very important to achieve a good seed yield and a correct thousand seed weight. The different cultivars have shown a wide ability to adapt to the Mediterranean climate.

Table 1. Seed yield (t ha^{-1}) and thousand seed weight (g) for each hemp cultivar.

Genotypes	Cultivars	Seed yield (t ha^{-1})		Thousand Seed Weight (g)	
		High Irr	Low Irr	High Irr	Low Irr
DIOECIOUS	Carmagnola	1.52 b	0.80 a	20.4 a	17.5 b
	Carmagnola Selezionata	1.55 b	0.56 c	20.4 a	19.1 a
	Eletta Campana	2.14 a	0.82 a	20.1 a	18.3 a
	Fibranova	1.61 b	0.88 a	18.3 b	16.3 c
	Fibrante	0.85 d	0.50 c	18.7 b	16.4 c
MONOECIOUS	Codimono	0.71 d	0.37 d	15.9 c	14.4 d
	Carmaleonte	1.28 c	0.76 b	18.1 b	16.2 c
	Dioecious	1.53 a	0.71 a	19.6 a	17.5 a
	Monoecious	0.99 b	0.56 b	17.0 b	15.3 b
	Mean	1.38	0.67	18.8	16.9

Figure 1. Percentage (%) of male and female plants for each hemp cultivar.



Acknowledgements

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Reducing Plant Height Of Old Wheat Varieties Through Agronomic Means Under Organic Management

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Introduction

Since the beginning of the 20th century breeding in wheat crop has mainly focused on yield improvements, which in turn led to reduced genetic variability and high input requirements to sustain productivity of current varieties (Guarda et al., 2004). Old wheat varieties, currently preserved in germplasm banks, were progressively abandoned, as they had relevant negative agronomic traits, such as excessive stem height, low yield, variable protein content and poor gliadins and glutenins patterns (Sanchez-Garcia et al., 2015). There is currently increasing interest to bring back such old varieties to cultivation, particularly in low fertile marginal areas and in organic farming for low-input production systems. The flours derived from these genotypes are also being appreciated by consumers within local supply chains (Sacchi et al., 2019).

This study reports results of the PSR project REVAVILOVGRA financed by the Veneto Region and aimed at recovering old/ancient wheat varieties, by providing an agronomic protocol for their cultivation under organic farming. Here particular reference is given to the challenge of reducing culm height, in order to: i) prevent lodging and ii) maximize yield and quality.

Materials and Methods

The trial was carried out in open field at the organic experimental farm of the University of Padova at Pozzoveggiani (Padova, NE Italy) during the 2020-21 growing season following a completely randomized block design (n=3; 40-m^2 plot size). Three old varieties of *Triticum aestivum* L. (Piave, Canove and Guà 113) and *Triticum spelta* (spelt, viz 'farro') were sown on 30 October 2020 and harvested on 29 June 2021. Sowing density was 150 seeds m^{-2}, and wheat was fertilized with 20 kg N ha^{-1} with manure at sowing, and 50 kg N ha^{-1} in spring time with two applications of 20+30 kg (tillering and beginning of culm elongation) of liquid beet distiller's residue (overall amount of 70 kg N ha^{-1}). In order to reduce culm height, compared to an absolute control (no nitrogen application), various treatments were investigated: 1) control: no additional treatments; 2) early culm cutting (beginning of March, with the attention to preserve the small apical spike); 3) copper foliar spraying in early March (4 kg Cu ha^{-1}); 4) four applications (2-week interval) of laminarin, as a commercial extract (Vacciplant ®) of the brown algae *Laminaria digitata*.

The culm height and the vegetational index NDVI were revealed periodically during the crop cycle, while grain yield and quality parameters [i.e., grain protein content (GPC), specific weight, thousand kernel weight (TKW)] at harvest, which occurred with a plot combine harvester.

Results

As a result of culm height monitoring during the cycle, in all the tested varieties plant size could be significantly reduced by early shoot cutting, and even more avoiding any fertilization (Figure 1). The effects of shoot cutting was less effective in *T. spelta*, but evident quite soon after the treatment in *T. aestivum* varieties and differences maintained afterward. The tested varieties revealed different average height at harvest time: *T. spelta* was the highest (125 cm), followed by var. Canove (117 cm), Guà 113 (116 cm), and Piave (108 cm). Early shoot cutting reduced shoot height from 10 to 20 cm, while copper

had a slight instant effect that disappeared later, and laminarin sometimes increased plant height. These results resembled the dynamics of NDVI over time.
In two of the most yielding varieties, i.e., Piave and Canove, the early cutting did not reduce grain yield nor the protein content. Indeed, a slight yield increase was associated with the cutting in var. Piave (4,8 t ha^{-1} vs. 4.4 t ha^{-1} of control and 3.8 t ha^{-1} of the absolute control), and with no variation in Canove (3.9 t ha^{-1} vs. 3.5 t ha^{-1} of the absolut control). Var. Canove in turn took advange from shoot cutting by increasing the protein content from 13.6% to 14.3%.

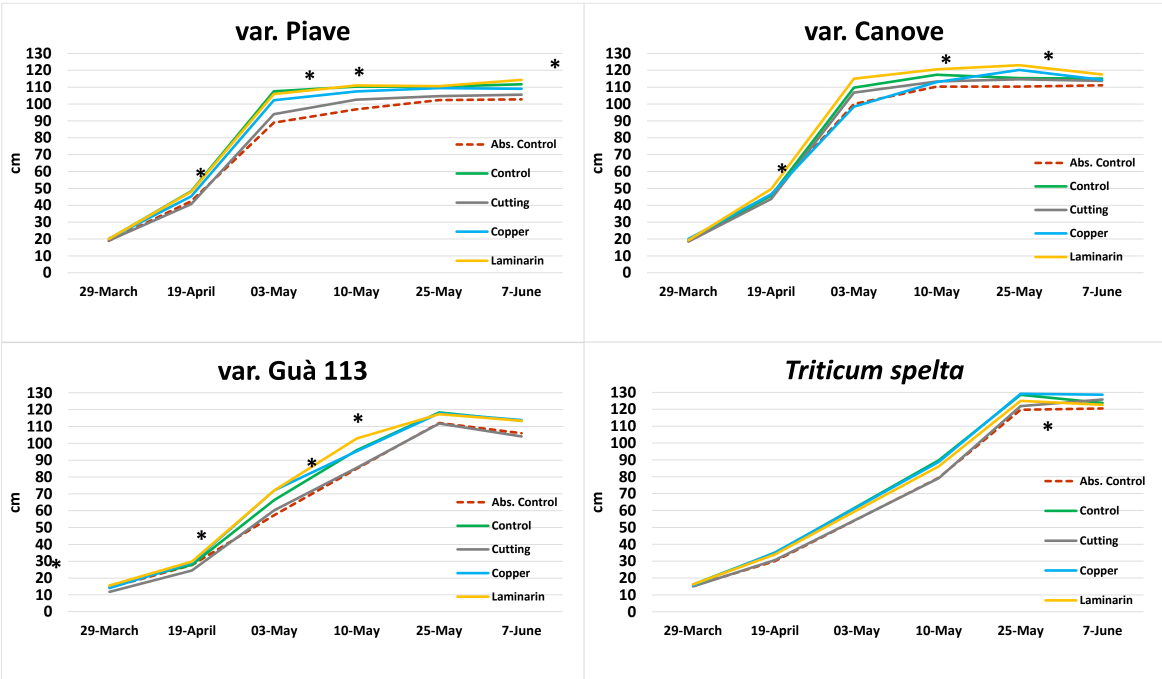

Figure 1. Dynamics of culm height in old wheat varieties with different treatments. Asterisks (*): significant differences among treatments (Newman-Keuls test, $p \leq 0.05$).

Conclusions

One of the main drawbacks of old wheat varieties is the elevated plant size, which cause high loadging risks under wind and storm events. Here we demonstrate that early canopy cutting, applied carefully in order to avoid any damage to the apex (with the small developing spike), can significantly reduce plant height without compromsing grain yield and protein contents. While copper and laminarin have a protection effects against pathogens in organic management, they had temporary (copper) or no effects (laminarin) on shoot vigour, althought on the contrary a biostimulant effect was sometimes observed by the algae extract laminarin. These results confirm preliminary effects of early shoot cutting during the 2019-20 growing season, proving robust data for accurate management of old wheats in organic management.

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Bio-economic Hemp Crop Modelling For The Assessment Of Adaptation And Economic Sustainability

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Introduction

Given the spread and the strong interest for the hemp cultivation in recent years, a methodology to assess the environmental adaptation of hemp crop and the economical sustainability of its yields, mainly focused on seed production and its derived products (oil and flour) is mandatory.

The methodology involves a crop simulation model (*Hplan*) for planning hemp productions. The procedure allows to create and evaluate production scenarios (obtained by the combination of market prices, soil conditions, agronomic practices and on-farm seed processing) in a specific meteorological context. A scenario evaluation example, involving a monoecious hemp variety (Fedora) and different irrigation strategies is presented. Scenario evaluation considers revenues from selling hemp products and costs of the production factors, giving the profitability of the different production strategies in a specific soil x climate x crop management environment.

Materials and Methods

The system described by the model is the hemp crop, considering its yields, with relation to the main environmental factors (temperature, water availability, nutrition). However, because the reliability of crop simulation models is low without a specific, local calibration based on field experiment data, it has been calibrated using field trials performed in Friuli Venezia Giulia (FVG) region. Beside the field phase of crop, the different possible on-farm transformation of hemp products have been also be considered, with relation to market product prices and costs.

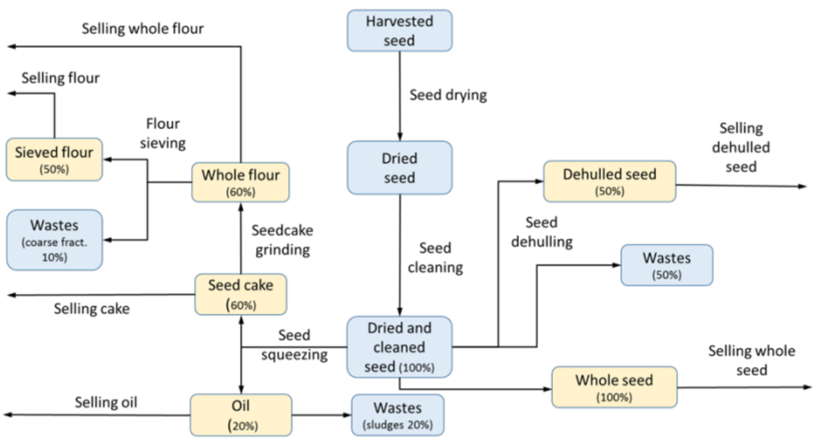

Figure 1. Farm transformation of hemp seed and relative weight percentages obtained from each process.

At farm, hemp seeds are dried (Figure 1) to allow their conservation. Then, seeds are stored and cleaned. Dried and cleaned seeds can be treated to create two types of product lines: 1. seeds (previously dehulled or as whole); 2. oil and flour. After whole seed pressing, a 60% of seed-cake, 20% of oil and 20% of sludges are obtained; seedcake can be sold as it is or grinded to obtain whole flour that, in turn, can be sold of sieved to obtain refined flour. Sold products are oil and refined or whole flour.

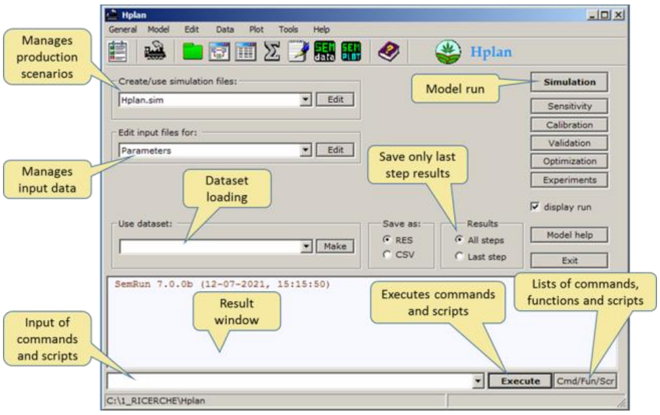

Figure 2. Main dialog of *Hplan* application to manage input data, running simulations and to analyze simulation results.

Modelling hemp production

Hplan derives from a previous hemp model (*Hcrops*; Baldini et al., 2020), improving many aspects to plan cropping/farm transformation strate-gies with the aim to maximize farm income. *Hplan* has been implemented using the SEMoLa simulation language (Danuso and Rocca, 2014) and uses a phenological model derived from literature (Amaducci et al., 2012; Cosentino et al., 2012).

Results

The model allows to carry out: simulation experiments and scenario analysis; identification of the convenience to hemp cultivation with relation to market prices; automatic calibration of parameters; optimization of technical choices in specific conditions of soil, climate and market; uncertainty analysis of climate and market variability; statistical processing of measured and simulated data; automation of procedures with command files (scripts) (Figure 2). An example of model results is reported in Table 1.

Table 1. Costs, gross saleable production (GSP) and Net income obtained by seeds, oil, and sieved flour simulated with *Hplan* for cultivar Fedora, under five different irrigation regimes. The revenue from stems selling is also included in every product type.

Irrigation strategy (allowed stress %)	Whole seed (€/ha)			De-hulled seed (€/ha)			Filtered oil+Sieved flour (€/ha)		
	Costs	GSP	Net income	Costs	GSP	Net income	Costs	GSP	Net income
0 (full irrig.)	1394	2492	1098	1573	7596	6023	2290	10891	8602
25	1394	2512	1118	1572	7610	6038	2288	10902	8614
50	1366	2317	951	1531	7036	5505	2194	10082	7888
75	1340	2137	798	1492	6492	5000	2104	9303	7199
100 (rainfed)	1322	2024	702	1466	6135	4669	2043	8789	6746
Mean	1363	2296	933	1527	6974	5447	2184	9994	7810

Conclusions

A hemp crop simulation model (*Hplan*) has been developed with the aim to evaluate production scenarios in different conditions of soil, climate and market prices as well as the on-farm yield processing to obtain the best economical results. For this purpose, several field experiments in the production areas and on-farm transformation activities (seed drying, cleaning, cold pressing, dehulling, etc.) has been performed and the results utilized to adjust the model parameters to obtain realistic simulations.

Hplan was able to represent quite well the complexity of the production processes and sensitive to the different environmental and management factors.

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Yield And Quality Traits Of Cherry Tomato As Affected By The Application Of A Plant-Derived Biostimulant

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Introduction

In Southern Italy, greenhouse tomato is often cultivated near the coast areas, mainly during the autumn-spring period, inside simple shelters with minimal microcliamte control (De Pascale et al., 2006). During these cycles, crops experience suboptimal temperature and light conditions, with negative effects on tomato yield potential and product quality, even from a functional viewpoint (La Malfa and Leonardi, 2001; Mauro et al., 2020). In this context, plant biostimulants (PBs) represent a recent innovation able to improve the bio-agronomic performances and nutritional profile of many vegetables (Rouphael and Colla, 2018). However, the wide and dynamic pool of commercial tomato cultivars requires constant updates about the PBs effectiveness, since the crops' responses are often genotype-dependent (Rouphael and Colla, 2018). For these reasons, we studied the effects of the application of a PB on fruit yield and quality in three cherry tomato cultivars, recently spread in the growing areas of Southern Italy.

Material and Methods

A greenhouse experiment was conducted over the 2019–2020 growing season, in an experimental greenhouse of the University of Catania (Catania, 37°24'28.17'' N, 15°03'36.74'' E, 5 m s.l.m.). On 5th September 2019, plantltes (three true leaves) of the cherry tomato cultivars Eletta, Kaucana, and Top Stellina were transplanted into 5 L plastic pots at a density of 3.33 plants m^{-2} (0.30 × 1.00 m), within an open soilless system having perlite as growing medium. The plants were trained at single stem up to the 8th cluster, pruning all clusters at 14 fruits. At the fruit setting of each cluster, plants were sprayed with an aqueous solutions containing a plant-derived biostimulant (0.1%, *v/v*) (Bioup TF®, Intertec s.r.l., Bibbiena, Italy) enriched with boric acid and zinc sulphate. Control plants were sprayed with tap water. Fruits were harvested at full ripening stage (from November, 7 up to January, 26) and after each harvest their fresh weight (FW) and dry matter (DM) content were determined (with a thermoventilated oven at 75 °C). The following determinations were carried out too: total soluble solids (TSS, through a digital refractometer and expressed as °Brix), titratable acidity (TA, by NaOH titration and expressed in g/L of citric acid, CA), total carotenoids and vitamin E contents (determined by HPLC). The commercial yield was also calculated at the end of the growing period. A randomized blocks design was adopted, with three replicates for treatment; each plot consisted of 9 plants (net of borders). All the data were subjected to analysis of variance and the means separated through the Tukey's HSD test ($P \leq 0.05$).

Results

Among the cultivars, 'Kaucana' showed the highest yield (11.4 kg m^{-2}) and fruit FW (27.3 g), whereas the highest fruit DM was recorded in 'Top Stellina' (11.3%); for both variables, 'Eletta' showed intermediate values (Table 1). The biostimulant application promoted fruit yield (+12%) along with fruit FW (+2.9 g); a significant effect was recorded for fruit DM content too (+17%) (Table 1). 'Top Stellina' showed the highest values for TSS (10.4 °Brix) and TA (8.2 g citric acid L^{-1}). The TSS/TA ratio, an important descriptor of fruit taste, highlighted a growing sourness passing from 'Eletta' (1.86) to 'Kaucana' (1.54), then to 'Top Stellina '(1.26) (Table 1). As compared to control, the application of Bioup® TF induced a significant increase both in TSS (+8%) and in TA (+10%), while no significat effects were recorded in relation to the TSS/TA ratio. 'Top Stellina' showed the strongest increases in terms of TSS and TA (+14% and +13%, respectively) (Figure 1A-B). The analysis of the antioxidant compounds content revealed a higher concentration in terms of total carotenoids and vitamin E in 'Top Stellina', whereas 'Kaucana' proved the lowest concentration for total carotenoids; on the other hand, 'Eletta' highlighted intermediate values (Table 1). When compared to control, the biostimulant application was associated to a significant increase in total carotenoids and vitamin E concentrations (+21 and +39%, respectively), with ‘Top Stellina’ proving the strongest rise for vitamin E (+68%) (Table 1; Figure 1C).

Table 1. Effects of the cultivar and the bio-stimulating treatment on the productive characteristics (quantitative and qualitative) of cherry tomatoes grown in greenhouses. Different letters within each column’s factor indicate statistically significant differences.

Treatments	**Yield**	**FW fruit**	**Dry matter**	**TSS**	**TA**	**TSS/TA**	**Total Carotenoids**	**Vitamin E**
	(kg/m^2)	(g)	(%)	(°Brix)	(g CA/L)		(μg/100 g FW)	(μg/100 g FW)
Cultivar								
'Eletta'	8.0 b	19.2 b	8.2 b	7.4 b	4.0 b	1.86 a	10856 b	1165 b
'Kaukana'	11.4 a	27.3 a	7.3 c	6.2 c	4.0 b	1.54 b	7481 c	1156 b
'Top Stellina'	5.1 c	12.3 c	11.3 a	10.4 a	8.2 a	1.26 c	12412 a	1469 a
Biostimolant								
Control	7.7 b	18.1 b	8.2 b	7.7 b	5.3 b	1.54 a	9264 b	1057 b
Treated	8.6 a	21.0 a	9.6 a	8.3 a	5.6 a	1.57 a	11235 a	1469 a
Interaction	NS	NS	NS	*	*	NS	NS	***

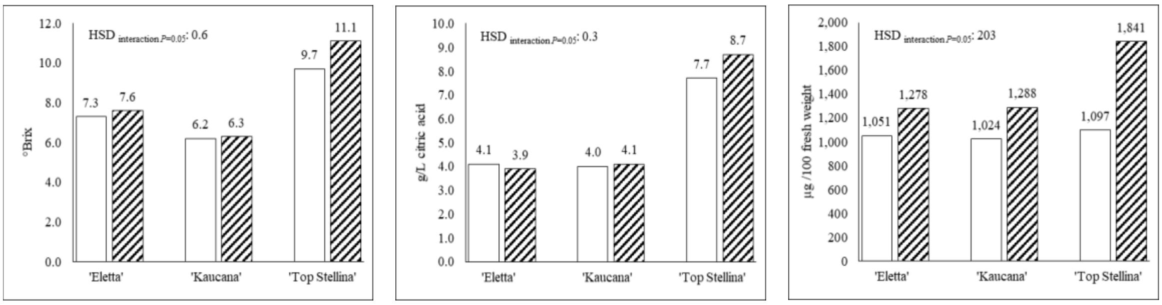

Figure 1. TSS (A), TA (B) and vitamin E concentration (C) of cherry tomatoes as affected by ‘genotype × biostimulant’ interaction. Light bars: control plants; streaped bars: treated plants.

Conclusions

The present experiment showed marked yield and compositional differences among cultivars. The PB application proved positive effects on almost all these variables. However, the genotype-dependent increase in vitamin E concentration implies the need for improved products and application protocols to maximize the functional gain attainable through the use of PBs.

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The Effect Of Sprouting On Phenolic Compounds, Glucosinolates And Antioxidant Activity Of *Camelina sativa* (L.) Crantz

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Introduction

Camelina (*Camelina sativa* L. Crantz) is an annual crop of the *Brassicaceae* family with good agronomic characteristics such as low input requirements for water, nutrients and pesticides, early ripening and stress tolerance (Maninder et al., 2021; Royo-Esnal et al., 2017; Royo-Esnal and Valencia-Gredilla, 2018). Sprouting is the technique aimed at producing edible sprouts (i.e., seedlings a few days after sowing, DAS), trendy food with increasing scientific interest and market for their high content in bioactive compounds (Galieni et al., 2020). In fact, most bioactive compounds, also called phytochemicals, are secondary metabolites of plants with antioxidant activity involved in many beneficial effect for human health, and they have been found to increase with germination in many plant species (Galieni et al., 2020). In the *Brassicaceae* family, phenolic compounds and glucosinolates are the main phytochemical classes (Kumar and Andy, 2012). Some literature is available on the increase of phytochemical content with sprouting of rapeseed and other *Brassicaceae* species (Falcinelli et al., 2017; Benincasa et al., 2019; Galieni et al., 2020), but no information is available at present on camelina sprouts. As for other species, the phytochemical content of seeds and sprouts is likely to vary with the genotype. On this basis, this study was aimed at assessing the effect of sprouting on the content of phenolic compounds and glucosinolates and on the antioxidant activity of five camelina genotypes.

Materials and Methods

Seeds of five camelina genotypes (Alba, Cceμ3, CO46, Joelle, Vera) were incubated on filter paper laid over sterile cotton contained in plastic trays (1.5 g of seeds per tray) and wetted with distilled water (75 mL). The trays were placed in a growth chamber (T= 20±1°C and RH= 70±5%) under photon flux density of 200 μmol m^{-2} s^{-1} and light/dark photoperiod of 16/8 hours. A completely randomized design with three replicates (trays) was applied. Sprouts were harvested at the stage of fully-expanded cotyledons (i.e., 6 DAS) collecting the whole seedlings (i.e., both shoot and root). Samples were stored at -20 °C until analytical determinations. Free and bound phenolic fractions were extracted according to Stagnari et al. (2017). The contents of polyphenols (P), and the antioxidant activity (DPPH, FRAP and ABTS tests) were measured according to Singleton and Rossi (1965) and Thaipong et al. (2006), respectively. Free and bound fractions of phenolic acids (PAs) were measured according to Bravi et al. (2021). Total P, PAs, DPPH (AA_1), FRAP (AA_2) and ABTS (AA_3) were calculated as the sum of free and bound fractions. Glucosinolates (GLS) were extracted in the same way of free phenolic fraction (Stagnari et al., 2017) and quantified using a validated UHPLC method.

Results

Germination percentage was higher than 90% in all genotypes and the individual sprout fresh weight was between 10 and 15 mg, with around 13-15% of dry matter concentration (data not shown).
In seeds of all genotypes the free fraction represented the only form of GLS and the greatest portion of total P, PAs and antioxidant activity. In seeds, genotypes did not differ substantially for P, and also the three tests of antioxidant activity revealed not univocal and not so relevant differences, whereas Alba

was so far the richest in free and total PAs and GLS, containing around twice of the average of the other genotypes (data not shown).

In all genotypes, sprouts showed an increase of free and total P and PAs, and antioxidant activity passing from seeds to sprouts. The bound fraction showed a less consistent trend, except for the increase of PAs which was recorded in all genotypes. However the bound fraction represented a much smaller portion compared to the free fraction, thus its effect on total values was little. Also GLS were increased by sprouting in all genotypes. Three single GLS were identified both in seeds and sprouts: glucoarabin, glucocamelinin and homoglucocamelinin (data not shown). Considering all the parameters (P, PAs, GLS and antioxidant activity tests), and especially the PAs, the cultivars which showed the highest increases passing from seeds to sprouts were Cceμ3, CO46 and Joelle, which approximated and in many cases overtook the values of Alba, except for GLS.

Table 1. Significant increase (+) and decrease (-) or invariance (≈) of free, bound and total phenols (P), phenolic acids (PAs), glucosinolates (GLS) and antioxidant activity tests (AA_1=DPPH; AA_2=FRAP; AA_3=ABTS) in sprouts of five camelina genotypes as compared to ungerminated seeds. A number before + or – means a n-fold increase.

Genotype	Free					Bound					Total					
	P	ΣPAs	AA_1	AA_2	AA_3	P	ΣPAs	AA_1	AA_2	AA_3	P	ΣPAs	AA_1	AA_2	AA_3	GLS
Alba	+	2+	+	2+	2+	2–	3+	–	3–	4–	+	2+	+	+	+	+
Cceμ3	2+	6+	2+	2+	2+	2–	8+	–	+	2–	2+	6+	2+	2+	+	2+
CO46	2+	6+	2+	3+	+	≈	5+	2+	3–	2+	2+	5+	2+	2+	2+	+
Joelle	2+	5+	3+	3+	2+	≈	2+	2+	–	≈	2+	4+	2+	2+	2+	2+
Vera	2+	2+	2+	3+	2+	2–	6+	+	2–	2-	2+	3+	2+	2+	+	≈

Conclusions

Camelina genotypes differed for the content of free and total phenolic acids and glucosinolates in seeds, with the highest values observed in Alba. In all genotypes, sprouting increased the values of phenols, phenolic acids, glucosinolates and antioxidant activity, however the increases, especially for PAs, were higher in genotypes which showed lower values in seeds. Therefore, sprouting comes out as an efficient tool to increase the phytochemical content and the antioxidant activity of camelina seeds.

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Health-Beneficial Properties Of Organically Grown Stinging Nettle (*Urtica dioica* L.)

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Introduction

The increasing impact of climate changes on crops production and cultivation, requires the selection of more resilient species. *Urtica dioica* L. is a perennial, low-requirement, and wild edible species. In recent years, stinging nettle has gained interest both scientifically and commercially because it may be considered as a source of added value in natural products by exploiting all the plant parts. Furthermore, several studies confirmed the presence of active compounds, especially in nettle leaves, with most promising application in the food/feed and cosmeceutical sectors (Di Virgilio et al., 2015). However, nettle-derived products are not currently produced on a large scale, mostly due to lack in cultivation guidelines and post-harvest management. To address the requisite for information on the influence of agronomical factors on health promoting bioactive components in leaf material under organic management, in this work stinging nettle (*Urtica dioica* L.) was organically cultivated in three locations (Emilia-Romagna, Italy) and analyzed over four harvests (September 2020 - September 2021).

Materials and Methods

Trials have been carried out at Tresigallo (latitude 44°49'26"N longitude 11°54'42"E, -1 m a.s.l.), Ozzano dell' Emilia (latitude 44°23′16″ N, longitude 11°25′54″E, 110 m a.s.l.) and Lizzano in Belvedere (latitude 44°12'53″N, longitude 10°51′50″E, 555 m a.s.l.) since April 2020. During cultivation period Tresigallo trials were rainfed, whereas in Ozzano (200 L ha^{-1} under emergency condition) and Lizzano (235 L ha^{-1} twice a week), irrigation was implemented. Weed management was carried out either manually or by mechanical hoeing. Total rainfalls and mean temperatures data were collected and the mean growing degree days (GDD) was calculated, for each location. Aerial biomass was harvested in September 2020, May 2021, July 2021, and September 2020 at each location and biomass yield was determined by weighing the fresh leaves. Leaf samples representative of each location and cut were evaluated for functional quality parameters: free and bound polyphenols (FP, BP) and flavonoids (FF, BF); antioxidant activities according to DPPH and FRAP assays; insoluble and soluble dietary fiber (IDF, SDF) (Dinelli et al., 2011) and ascorbate (Shivembe A., 2017). In addition, as nitrate is considered an antinutritional component of leaves, it was extracted and quantified according to Raimondi et al. (2006). One-way analysis of variance (ANOVA) in conjunction with Tukey's honest significant difference was performed for comparing the three growing locations. Significance between means was determined by least significant difference values for $p < 0.05$. Discriminant analysis was applied to the standardized data matrix of functional quality parameters recorded in the three growing locations and carried out by using Statistica 6.0 software (2001, StatSoft, Tulsa, OK, USA).

Results

The leaf biomass levels recorded in second year of crop age were comparable to the overall above-ground green biomass reported by Jankauskienė (2015). A huge yield was obtained in September 2021 cut (8902 kg/ha) for Lizzano and Ozzano locations. The highest and lowest biomass were consistently obtained at Lizzano (12993 kg/ha) and Tresigallo (1057 kg/ha), respectively. Results of functional qualitative parameters are listed in Table 1. TP, TF are higher in Tresigallo and were analogous to the levels extracted previously from nettle leaves (Biesaida et al., 2010). DPPH and FRAP in stinging nettle leaves were not significantly different from the lower yielding location of Tresigallo and the higher yielding location of Lizzano. Ascorbate higher levels of Lizzano were analogous to that obtained in literature (Radman et al., 2015). In May 2021 harvest, the increased polyphenol content and antioxidant activity, also coincided with increased in fiber content (IDF, SDF). Concerning nitrate content was significantly below the threshold level set by the European Food Safety Authority, for all locations and harvest cuts.

Table 1. Mean values of the health-promoting compounds and the anti-nutritional compound, nitrate, in the leaf material of *Urtica dioica* L. for three locations and four harvest cuts. L=Location; C=Cut; Ns = not significant, FP and BP (mg GAE/100gFW), FF and BF (mg CE/100gFW), FRAP (mmol Fe^{2+} 100 g^{-1} FW), DPPH (mmol TE g^{-1} FW), ASC = ascorbate (mg/100gFW), IDF and SDF (%), N = Nitrate (mg/kg FW).

		FP	BP	FF	BF	FRAP	DPPH	ASC	IDF	SDF	TDF	Nitrate
Location	Tresigallo	588 a	35.6 a	519 a	25.0 a	98.7 a	51.0 a	41.9 b	54.2 ab	15.0 a	69.3 a	790 a
	Ozzano	452 b	38.3 a	360 b	16.9 b	86.6 b	38.1 b	32.9 c	52.2 b	14.2ab	66.4 a	530 b
	Lizzano	445 b	28.8 a	374 b	17.3 b	102 a	53.0 a	65.7 a	56.2 a	13.3 b	69.4 a	938 a
Harvest	Sept 2020	404 c	46.2 a	301 b	25.9 b	77.1 c	26.9 c	47.1 ab	50.4 c	13.7 ab	64.1 b	1544 a
Cut	May 2021	701 a	47.2 a	466 a	9.6 c	136 a	59.0 b	38.8 b	58.7 a	14.8 ab	73.6 a	466 c
	July 2021	547 b	30.6 b	560 a	32.5 a	102 b	72.7 a	52.5 a	53.0 bc	15.1 a	68.1 b	282 c
	Sept 2021	327 c	13.0 c	344 b	11.0 c	65.5 c	30.8 c	49.0 ab	54.8 b	13.0 b	67.8 b	719 b
L x C		ns	***	***	***	***	***	***	***	*	***	*

To examine a possible grouping of the nettle leaf samples for health promoting components and location for each harvest period, PCA was carried out. The harvests of May and July 2021 gave the highest yields of health-promoting components. Considering both yield and bioactive components, Lizzano and Ozzano in May are recommended for collective extraction of ascorbate, flavonoids, and antioxidant activities. In July, despite positive association with polyphenols and antioxidant activity in Ozzano, yield was severely compromised. September 2021 was associated with lower levels of all bioactive components with respect to the previous cuts. Meteorological factors impacted on determining both the expression of bioactive components as well as the yield in each of the locations, in particular significant inverse relationship between temperature or GDD and the expression of FP (hence TP), DPPH, FRAP and IDF (hence TDF) was evident).

Conclusions

The potential for the cultivation of commercial stinging nettle under sustainable organic farming practices (low-input and herbicide/pesticide free) in Emilia-Romagna, Italy, for harvesting leaf bioactive components was evaluated. The present study showed that stinging nettle cultivation was feasible. Satisfactory yields in combination with high levels of polyphenols and flavonoids, as well as DDPH and FRAP, were obtainable in May and July. Moreover, high levels of ascorbate, in combination with high yields, were obtainable in July and September. Only Lizzano met the yield criteria for the harvest of polyphenols (flavonoids), with associated antioxidant activities in May and July.

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Gas Exchange, Leaf Characteristics And Enzymatic Activity In Maize Seedlings As Affected By Light Spectrum And Endogenous Selenium Content

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Introduction

In indoor crop production systems, the energy supply for photosynthesis is mainly provided by Light Emitting Diode (LED) lamps which are capable of modulating either the intensity or the spectrum of the incident light. Many researches have focused on the impact of different combinations of red and blue light on plant growth and development. In particular, several studies showed that dichromatic blue+red light improves photosynthesis rate, growth, pigment and antioxidant compounds content in cereal seedlings (Bartucca et al., 2020). Similarly, selenium fortification can enhance antioxidant content and enzymatic activities in maize grains (D'Amato et al., 2019) as well as in the sprouts derived from these seeds (Benincasa et al., 2020). This study was aimed at evaluating the role of endogenous selenium content in maize grains on gas exchange, leaf morphology and oxidative status of maize seedlings grown under different combinations of Blue/Red light.

Materials and Methods

The experiment was carried out in the LED Growth Chamber (LED-GC) at the Department of Agricultural, Food and Environmental Sciences of the University of Perugia (Italy). Maize kernels having different endogenous selenium concentration, namely 0.28±0.012 µg Se g^{-1} DW (control, C) and 3.10 ±0.181 µg g^{-1} DW (High Se, **HSe**) were sown in pots filled with quartz sand at a density of 42 individuals per pot. After the coleoptile tips became visible, seedlings were grown for 9 days until BHC stage 12.5 (Lancashire et al., 1991) under 16/8 hours light/dark regime, with light intensity of 215±5.0 µmol photons m^{-2} s^{-1}, air temperature of 28/24±0.5 °C and RH% of 65/80±3.0. In a two-factor factorial design with 3 replicates, Control and HSe seedling were grown under three different light spectra: **B100**, monochromatic blue; **R100**, monochromatic red and **B20R80**, dichromatic blue:red (i.e. 20% blue + 80% red photons).

The canopy CO_2 gas exchange under light (net assimilation) and in the dark (respiration) were determined at BHC 12.5 by using an infrared gas analyser (ADC-LCA3, Delta T devices, UK), connected to a customized glass chamber having an internal volume of 34 L. Just after gas exchange measurement, the SPAD value of fully expanded leaf blades of ten plants per pot was determined (Minolta, SPAD-502), then length (collar to tips) and maximum width of the youngest fully expanded leaves of the same plants were recorded by image analysis. The level of lipid peroxidation in plant tissue was measured based on the MDA (Malondialdehyde) content of the shoots. The MDA was determined in a sample of 20 shoots per pot according to Quaglia et al. (2021).

Statistical analysis was performed by AnOVa. Means were separated by Tukey's HSD test at $P<0.05$ and significance letters were reported in table and figures.

Results

Net assimilation was significantly affected by light spectrum (Figure 1) while dark respiration was not. The effect of endogenous Se content was negligible on both gas exchange parameters (Figure 1).

Leaves reached the highest SPAD value under dichromatic light (37.5^{A} in B20R80 vs 34.9^{B} and 34.2^{B} in B100 and R100, respectively, pooled SEM 0.62^{**}). Light spectrum strongly affected also the leaf shape as the leaf length was increasing according to the red photons percentage (157^{C}, 172^{B} and 197^{A} mm in B100, B20R80 and R100, respectively, pooled SEM 2.34^{**}) while the opposite occurred for the leaf width (12.9[A], 12.5A[B] and 11.5[B] mm, respectively, pooled SEM 0.28[*]). As a result, leaf area was not affected by light spectrum. However, the light spectrum affected the shoot height at first leaf collar (83[A] mm in R100 against 57[B] and 58[B] mm in B20R80 and B100, respectively, pooled SEM 2.1[**]). Thus, seedlings under monochromatic red light showed paler leaves, taller plants and a sparser canopy as compared to the other light spectra (Figure 2).

The effect of endogenous Se content on leaf and canopy characteristics was always negligible. On the contrary, shoots from Hse grains showed the lowest MDA content at any light spectrum (Table 1). However, the reduction of MDA in HSe shoots was lower in B20R80 (-17%) than in monochromatic lights (-25% and -35% in B100 and R100, respectively).

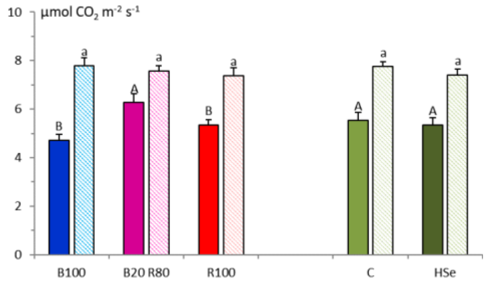

Figure 1. Canopy net assimilation (full bars) and dark respiration (dashed bars) in maize seedlings at BHC 12.5. Means followed by the same letters are not statistically different for P<0.05 (Tukey's HSD test).

Figure 2. Side and top views of maize seedlings under B100, B20R80, and R100 light. Horizontal lines give a reference of canopy height (cm). Only control seedlings are shown in figure, since no difference was observed between HSe and control seedlings.

Table 1. Malondialdehyde (MDA) content in maize shoots at BHC 12.5.

	MDA (μmol g^{-1} FW)		
	Control	Hse	average
B_{100}	33.1 ^{b}	24.9 ^{c}	29.0 ^{B}
B_{20} R_{80}	38.2 ^{a}	31.6 ^{b}	34.9 ^{A}
R_{100}	33.3 ^{b}	21.6 ^{d}	27.4 ^{C}
average	34.9 ^{A}	26.0 ^{B}	
pooled SEM	light spectrum		0.360 **
	endogenous selenium		0.294 **
	interaction		0.509 **

Means followed by the same letters are not statistically different for P<0.05 (Tukey's HSD test). *, **, n.s.: significant at P<0.05, 0.01 and not significant, respectively (F test).

Conclusions

Results confirm that dichromatic blue+red light, as compared to monochromatic light, increases chlorophyll content in leaves and boosts net assimilation in C4 maize seedling. As already observed in einkorn by Bartucca et al. (2021), monochromatic red light strongly affects also leaf and canopy morphology. In agreement with (Del Pino et al., 2019), high endogenous Se protects maize shoots from light-induced oxidative stress by counteracting membrane lipids peroxidation.

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Preliminary Investigation On Agronomic Response Of Sugarcane Accessions In Sicily

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Introduction

Sugarcane is one of the most important industrial crops and worldwide occupies an area of 26,466,945 ha (Faostat 2022). It represents an important source of food and bioenergy in many tropical and subtropical countries. Recently, the sugarcane supply chain has been providing a number of products in addition to sugar such as pulp, paper, alcohol, xylitol, chemicals, bio-food, feed, electricity and drinking juice (Li and Yang, 2015). Furthermore, the sugarcane juice can be used for the creation of new beverages to be launched on the market, innovating the offer of the sector. Many historical sources (Abulafia, 2008; Signorello, 2006) report the ancient cultivation of sugarcane in the Mediterranean area and, in particular, in Sicily. This crop, once product excellence of this area, was abandoned towards the end of the 1600s, after centuries of cultivation, due to the decline in the profitability of investments due to competition from foreign countries. Nowadays, within the sugarcane varieties, there are cultivars which are characterized by a certain tolerance to cold (Van Heerden et al., 2014). This allows the possibility of expanding the range of sugarcane varieties in various regions and/or favouring the reintroduction of the crop in environments other than those of origin. The composition and quality of the sugarcane juice are influenced by endogenous and exogenous factors (Ghosh and Balakrishnan, 2003). Genotypic variability is one of the aspects that, among the intrinsic factors, more influences the content and the aromatic profile of the juice, especially in response to the environment (Xiao et al., 2017). The aim of this study was to assess the agronomic and productive response of 6 varieties and 5 accessions of sugarcane, obtained from different geographical areas, in a Mediterranean environment.

Methods

The study was carried out from 2021 to 2022 at the “Orleans” experimental farm, University of Palermo (Italy) (38 ° 06′26.2 ″ N, 13 ° 20′56.0 ″ E, 31 m a.s.l.). Portions of culm with a bud were planted in pots of 48 cm (40 l) in May 2021. The substrate was a mixture of peat (30%) and Mediterranean red earth (70%). The sugarcane cultivars, tested in this study, are showed in Table 1. The culms were cut into portions at the level of each single node. The internodes were then washed with tap water to remove foreign particles from the vegetable parts. After rinsing, a roller extractor was used to extract the juice. The juice was filtered and collected in a graduated container. The total soluble solids content of the juice was determined using a portable refractometer and the values were expressed as °Brix. The pH was measured using a digital pH meter. Buffers of pH 4.0 and 7.0 were used to standardize the equipment. A randomized block design was used with three replications.

Table 1. Plant material under study

Variety / accession	Origin	Centre
KN 07-0028	Sudan	Kenana
KN 07-0029	Sudan	Kenana
CP 06-2495	USA-Florida	USDA
CP 09-1952	USA-Florida	USDA
CP 09-4153	USA-Florida	USDA
CP 10-1208	USA-Florida	USDA
Canne rouge	Caribbean	-
Baltasià	Caribbean	-
Biscuit	Caribbean	-
Ananas	Caribbean	-

The morphological and productive parameters were determined at harvest in April 2022. Data were compared using analysis of variance. The difference between means was carried out using the Tukey test. Statistical analysis was performed using the package MINITAB 19 for Windows.

Results

The analysis of variance (Table 2) showed significant differences for most traits (plant height, number of nodes, average internode diameter, weight millable canes, fresh biomass weight and total juice), highlighting a good phenotypic variability which can be considered useful for a preliminary selection of genotypes suitable for the Mediterranean environment. In particular, Canne Rouge, Baltasià, Biscuit and Ananas accessions showed the best values for both morphological and production characteristics. The varieties originated from Florida showed intermediate values followed by those from Sudan, which showed the lowest values.

Table 2. Effects of Variety/accession on biometric and production parameters.

Variety / accession	Plant height (cm)	Number of nodes (n)	Millable canes lenght (cm)	Average internode length (cm)	Average internode diameter (mm)	Weight millable canes (g)	Average internode weight (g)	Fresh biomass weight (g)	Dry weight biomass (g)	Total juice (ml)	°Brix of juice	pH of juice
KN_07-0028	83.66 c	12.66 bc	86.43 a	6.93 a	19.65 cde	294.83 b	25.44 a	486.16 b	34.81 a	152.33 c	16.29 c	5.36 a
KN_07-0029	115.33 abc	12.0 c	111.36 a	8.76 a	16.73 e	307.66 ab	30.07 a	471.0 b	39.97 a	165.0 c	16.93 c	5.45 a
CP_06-2495	114.0 abc	13.33 abc	109.63 a	8.28 a	20.34 cde	405.33 ab	31.24 a	631.83 ab	38.28 a	219.13 abc	19.83 ab	5.58 a
CP_09-1952	97.0 bc	13.33 abc	95.10 a	7.12 a	20.18 cde	315.73 ab	28.56 a	596.66 ab	34.50 a	171.20 bc	20.13 a	5.52 a
CP_09-4153	86,66 c	13.0 abc	86.20 a	7.19 a	20.89 cd	326.66 ab	28.93 a	586.83 ab	36.38 a	165.66 c	19.5 ab	5.46 a
CP_10-1208	122.33 ab	15.33 ab	110.40 a	7.17 a	22.81 abc	517.16 ab	33.69 a	729.83 ab	36.56 a	218.33 abc	20.60 a	5.22 a
Canne Rouge	134.66 a	15.66 a	118.05 a	8.80 a	21.20 bc	473.36 ab	36.93 a	743.66 ab	37.66 a	260.66 ab	19.33 ab	5.42 a
Baltasia'	102.66 abc	15.66 a	99.30 a	7.25 a	25.90 a	553.50 ab	41.04 a	910.33 a	40.19 a	266.60 a	20.73 a	5.39 a
Biscuit	131.00 ab	15.33 ab	118.16 a	8.03 a	16.93 de	343.0 ab	25.57 a	561.66 ab	35.55 a	174.33 bc	18.33 bc	5.49 a
Ananas	107.66 abc	13.66 abc	99.33 a	7.28 a	25.17 ab	569.66 a	43,77 a	944.16 a	37.41 a	285.33 a	19.66 ab	5.02 a
p-value	0.001	0.001	0.130	0.110	0.001	0.006	0.064	0.004	0.984	0.038	0.001	0.784

Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Tukey's test.

The cultivation area and production management play a fundamental role for the qualitative indices of sugarcane juice (Xiao et al 2017). Taking the °Brix of fresh juice into consideration, it was found that 7 genotypes (Ananas, Baltasià, CP_10-1208, CP_09-1952, CP_06-2495, Canne Rouge and Biscuit) showed high values for this parameter (18.33 - 20.73 °Brix) in accordance with Kohli et al. (2019) and Chauhan et al. (2017). Ramachandran et al. (2017) report lower values (16.4 °Brix), however other authors underline that the sugar content in the crude juice is between 8 and 16 °Brix, on average (Hoareau et al. 2010).

In addition to the °Brix analysis, pH monitoring is a key parameter for the production of fresh sugar cane juice; in fact, high starting values of pH can cause the degradation of sucrose into fructose and glucose even before the marketing stage (Saetear et al. 2021). As for the ° Brix, the pH values detected in our study ranged from 4.84 to 5.55 on average and were confirmed by Ramachandran et al. (2017), Kohli et al. (2019), Chauhan et al. (2017), Qudsieh et al. (2001) and Saetear et al. (2021).

Conclusions

The results obtained in this study are promising and highlight that the varieties and the cultivation area are suitable for the production of fresh sugarcane juice. Further studies are underway to investigate the agronomic response of different accessions of sugarcane in Sicily.

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Random Forest Classification Of Protein Crops with UAS Multispectral Data

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Introduction
Remote Sensing data use in land cover mapping has widely increased in recent years. Application of these techniques in agriculture has been aimed in assessing fundamental aspects like soil erosion (Ganasri et al. 2016), weed management (Huang et al. 2018) crops stress (Sun et al. 2019) yield (Bu et al. 2016), and also important ecological services like Carbon stock (Guo et al. 2021). Since the lack of research in this field on some spread but poorly investigated crops, we conducted a study aimed to classify Chickpea (*Cicer arietinus* L.*),* Fava bean *(Vicia faba* L.*),* Lentil (*Lens culinaris* Medik.) and Quinoa (*Chenopodium quinoa* Willd.) by applying Random Forest modelling techniques with multispectral and photogrammetric data acquired by unmanned aerial system (UAS).

Materials and Methods
The study was conducted during the growing season 2021 in two study areas located in Udine (Italy-IT) and Lelystad (Netherlands-NL). Crops investigated in both sites were Chickpea (CP) and Fava bean (FB), while Lentil (LN) and Quinoa (QN) were grown in NL only.
For each site, remote sensing data has been collected four times during the growing season. In particular, altum and multispectral data have been acquired with a multispectral camera equipped on an unmanned aerial vehicle. Spectral bands acquired were Blue (475nm), Green (560nm), Red (668nm), Red Edge (717nm) and Near-Infrared (842nm). These bands were used to calculate an ensemble of 28 vegetation indices (VIs). Furthermore, photogrammetric techniques were been used to generate digital terrain and crops elevation models, in order to estimate crops canopy volume (*Vcanopy*, m^3m^{-2}).
A three-steps Random Forest (RF) classification was applied to sensed data. Three RF models have been implemented with different sets of features: i) *RFbase*: a base model fed with single bands reflectance and photogrammetric canopy volume; ii) *RFall*: a comprehensive model where all VIs have been integrated to *RFbase* data; iii) *RFmin:* a minimum model fed with a set of not-related input features (Spearman's correlation coefficient < 0.65), in order to exclude redundant information.
For each type of model, there were tested multiple combinations of generated trees number (*N*) and variables randomly sampled at each node (*m*). Each model was elaborated on a training dataset, a random selection of 70% of data. The remaining 30% of data were matched in a confusion matrix with models' predictions to test the performance. For each combination, the whole process has been repeated 50 times, in order to exclude possible biases due to impaired random data split and selection in the model.

Results
Oprimal models performances are summarized in Table 1. All models performance is notable, with low values of out-of-bag error (≤0.10) and high values of accuracy (≥0.90), kappa ((≥0.86) and sensitivity ((≥0.89). Despite differences between model types are low, there is a general improvement along the three-steps procedure. The Implementation of spectral bands elaboration through VIs increased models' performance, but the best results were obtained with *RFmin* by using a restricted selection of features.

Table 1**.** Performance of Random Forest models for Crops' Classification, according to the assessed optimal number of trees to grow (*N*) and variables randomly sampled at each split (*m*).

Model	N° of features	N	m	OOB error	Accuracy	Kappa	Sensitivity	Computational time (s)
RFbase	6	400	3	0.10	0.90	0.86	0.89	0.056
RFall	34	700	12	0.09	0.91	0.87	0.90	0.249
RFmin	7	600	2	0.08	0.93	0.90	0.92	0.085

Local importances of the three best predictors for each model type, expressed as mean model accuracy decrease, are represented in Figure 1. In all models, the most important features to distinguish between crops structures were photogrammetric canopy volume (*Vcanopy*) and the Red Edge band. Significant has also been the information provided by the variation with red band of the Modified Red Edge Simple Ratio Index (*rMRESR*).

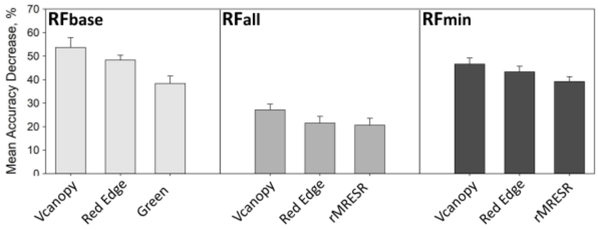

Figure 1. Ordered local importance of the three best predictors for each Random Forest model.

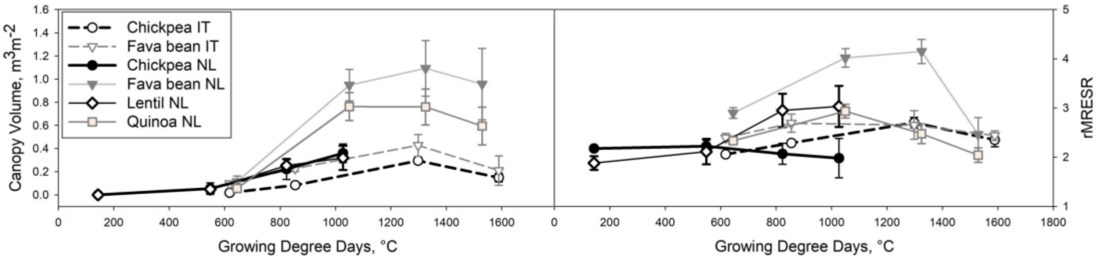

Figure 2. Differences in crops *Canopy Volume* and *red Modified RedEdge Simple Ratio* during the growing season 2021 in Italy (IT) and Netherlands (NL). Cumulated Growing Degree Days (°Cday, Tbase=0°C) as independent variable.

Conclusions

RF is a useful tool for classify Protein Crops. It allows to effectively combine data of crops in different sites having different growth status. Integration of VIs, particularly rMRESR, significantly improves crops classification, but an accurate selection should be done to avoid information redundancy and limit the required computational power..

Despite canopy volume and other significant VIs (*e.g. rMRESR*) have been identified as predictors of canopy structure, a separate evaluation of these parameters is not sufficient to get comparable results with those provided by integrating all data with RF modelling.

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Evaluation Of Resilient Cereals Cultivation For Future Innovative Food-supply Chains: A Case-study On Millet And Sorghum From Emilia Romagna Region

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Introduction

Resource-intensive agricultural practices contribute to global warming, the predominant driver of climate change. Consequently, it is necessary the evaluation of possible alternative climate resilient crops but also of sustainable management practices. Millet and sorghum could represent possible alternatives to corn, which is one of the crops that suffers the most from the impacts of climate change. Compared to corn, millet and sorghum don't require high inputs, are associated with lower greenhouse gases (GHG) emissions, grow in marginal regions, have shorter growth cycles and more stable yields (Wang et al., 2018). Aside from the selection of resilient crops, the success in coping with climate change can only be achieved through a multi-disciplinary approach, based on the adoption of sustainable agricultural practices to reduce negative impacts on soil properties, biodiversity and environment.

Materials and methods

The present study examined the agronomic performances of rainfed organic proso millet, sorghum and corn, without any fertilizer, over a three-year period under variable climatic conditions in one farm, located in Ravenna province. In addition, biodiversity monitoring, soil characteristics, environmental and cost impacts analysis were carried out, in order to assess the viability of resilient practices that were adopted, in comparison with a conventional corn cultivation system. Biodiversity impacts were evaluated with the use of pitfall traps for ground dwelling arthropods. Environmental and cost impacts were evaluated with standardized Life-Cycle Assessment and Life-Cycle Costing (LCA and LCC), that quantify global warming potential (GWP), acidification potential (AP), eutrophication potential (EP) and costs, comparing data from additional organic and conventional farms.

Results

The main agronomic performances of proso millet, sorghum and corn over the three-year period are shown in Table 1. The millet yields in the present study exceeded those of the Mediterranean basin over the same period (FOASTAT 2021). Although all three crops were cultivated under the same sustainable practices, the higher yield instability of corn is probably due to the high water demand of this crop (Wang et al., 2018). Sorghum was higher yielding than both corn and proso millet, but in terms of yield stability, sorghum did not perform as well as millet (Table 1).

Table 2. Means and standard error of the principal agronomical parameters monitored in three years trial. Different letters (a–c) indicate significant differences between the crops with $P \leq 0.05$. "ns" is not significant

Crop	Crop cover (%)	Weed cover (%)	Yield (t ha^{-1})	Pathogen incidence (0-10)	Pathogen severity (0-10)
Proso millet	73.33 ± 10.18 a	20.00 ± 5.36 b	3.28 ± 0.10 ns	0.22 ± 0.11 b	0.00 ± 0.00 b
Sorghum	65.56 ± 12.52 a	25.56 ± 9.09 b	4.17 ± 1.69 ns	2.11 ± 0.11 a	0.56 ± 0.29 ab
Corn	20.56 ± 0.56 b	76.67 ± 7.64 a	3.13 ± 1.44 ns	2.00 ± 1.68 a	2.33 ± 1.68 a

Arthropods abundance and activity density varied over the three-year period in both the compared organic and conventional systems. The abundance as well as the associated activity density of the ground beetles, spiders and harvestmen in the organic field exceeded those of the conventional field, showing that rotation schemes, plant biodiversity, conservative tillage practices and not using synthetic pesticides and fertilizers have a positive impact on arthropods biodiversity.

Improved soil quality in the organic field, compared to the conventional field, was evident, considering the significantly higher organic matter content, corroborating the collective impacts of rotation schemes, crop diversification, minimum tillage, and arthropod numbers on soil quality (De Backer et al., 2009).

Ultimately, LCA and LCC data showed detrimental GWP, EP and AP land impacts were significantly higher under conventional management practices compared to those of the organic system for both corn and sorghum, supporting the large consensus that organic agriculture has lower environmental impacts per unit of land than conventional agriculture (Table 2).

Table 2. Life cycle analysis (LCA) showing the contribution global warming potential (GWP), eutrophication potential (EP) and acidification potential (AP) outputs expressed on a land-based approach. The GWP, EP and AP for organic (ORG) maize and sorghum is compared with conventional (CON) maize and sorghum.

		Corn		Sorghum	
		CON	**ORG**	**CON**	**ORG**
Functional Unit		**ha**	**ha**	**ha**	**ha**
GWP	$kgCo_2eq$	2859.85	291.00	2305.90	267.75
EP	$kgPO_4eq$	5.64	0.54	4.2940	0.6173
AP	$kgSO_2eq$	4.81	3.01	3.7355	2.859

Of great potential, as environmentally sustainable alternatives to conventional corn are organic sorghum, and more specifically organic millet, implying a potential cost gain and yield stability under adverse conditions.

Conclusions

From a multi-disciplinary approach, we highlight the potential of sorghum and millet cultivation, as alternatives to corn in Italy. Under rainfed, organic management, over three years, proso millet yielded consistently, compared to organic sorghum and corn. From the LCA analysis, the GWP and EP impacts of organic proso millet and sorghum cultivation were comparable and significantly lower than conventionally cultivated sorghum and corn. The lower impacts were predominantly attributable to the absence of fertilizer inputs. Moreover, the organic management system reported improved land impacts in terms of organic matter content and arthropod number, compared to the conventional system. From the LCC analysis, organic proso millet and sorghum also registered lower environmental emissions and costs than conventional sorghum and corn.

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Irrigation Regimes In Quinoa: First Results

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Introduction

Quinoa (*Chenopodium quinoa* Willd.) is an emerging crop of Amaranthaceae botany family, it is native of the Andean regions and its scientific and commercial interest is increasing, thanks to its high content in proteins (14-20%) and its high antioxidant activity. The seed of quinoa is a gluten-free product, used for years as a new functional food. For the agronomic aspect it is considered a resistant specie to several stresses such as salinity, high and low temperatures and different soil pH (Jacobsen, 2017). Geerts et al. (2008) determined that the most sensitive stages to water stress in quinoa are pre-flowering, flowering and milky grain stages.

The aim of the experiment is to assess the effect of application of two different irrigation regimes on cultivated quinoa in Southern Italy.

Materials and Methods

The experiment was carried out at the "CREA-CI" experimental farm in Foggia, Italy, during the 2021 growing season. The soil is alluvial silty-clay and the climate is "thermo-accentuated Mediterranean" with temperatures below 0 °C in winter and above 40 °C in summer and with average annual rainfall of 550 mm. The experimental design, a completely randomized block with 3 replications, consisted of 6 plots, 48 m^2 each one (6m x 8m), with 2 different irrigation regimes: IRR3 with 3 irrigations, and IRR5 with 5 irrigations. The irrigation supplies were applied at the following phenological stages: sowing (IRR3; IRR5), emergence BBCH 12 (IRR5), flowering at 10% BBCH 62 (IRR3; IRR5), flowering at 50% BBCH 67 (IRR3; IRR5), milky grain seed stage BBCH 81 (IRR5). Each irrigation regime received 40 mm at sowing and at emergence, and 70 mm of water for the following irrigation supplies. The irrigation system consisted of driplines placed in alternate crop rows. The quinoa sowing (cv Regalona Baer) was performed on 31st March in rows 50 cm apart and at a density of 25 seeds m^{-2}.

During the growing season, phenological dates, plant height, soil moisture at 0-30 cm depth with gravimetric method were recorded. At harvest (30th August) seed yield, thousand kernel weight and seed moisture were measured; finally, ten plants were taken from each plot and morphological traits were recorded. Statistical analysis (ANOVA) was carried out according to the experimental design, and t-test as mean separation test.

Results

The climatic behavior of 2021 was characterized by extremely low precipitation (only 143 mm of rainfall from March to July) and with 3 heat waves in the period from 28th July to 8th August, with maximum temperatures over 40°C, during the quinoa seed repening stage. The applied seasonal irrigation amounts were 180 and 281mm for IRR3 and IRR5, respectively.

These first results show no significant differences for plant height and plant fresh biomass yield (Fig. 1 and Tab. 1) between the two treatments. The soil moisture content followed the irrigation regimes, higher in IRR5 than IRR3 in the last two sampling dates (Fig. 2).

Seed yield level was heavly affected by high temperatures during flowering that caused low flower fertility and seed abortion. From the statistical analysis, both seed yield and thousand seed weight resulted higher in IRR5 than in IRR3 (Tab. 1), and this confirms the positive effect of the irrigation application during the quinoa milky grain seed stage (Geerts et al., 2008).

These first results, even if derived from only one year of experiment, are online with previous experiences in the same environment and with the same quinoa variety, where seed yield in the range 0,5-2.0 t ha^{-1}

with seasonal water supplies (rainfall + irrigation) from March to July of about 300-400 mm were recorded (De Santis et al., 2016; De Santis, unpublished data). Even if the quinoa has a sensitive stomatal closure, allowing, during soil drying, the plants to be able to maintain leaf water potential and photosynthesis, a certain soil water availability during seed repening resulted essential to provide a satisfactory seed yield and quality levels.

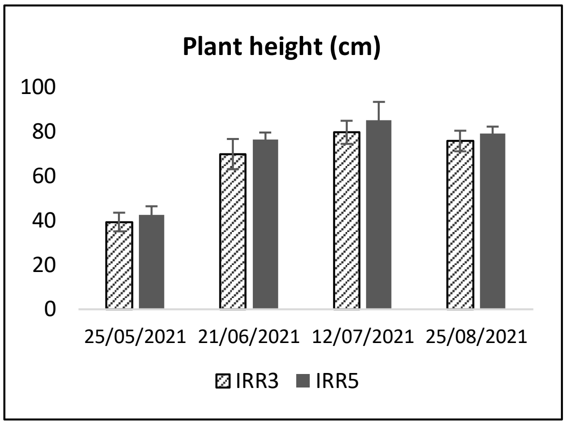

Figure 1. Quinoa plant height of the two irrigation treatments measured during the growing season.

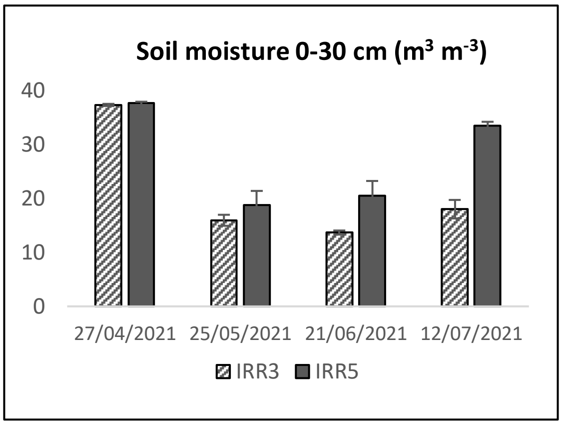

Figure 2. Volumetric soil moisture content of the two irrigation treatments during the quinoa growing season.

Table 1. Total plant biomass, percentage of plant dry matter, seed yield and thousand kernel weight at harvest (different letters indicate different values at P<0.05, t-test).

Irrigation treatments	Fresh plants biomass yield (t ha^{-1})	Total plants d.m. (%)	Seed yield (t ha^{-1})	1000 kernels weight (g)
IRR3	8.78	60.34	0.59 b	1.50 b
IRR5	9.46	48.70	0.98 a	2.03 a

Conclusions

The results showed that quinoa, even if it needs of moderate water supplies to be cultivated in the climatic conditions of southern Italy, had a good response to irrigation treatment. The importance to maintain a certain soil moisture level also during the seed formation and repening resulted essential to obtain adequate seed yield, size and weight.

Acknowledgements

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Yield And Quality Traits Of Six White Lupin Genotypes Grown In A Mediterranean Area

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Introduction

The EU is heavily dependent on imported soybean for its domestic consumption of livestock sector, being widely exposed to risks associated with world trade. Among grain legumes, lupin species (*Lupinus* spp.) could represent a valuable and sustainable alternative protein source for both monogastric and ruminant feeding, capable of replacing soy without loss of quantity and quality of livestock products (Sedláková et al., 2016; White and Staines, 2007). Indeed, lupins have been suggested as possible alternative crops and traceable protein sources in Europe due mainly to their agronomic and quality desirable traits (Chiofalo et al., 2012), and nowadays, a growing interest in the production of white lupin (*Lupinus albus* L.) for animal feed has been observed, due to its seed nutritional quality and the potential benefits for health. To this end, the aim of the present research was to explore the productive traits and chemical composition of six genotypes of white lupin, grown side-by-side in a Mediterranean environment, in order to evaluate the possibility of introducing this species in animal feeding.

Materials and Methods

Six genotypes of *Lupinus albus* L. (Volos, Luxor, Lublanc, Multitalia, Ecotype F and Ecotype G) were sown in a medium-textured loamy soil in Southern Italy (Calabria, 38°04’51” N, 15°40’49” E) with nearly neutral pH (6.75), low salinity (0.6 mS cm^{-1}), poor organic matter (0.69%), low nitrogen (0.62 g kg^{-1}) and exchangeable P_2O_5 (1.0 mg kg^{-1}), and high assimilable K_2O (285 mg kg^{-1}). Plots of 8 m^2 (4 × 2 m), three times replicated in a randomized block design were adopted. Sowing was executed on 22 November 2013 with a plant density of 60 plant m^{-2} on a ploughed and fertilized soil with 100 kg ha^{-1} of P_2O_5. Weed control was done just after sowing, on 25 March and on 7 May by hand. Seeds were harvested between May and June, according to the physiological maturity of genotypes. Yield components (pods $plant^{-1}$, seeds pod^{-1} and thousand seed weight) were evaluated using ten plants for each plot, while total seed yield was determined on the two central rows in each plot.
Proximate chemical analyses of the lupin seed samples were carried out according to the official methods of analyses (AOAC, 2019) in triplicate. All determinations were expressed as it is, and the seed moisture content ranged from 80 g kg^{-1} in Multitalia and Ecotype G to 96 g kg^{-1} in Volos.
Data were analysed by a one-way ANOVA. Before conducting the ANOVA, Bartlett’s test was run to verify the assumption of homogeneity of variances according to the randomized block design. Differences between means were evaluated for significance using the Tukey’s test at 95% confidence level, with percentage values previously arcsin √% transformed ((Minitab, LLC, Statistical Software, Pennsylvania, USA).

Results

Yield components, namely the number of pods per plant, the number of seeds per pod and the thousand seed weight, as well as seed yield were significantly different among lupin genotypes (Table 1).
The number of pods per plant was the significantly highest in Multitalia, Ecotype F, Ecotype G and Lublanc (on average 4.5), and the lowest in Luxor (3.4). Volos differed neither from the highest nor from the lowest values. The number of seeds per pod was the significantly highest in Luxor, Ecotype G and Lublanc (on average 3.5), and the lowest in Volos (2.4). Ecotype F and Multitalia differed neither from the highest nor from the lowest values. The thousand seed weight was the significantly highest in Multitalia and Lublanc (on average 426.3 g), and the lowest in Luxor, Ecotype F, Ecotype G and Volos

(on average 326.7 g). The seed yield was the significantly highest in Lublanc (3.5 Mg ha^{-1}), and the lowest in Volos (1.02 Mg ha^{-1}). Multitalia differed neither from Lublanc nor from Luxor. Ecotype G differed neither from Luxor nor from Ecotype F.

Table 1. Yield component (number of pods per plant, number of seeds per pod, thousand seed weight) and seed yield of the six genotypes of *Lupinus albus*. Mean values followed by different letters within the same row differ significantly ($P \leq 0.05$).

Genotype	Pods/plant (n.)	Seeds/pod (n.)	TSW (g)	SY (Mg ha^{-1})
Volos	3,90ab	2,38b	347,1b	1,02d
Luxor	3,40b	3,70a	332,6b	2,27b
Lublanc	4,25a	3,40a	414,9a	3,49a
Multitalia	4,70a	3,15ab	437,6a	2,78ab
Ecotype F	4,42a	3,20ab	315,3b	1,64c
Ecotype G	4,40a	3,52a	311,7b	1,82cb

The chemical composition in the six genotypes of white lupin seed is shown in Table 2. Volos showed the significantly highest crude protein, crude fibre and ash content, and the lowest oil content. Lublanc and Multitalia showed the highest oil and the lowest ash content. Lublanc had also the lowest crude protein and Multitalia the lowest crude fibre. Both Ecotype F and G showed the highest crude fibre and ash, but the lowest crude protein (Ecotype F) and oil content (Ecotype G).

Table 2. Crude protein (CP), ether extract (EE), crude fibre (CF) and ash content (ash) of the six genotypes of *Lupinus albus*. Mean values followed by different letters within the same row differ significantly ($P \leq 0.05$).

Genotype	CP	EE	CF	Ash
		g kg^{-1}		
Volos	356a	86,0d	120a	30,9a
Luxor	331b	92,5c	120a	30,4a
Lublanc	331b	112a	111ab	27,1b
Multitalia	342ab	107a	101b	26,9b
Ecotype F	327b	96bc	116a	27,7b
Ecotype G	340ab	99b	113a	27,8b

Conclusions

Overall, this study proved the potential of white lupin as an alternative winter legume crop for Mediterranean environments. As regards the proximate composition, lupin genotypes showed interesting quality traits; on average, the high protein content (397 g kg^{-1}, dry matter), the low fibre content (133 g kg^{-1}, dry matter) and the oil content (116 g kg^{-1}, dry matter), make lupin seeds a valuable protein and energy source for animal feeding. Out of the six tested genotypes, Multitalia was amongst the highest yielding, with high pod number per plant, seeds per pod and thousand seed weight; furthermore, its crude protein and ether extract were in the upper range, while crude fibre and ash content in the lowest range. Nonetheless, further investigation on current genotypes and further landraces on agronomic traits, as well as qualitative traits, will be key to its use in the livestock sector and to tackling sustainability challenges.

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Comparing Productivity And Quality Of Different *Amaranthus* Species In Southern Italy

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Introduction

Amaranth (*Amaranthus* spp.) is considered a pseudo-cereal and in the Mediterranean area interest has raised due to its suitability to different environmental conditions, the high biological value of proteins, its fatty acid profile characterized by high levels of unsaturated fatty acids (Gresta et al., 2020) and the presence of bioactive compounds (Oteri et al., 2021). Although these potentialities, amaranth is still a neglected and underutilized crop. In order to contribute to its use in current cropping systems, species with profitable yield and high-quality traits of the grain, ultimately able to compete with other grain crops need to be identified. The present research aims to explore the agronomic traits and proximate composition of five amaranth species, namely *A. cruentus*, *A. hypochondriacus*, *A. hybridus*, *A. caudatus* and *A. tricolor*, grown in a semiarid Mediterranean area, with the purpose of increasing the knowledge of these plants, as a source of nutrients for animal feeding.

Materials and Methods

Five species of amaranth grains, which seeds were obtained from the USDA seed bank (Washington, DC, USA), *A. cruentus* (plant inventory, PI: 605354), *A. hypochondriacus* (PI: 568125), *A. hybridus* (PI: 652417), *A. caudatus* (PI: 511681) and *A. tricolor* (PI: AMES 5354) were compared in a randomized block design. The field trial was carried out in Bovalino (20 m a.s.l. 38°08'N, 16°10'E, Calabria, Italy) in a soil with a sandy-loam texture. Seeds were firstly sown in the tray and then plantlets were transplanted at a density of 10 plants per m^2 in plots of 9 m^2 (3×3 m) on 25 April 2014, in a randomized block design three-time replicated. A basic fertilization (40 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}) was applied before transplant, and a further 80 kg N ha^{-1} were broadcasted before anthesis. Seeds were harvested in relation to the degree of maturation of the different species and threshed with a laboratory thresher. Thousand seed weight and seed yield were measured. Before all analyses, amaranth seeds were ground to pass a 1.1 mm screen. Proximate chemical analyses of the amaranth seed samples, such as crude protein, ether extract, crude fibre and ash, were carried out according to the official methods of analyses (AOAC, 2019) in triplicate. All determinations were expressed as it is, and the seed moisture content ranged from 10.9% in *A. tricolor* to 10.2% in *A. cruentus*. Total starch was determined using a Megazyme Total Starch Assay Kit. Data were analyzed by a one-way ANOVA. Before conducting the ANOVA, Bartlett's test was run to verify the assumption of homogeneity of variances according to the randomized block design. Differences between means were evaluated for significance using Tukey's test at 95% confidence level, with percentage values previously arcsin √% transformed (Minitab, LLC, Statistical Software, Pennsylvania, USA).

Results

The seed yield of amaranth was significantly different among species ($P \leq 0.05$), and ranged from the highest value of 382 g/m^2 in *A. cruentus* to the lowest of 33.6 and 29.0 g/m^2 in *A. caudatus* and *A. tricolor*, respectively (Table 1). *A. hypochondriacus* (274 g/m^2) and *A. hybridus* (257 g/m^2) did not differ significantly from *A. cruentus.*

1. *hypochondriacus* showed also the highest thousand seed weight (0.84 g), and not significantly different from that of *A. cruentus* (0.71 g). This latter did not differ from the TWS of *A. caudatus* and *A. tricolor* (0.64 g on average). The overall lowest TSW was recorded in *A. hybridus* (0.28 g).

Table 1. Thousand seed weight (g) and seed yield (g m^{-2}) of the five Amaranthus species (n=15). Mean values followed by different letters within the same column differ significantly ($P \leq 0.05$).

Genotype	1000-seed-weight (g)	Seed yield
A. cruentus	0,71ab	382a
A. caudatus	0,66b	33,6b
A. tricolor	0,62b	29,0b
A. hypochondriacus	0,84a	274a
A. hybridus	0,28c	256a

The significant highest crude protein (CP) was recorded in *A. tricolor* (18.5%). *A. caudatus*, *A. hypochondriacus* and *A. hybridus* showed CP values higher than 15.4%. The lowest CP value was observed in *A. cruentus* (14.9%) as compared to the other species (Table 2).

The highest oil content was observed in *A. hybridus* (7.1%), followed by *A. tricolor* and *A. cruentus* (6.4%, on average). The lowest values were found in *A. caudatus* and *A. hypochondriacus* (5.5%, on average). Crude fibre (CF) ranged from the significantly highest value of 17.2% in *A. hybridus* (17.2%) to the significantly lowest in *A. caudatus* (4.0%). Intermediate values were observed in *A. tricolor* (12.2%), while the remaining species had similar CF (from 4.5% to 5.3% in *A. cruentus* and *A. hypocondriacus*, respectively). The total starch content was highest in *A. cruentus* (60%) and *A. caudatus* (59.9%) and the lowest in *A. hybridus* (45.2%). Intermediate values were observed in *A. hypocondriacus (51.2%)* and in *A. tricolor* (48.3%).

A linear, negative relationship was found between the fibre content and the total starch content, hence, the higher the fibre the lower the starch in the five *Amaranth* species (y= -1.014x+61.67, R^2 = 0.77).

Table 2. Crude protein (CP, %), ether extract (EE, %), crude fiber (CF, %), ash (%) and starch (%) of the five Amaranthus species (n=15). Mean values followed by different letters within the same column differ significantly ($P \leq 0.05$).

Genotype	CP	EE	CF	Ash	Starch
A. cruentus	14,9d	6,35b	4,49d	3,01d	60,0a
A. caudatus	15,9b	5,57c	3,96e	2,51e	59,9a
A. tricolor	18,5a	6,49b	12,2b	3,8a	48,3c
A. hypochondriacus	15,6bc	5,39c	5,25c	3,17c	51,2b
A. hybridus	15,4c	7,06a	17,2a	3,29b	45,2d

Conclusions

From a productive point of view, *A. cruentus*, *A. hypochondriacus* and *A. hybridus* resulted largely the most productive species suggesting these may open new perspectives as alternative crops to the traditional cereals for irrigated areas of Mediterranean environments. Proteins and lipids showed a higher content than most common cereals. According to present findings, grain amaranth can be recommended as a promising non-conventional source for animal healthy diets provided that further studies will ascertain the best species for Mediterranean environmental conditions, animal species, and sustainability of the cultivation phase.

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Soil Quality Traits Under A Crop Of Dark Fire-Cured (Kentucky) Tobacco As Affected By Organic Fraction Of Municipal Soil Wastes Compost And Green Manure

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Introduction

Fertilization with organic fraction from municipal solid wastes (OFMSW) and green manure are two agronomic practices of great interest for sustainable agriculture considering the several beneficial effects they have on both soil properties or crops. Recently, Sifola et al. (2022) reported some interesting results of the effects of OFMSW compost on yield and quality of Dark fire-cured (Kentucky) tobacco products. The main aim of the present study was to investigate the effect of OFMSW compost in combination with green manure and mineral nitrogen (N) fertilization on soil chemical characteristics (nutrient enrichment, C/N, organic matter content) under a Kentucky tobacco crop.

Materials and Methods

A field experiment was conducted in 2019 at the Center for Testing and Transfer of Innovation of the Tuscany Region located at Cesa (Marciano della Chiana, AR, ITALY). Green manure (faba bean minor, cv. Scuro Torre Lama as cover crop) and bare soil (as control) were factorially combined with or without OFMSW compost fertilization. Bare soil without OFMSW compost received a dose of mineral N fertilization of 160 kg ha^{-1} (standard for that area) while plots treated with OFMSW compost or green manured received a dose of mineral N fertilization of 100 to 50 kg N ha^{-1}, respectively, to integrate, up to 160 kg N ha^{-1}, the amount of N supplied by both OFMSW compost, green manure and both. The cover crop was sowed on October 26, 2018 and manured on May 8, 2019. OFMSW compost was applied on June 10, 2019 at a rate of 16.3 Mg ha^{-1} of dry matter. Amount of nutrients and organic C applied with compost is the following: organic carbon 4.5 Mg ha^{-1}, 57 kg ha^{-1} nitric N, 36.6 kg ha^{-1} P e 199.2 kg ha^{-1} K.

Tobacco seedlings (cv. Foiano) were transplanted on June 12, 2019 at 1×1 m plant spacing. Plants were regularly irrigated with 10 waterings on June 13 and 28, on July 17 and 26, on August 9, 13, 19 and 22, on September 2 and 10 2019. Seasonal irrigation volume (100% ETcrop, calculated as reported by Sifola and Postiglione, 2003), amounted to 2120 m^3 ha^{-1}. At 43 (beginning of rapid growth and stem elongation) and 106 (commercial harvest) days after transplanting (DAT), soil samples were collected at 2 depths (0-0.3 and 0.3-0.6 m) from the central part of each plot and on row, to determine organic matter content (OMC, %), mineral N (N-NO_3^- and N-NH_4^+, kg ha^{-1}), the C/N ratio and P and K content (mg kg^{-1}) and root weight density (RWD, mg cm^{-3}).

Results

The effect of sampling depth, cover crop and compost treatments on soil OMC during cropping and at the final harvest is reported in Table 1. The OMC at 0-0.3 m soil layer was always higher than that at the deeper layer (0.3-0.6 m) although significantly only at 43 DAT (Table 1). At commercial harvest (106 DAT), there was a significant positive effect of both OFMSW compost and green manure on OMC. At 43 DAT the effect of OFMSW compost was more evident on bare soil than green manure (Green manure × OFMSW Compost interaction was significant; data not shown). As for soil nitric N content, there was a significant interaction Soil depth × Green manure at 43 DAT (Table 1). In particular, the nitric N content of the soil decreased under OFMSW compost in the bare soil plots whereas under green manure it was more than double when OFMSW compost was applied compared to the untreated plots (data not shown).

At final harvest (106 DAT), in all experimental conditions the nitric N content was almost halved compared with that recorded 43 DAT (Tab. 1). The C/N ratio varied between 6.5 and 11.5. It increased with time (+8% on average) and was significantly higher in green manured plots than in bare soil at 106 DAT (Table 1). No effect of soil depth or OFMSW compost was evident at both crop stage (Table 1). The P content of the soil (mg kg^{-1}) at 43 DAT was significantly higher in the bare soil plots than in those with green manure and at 106 DAT in the plots treated with compost compared to the untreated ones (Table 2). In the case of the K content in the soil, at 43 DAT it was higher in bare soil than in field bean green manure, while the opposite occurred at 106 DAT (Table 2). As for root growth, at 43 DAT the greatest root development was within 0-0.3 m soil layer (Table 2). At both 43 and 106 DAT, both green manure and OFRSW compost showed a positive effect on root development (Table 2).

Table 1. The effect of soil depths, green manure and OFMSW compost on OMC, NO_3-N and C/N. Different letters indicate significant differences at P<0.05 and 0.01

	OMC (%)		N-NO_3 (kg ha^{-1})		C/N	
DAT	43	106	43	106	43	106
0-0.3 m	1.31 b	1.56	56.0	24.0	7.6	8.5
0.3-0.6 m	1.13 a	1.37	62.9	21.0	7.6	7.9
Bare soil	1.25	1.30 a	68.9	21.8	7.6	7.7 a
Green manure	1.18	1.63 b	49.9	23.1	7.6	8.7 b
Compost	1.30 B	1.68 B	67.9	25.1	7.7	8.4
No Compost	1.13 A	1.24 A	51.0	19.8	7.5	8.0

Table 2. The effect of soil depths, green manure and OFMSW compost on P, K and RWD. Different letters indicate significant differences at P<0.05 and 0.01 (capital).

	P (mg kg^{-1})		K (mg kg^{-1})		RWD (mg cm^{-3})	
DAT	43	106	43	106	43	106
0-0.3 m	65.2	69.9	174.8	155.1	1.08 b	3.23
0.3-0.6 m	44.9	63.4	155.3	148.5	0.37 a	2.60
Bare soil	68.3 B	63.8	185.5 B	135.1 a	0.55 a	2.30 A
Green manure	41.9 A	69.5	144.6 A	168.4 b	0.91 b	3.53 B
Compost	56.6	73.4 B	166.4	155.0	1.01 B	3.55 B
No Compost	53.6	59.9 A	163.7	148.6	0.45 A	2.27 A

Conclusions

As expected, both green manure and OFRSW compost resulted in enrichment of OMC, nutrients (N, P and K), as well as improving root growth. Furthermore, the C/N ratio was increased by both treatments indicating that OFRSW compost and green manure allow C/N to proceed towards the range 9-11 reported as the best conditions for having a balanced degradation of organic matter, thus determining a correct release of N, as well as other nutrients for crop uptake. In particular, the increase of C/N ratio within a range 9-11 is reported as a right way for a more effective condition in terms of both improving the efficiency of N fertilization and reduction of the potentially leachable nitric N from the soil. These are the main reasons to recommend the use of OFMSW compost and green manure in a more sustainable agriculture.

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Land Suitability Assessment For Linseed Introduction In Tuscany Based On A Cultivar-Specific Phenological Model

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Introduction

Crop diversification is one of the main strategies of agroecological transition, playing a key role in enhancing land resource utilization, reducing the agricultural inputs, alleviating biotic and abiotic stresses, and stabilizing yields and economic returns. At the same time, it is a key adaptive action in response to weather challenges. In this contest, linseed represents a possible alternative for Tuscany cropping systems as autumn-winter crop thanks to its ability to withstand low winter temperatures a few degrees below zero, even in the early stages of plant vegetative development. However, crop performances, in term of seed yield and quality, can be negatively affected by spring frost during the flowering stages, as well as by high temperatures and drought occurring from the early flowering stage to seed development, with adverse effects on flower fertility and seed filling (Cross et al., 2003). On the other hand, Tuscany region is characterised by a Mediterranean climate with a great interannual variability in weather conditions with frequent occurrences of spring frost, that usually takes place during April, and high temperatures and prolonged drought in the late spring. Furthermore, rainfall distribution and crop evapotranspiration are strongly affected by the orography of the region, as well as minimum and maximum temperatures are influenced not only by latitude, but also by altitude and distance from the sea. Finally, the different soil texture gradients determine, under the same weather conditions, a strong variability in crop responses due to their effect in the soil hydrological properties and, consequently, on the entire soil-water-crop system. So, within the "SIC-OLEAT - Crop Innovation Systems for Tuscany Oilseed Crops" project, funded by Tuscany Region (PSR 2014-2020), land suitability to linseed cultivation in Tuscany was evaluated, starting from the phenological observations directly recorded from the experimental trials carried out in 2 different locations (San Piero a Grado – Pisa province and Alberese – Grosseto province) for 2 consecutive growing seasons (2019 and 2020) comparing 5 linseed varieties and different sowing times.

Materials and Methods

A model for estimating exposure to risks associated with environmental conditions was developed in *plpgsql* language, able to perform simultaneous simulations on multiple geographical areas and on multiple cultivars. The implemented model was based on a specific cultivar module of phenology and on modules dedicated to the calculation of risk levels from stress associated with cold, heat and water shortage in the early flowering stages and from full flowering to seed ripening. The inputs of the model were: (i) daily meteorological data (Tmin; Tmax; rainfall; evapotranspiration) of a climatic series of 42 years (from 1979 to 2020) provided by the AGRI4CAST (JRC, European Commission EU, Science Hub), in a spatialized grid format, with cells of 25 km on each side; (ii) data of the hydrological constants of six prevailing soil classes estimated using the Soil Water Characteristics model (Saxthon and Rawls) starting from the texture and organic matter values of the LAMMA-CRES soil map; (iii) GDD and phenology collected from the field trials carried out within SIC-OLEAT project, in 2 different locations (San Piero a Grado – Pisa province, 43°40’29’’, 10°18’47’’and Alberese – Grosseto province, 42°41’38’’, 10°08’29’’) for 2 consecutive growing seasons (2019 and 2020) comparing 5 linseed varieties (Galaad, Libra, Kaolin, Sideral, Szafir) and different 2 sowing times (autumn and spring). Water stress has been assessed via adimentional index (+1/-1) specific for each cultivar and soil type.

Results
According to the temperature trend, the model identifies that in the colder areas of Tuscany, the autumn sowing should be performed at the end of September-mid October, while the spring sowing in April-May. In the lowland and costal areas, characterized by a warmer climate, autumn sowing should be accomplished at the end of October-beginning of November and the spring one in March-April. The model highlighted that in the case of spring sowings, there is no risk of low temperature (Tmin<0 °C) during flowering, while for autumn sowing the risk is moderate. Areas on which all 5 cultivars are exposed to frost risk at the beginning of flowering are limited (3 cells out of 66). In Tuscany, the risk of high temperatures (average daily temperature > 25 °C) during flowering is low for spring sowing and substantially non-existent for autumn crops. Zero risk (no variety exposed) is present just in a limited number of cells and the cultivars most likely exposed to high temperature are Sideral and Libra. Furthermore, the model identified soil type and sowing time as the main factors in determining water stress risk, independently from the cultivar; the risk tends to increase with both clay content types- due to the low rain infiltration and water storage capacity - and spring sowing.

Conclusions
The conformation of Tuscany implies a not negligible climatic variability, in terms of rainfall and temperature across the region. The results obtained in the present study, even if preliminary, have allowed to highlight that, for each sub-area, the temperature related risk can be reduced by the identification of the best "sowing time x variety" combination. However, since water deficit is mainly driven by texture and linseed is a rainfed crop, the reduction of water stress risk could be achieved by growing linseed on sandy-loam soil. The implemented model has shown that the autumn sowing, in comparison with the spring one, does not involve an increase in the risks associated with cold/frost during both flowering and seed development, and a significant advantage in reducing the high temperature and drought related risks can be achieved.

Acknowledgements
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Sustainable Production Of Inulin In Mediterranean Condition: Cultivation Of Jerusalem Artichoke In Organic Farming In Apulia Region

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Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.) is a perennial plant of the *Asteraceae* family. Native to North America and Canada, it was imported to Europe by the first French colonists. The first reference to cultivation of this plant in Europe dates about 1600. Jerusalem artichoke present a high adaptability that allowed to this plant to grow in Italy and in all European countries with a mild climate. The fleshy roots (tubers) of the Jerusalem artichoke are the edible part; with flavor that vaguely recalls that of the artichoke, hence the name "Jerusalem artichoke" with which it is sometimes called. The interest of this plant is just in this part, rich in inulin and fructo-oligosaccharides, substances that can be fermented directly because the enzyme fructan 1-exoidrolase (1-FEH; EC 3.2.1.80), present in the tuber, is responsible for their natural depolymerization. Jerusalem artichoke can be effectively grown for energy production and is also a natural source of inulin, oligofructose, and fructose compounds with nutritional and functional attributes (food and feed). The use of this tubers in the field of functional foods present several possibilities, with positive perspective of growing, considering the impressive growing of this market, as effect of Covid 19, and estimated in a market of 180 bilion of USD. Different are the product that can be obtained from Jerusalem artichoke, beneficial to individuals with type 2 diabetes, obesity and cardiovascular disorders. With the aim to evaluate the cultivation of Jerusalem artichoke in organic farming in Apulia region, we report the preliminary results related to trials carried out during the winter 2020.

Materials and Methods

On farm experiments were carried out in 2020 in Lucera, FG, 41.31'37.1''N, 15°24'18.8''E. The soil was silty clay, with a good content in organic matter and nutrients. The cultivation was carried out according the organic system, in a rotation whit durum wheat. Two cultivars of Jerusalem artichoke were compared (Violet of Rennes - VR and White of Provence - WP), planted according to a density of 3 plants m^{-2} (80 cm x 40 cm) the 10th of March of 2020.

Four irrigation treatments (100%, 50%, 25% of field capacity and rainfed) were applied to the two varieties based on Decision Supporting System - Bluleaf®. The system is composed of soil moisture sensors connected with a control unit able that send data to Cloud. Field Capacity and recharging point was established according a pedo-transfer formula (Saxton, 2006). Harvest was effected at complete dessication of above ground biomass. Total production of tubers, and divided for class of dimension, was estimated.

The quality of tubers was assessed by ISPA-CNR, Bari (Italy). In particular, sugar and inulin content were evaluated by AE-HPLC, using a Dionex chromatographic system (ED40 electrochemical detector, GP50 gradient pump, PeakNet5.11 software) and a CarboPacPA1 column (4x250 mm) (Dionex Corporation, Sunnyvale, CA, USA), as reported by Sergio et al. (2016).

Results

The data recorded were influenced by meteorological trend, that showed during the growing period of Jerusalem hartichoke (April-October) a total of precipitation of about 350 mm, above the average of normal condition (280 mm). This had positive effect also on growing in rainfed condition of Jerusalem artichoke, that presented a production average of 34 t ha^{-1} of fresh tuber, ranging between 25,4 t ha^{-1} in WP Irrigation 0 to 39,0 t ha^{-1} in VR Irrigation 100. In average, VR variety presented higher production (36,5 tha^{-1}) than WP (31,7 t ha^{-1}) (Fig. 1).

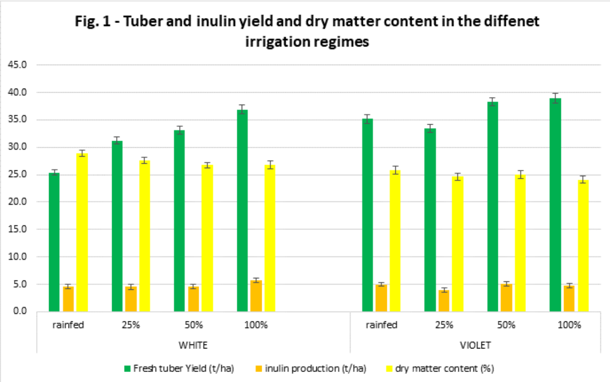

Fig. 1 - Tuber and inulin yield and dry matter content in the diffenet irrigation regimes

Considering the dry matter content, we found higher values in WP cv, 27,5% respect to VR cv, 24,9%, and tendency, not significat to increase value whit reduction of irrigation regimes, and differences between rainfed and full irrigated treatments of about 1% in dry matter content.

Considering the simple sugars, the presence of glucose (17-32 mg/100 f.w.), fructose (33-76 mg/100 f.w.) and sucrose (840-1283 mg/100 f.w.) was recorded, depending on cultivar and irrigation regime. The sucrose content tended to be higher in the WP cv than in the corresponding treatments of VR cv. In both cultivars, the sucrose content did not show significant differences among the irrigation treatments; on the contrary, its content resulted significantly higher in non-irrigated samples of the VR cultivar (Fig. 2) .

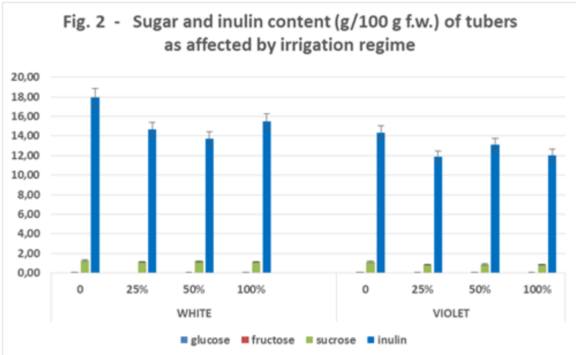

Fig. 2 - Sugar and inulin content (g/100 g f.w.) of tubers as affected by irrigation regime

As regards the inulin content, higher average values in the cv WP compared to VR were found (i.e., 15.5 and 12.8 g/100 g f.w., respectively). Moreover, it was observed that the irrigation regime did not cause remarkable changes in inulin content; the highest inulin content (about 18.0 g/100 g f.w.) was found in the non-irrigated samples of the cv WP (Fig. 2).

Conclusions

The preliminary results about cultivation of Jerusalem hartichoke in organic farming indicate the good potential productivity of this plant in Mediterranean environment. Irrigation represents an input that can increase the production of this plant, that in any case can respond also in rainfed condition, if that condition during the season give the possibility to support for at least 250 mm and in some physiological phases, as happend in the 2020 year.

The results indicate that the irrigation regime did not significantly affect the tuber inulin content of both cultivars, while the non-irrigated samples showed higher inulin content than the irrigated treatments.

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Session 3

2050 perspective: how to produce better?

ORAL PRESENTATIONS

Farming Practices For Organic Durum Wheat Grown In Mediterranean Environment

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Introduction

Recent trends in fertilizers cost and their scarcity on the international market are shrinking agricultural sown areas, with detrimental impacts on crop yields and food supply even in the current season (Benton et al., 2022). Together with the need to foster the sustainability of farming practices, this situation pushes researchers to find alternatives to massive mineral fertilizer use. The adoption of organic fertilizers and the shift towards conservative agriculture are regarded as promising solutions to the purpose. Here we present an experimental study conducted with the primary aim of providing farmers with practical, innovative, and sustainable fertilization strategies to stabilize the yield of organic durum wheat, the main ingredient of pasta, a symbol of the Italian agri-food industry in the world. We implemented alternative organic nitrogen and sulphur foliar applications combined with the addition of selenium (Se), evaluating their effects on multifaceted aspects of durum wheat production i.e., yield, grain protein concentration, plant N content, dry plant biomass, and harvest index.

Materials and Methods

Experimental field trials were conducted in 2017-2018 (2018) and 2018-2019 (2019) in Foggia, Southern Italy (41°46′ N, 16°54′ E). Four varieties (Marco Aurelio, Nadif, Old Saragolla, and Cappelli) of durum wheat (*Triticum turgidum* spp. *durum*) were grown on clay soil (USDA, 1999). The sowing dates were 1st December (2018) and 24th November (2019), with a seeding rate of 350 germinable seeds m^{-2}. Four organic fertilization strategies were evaluated: 1) the control, where only 50 kg ha^{-1} of dry blood meal was applied at sowing (CTR); 2) CTR, plus 45 kg ha^{-1} of foliar organic S applied at flag leaf stage (CTR+S); 3) CTR, plus 45 kg ha^{-1} of foliar organic N applied at heading (CTR+N); 4) CTR, plus organic N and S foliar application at flag leaf and heading stage, respectively (CTR+NS). The effect of the trace element Se was evaluated by comparing Se0, the control without selenium, and Se60, where one foliar application of sodium selenate (60 g ha^{-1} of Na_2SeO_4) was applied at the booting stage. The field experiment was arranged in a split-split plot design with three factors and three replicates, i.e., the variety in the main plot, the organic fertilization in the plot, and the selenium application in the sub-plot (10.2 m^2). A weather station close to the experimental field recorded daily precipitation and temperature. Total precipitations were 401 mm (2018) and 299 mm (2019), with average temperatures of 13.5 °C in 2018 and 11.7 °C in 2019. Plant dry weight, plant N content, Harvest Index (HI, the ratio between grain weight to aboveground dry matter), yield, and grain protein concentration (GPC) were evaluated at physiological maturity. Multivariate analyses were performed to unravel the relationships among these experimental variables and to gain insights into experimental results. Correlation analyses followed by Principal Component Analysis (PCA) were performed using all experimental variables. The tested factors (growing season, variety, organic fertilizer, and Se application) were used as supplementary qualitative variables in the PCA (Mongiano et al., 2018). We then applied a non-supervised Hierarchical Clustering on Principal Components (HCPC) using Euclidean distance and Ward’s criterion to identify groups of data showing similar behavior. The cluster means for any indicator of durum wheat production was tested under the null hypothesis that its distribution did not vary across clusters. Finally, a v-test was performed to characterize the clusters considering both active and supplementary variables, under the null hypothesis that the cluster average did not differ from the global mean.

Results

Three clusters emerged from the HCPC performed (Figure 1). All the experimental variables significantly contributed to explain the intra-cluster variance ($p \leq 0.001$), with GPC and yield as the top contributors. Cluster 1 (C1) was entirely composed of experimental data collected in 2019, and showed a prevalence of Marco Aurelio (56% of the data). Cappelli was not represented in C1. Emerging properties from C1 were high HI ($\bar{x}$=0.43, overall mean = 0.33), average yield ($\bar{x}$=2.8 t ha^{-1}, overall mean =2.7 t ha^{-1}) and low GPC ($\bar{x}$=10.2%, overall mean = 11.8%). In C1, the Se application did not significantly affect yield ($\bar{x}$ Se0 = 2.9 t ha^{-1}, sd = 0.5 t ha^{-1}; $\bar{x}$ Se60=2.7 t ha^{-1}, sd = 0.4 t ha^{-1}) and GPC ($\bar{x}$ Se0 = 10.2%, sd = 0.5%; $\bar{x}$ Se60=10.1%, sd = 0.4%). Cluster 2 (C2) grouped experimental data from 2018 exclusively, with a significant presence of Se60 application (58% of the data), whereas Se0 was significantly under-represented. All varieties were almost equally present in C2, with percentages ranging from 23% (Marco Aurelio) to 27% (Nadif). All experimental variables belonging to C2 were significantly higher than the global average in C2, especially GPC ($\bar{x}$=12.9%, overall mean = 11.8%) and yield ($\bar{x}$=3.1 t ha^{-1}, overall mean =2.7 t ha^{-1}). In C2, Se application played a determinant role, as Se60 treatment led to yield value of 3.3 t ha^{-1}, corresponding to 19.4% increase with respect to yield in Se0. The effect of Se application on GPC was negligible. Cluster 3 (C3) was the only cluster where both growing seasons were represented, despite 80% of the data belonged to 2019. Nearly half of the data in C3 belonged to Cappelli, and Se0 treatment was over-represented. This cluster was characterized by high plant dry weight ($\bar{x}$=9.4 t ha^{-1}, overall mean = 8.52 t ha^{-1}), average GPC ($\bar{x}$=11.5%, overall mean = 11.8%), and low HI ($\bar{x}$=0.2, overall mean = 0.3) and yield ($\bar{x}$=2.0 t ha^{-1}, overall mean = 2.7 t ha^{-1}). In C3, Se application caused a decrease of the yield (-13%) as well as a slight reduction in GPC.

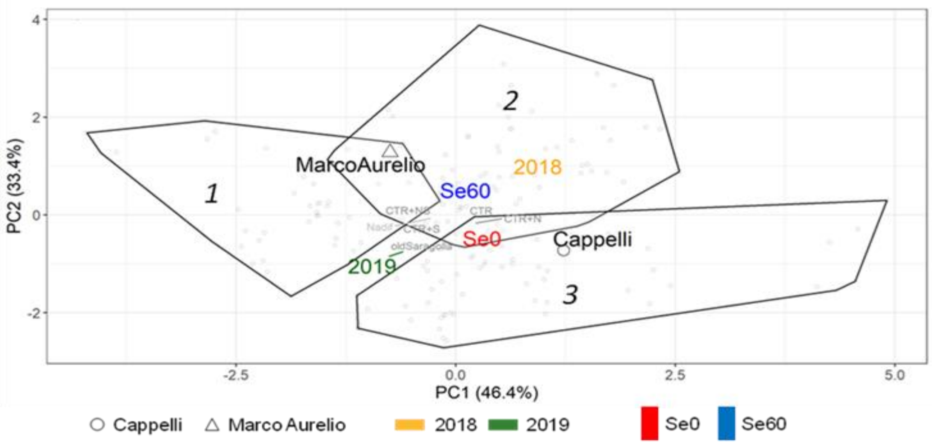

Figure 1. PCA biplot with clusters delimitation; the barycenter of the supplementary variables mostly contributing to cluster variances are reported in the legend. The other supplementary variables are reported in grey.

Conclusions

This study confirms that the varietal choice is the most remarkable management practice influencing organic durum wheat yield, whereas the foliar organic fertilization tested had minor influence on yield and quality. However, the effect obtained by implementing a Selenium-based foliar fertilization demonstrated to have a beneficial effect on organic durum wheat yield, depending on weather conditions. Although this element does not play an essential role in wheat physiological processes, it proved to be an efficient contributor to yield in 2018, without reducing GPC. This evidence strengthens the need to better investigate the effect of Se foliar application on organic durum wheat, in order to deliver clear and feasible practices to be operationally implemented by farmers in the next years.

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A Survey Of Weed Distribution In Italian Rice Fields Related To Agronomic Techniques

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Introduction

The Italian rice area is characterized by the presence of a specialized weed community, consisting of species able to grow in fields often flooded for a variable time period. Although rice is often cultivated in monocropping, the agronomic practices may be quite variable depending on farmer's choice and on the local soil and climatic conditions; these characteristics may affect the floristic composition of the weed community. The agronomic techniques adopted in the Italian rice farms has evolved rapidly over the past decade, a period in which, for example, the dry seeding of rice has become prevalent (Ferrero et al., 2020). Such changes have likely favored an increase in the presence of species more capable of growing under non-flooded conditions. Weed management techniques have also changed in the last years with an increasing area devoted to the cultivation of herbicide-resistant rice varieties further contributing to the changes of the species distribution in the rice fields (Gómez de Barreda et al., 2021).

The objective of the study was to map the distribution and abundance of different rice weeds through farmer's interviews and weed density surveys conducted in 2017-2020 in several rice farms distributed in the main Italian rice-growing area. The weed presence was then related to the main agronomic practices applied in the area and to the soil characteristics.

Materials and Methods

A series of farmer's interviews were conducted in 2018-2020, involving about 1000 rice farms. The questions were related to the rice area cultivated in each farm, the most spread weeds, the extension of the flooded and dry rice seeding area, the farmer's perception of increasing and decreasing weeds, the area devoted to crop rotation, the techniques adopted to prepare the soil (plowing or minimum tillage) and the presence of probable herbicide-resistant weeds.

Weed density was estimated in 295 rice plots in different sites of the main Italian rice area by counting and determining all the weed species. The assessment was carried out in non-weeded plot in each site in three different time during the crop cycle. All the surveyed plots were geographically localized and the type of rice seeding (flooded or dry) was also recorded.

Data from interviews and field assessments were both analyzed through descriptive statistics, such as frequency of different weed species detected by the farmers in their fields and frequency of the application of different management practices. ANOVA was applied on weed density assessement to find significant differences in weed presence between type of seeding. Weed density, the area infested by the different weeds species over the total rice area of each farm, the rice area of each farm, the type of seeding, the soil texture and soil pH of the surveyed areas were analyzed through a PCA and a two-steps cluster analysis to detect which variables accounted most for the data variability.

Results

The farmer's interviews highlighted that in 2018 flooded seeding was performed on 53% of the rice fields, while in 2020 this percentage decreased to 44%. Before seeding, fields were mainly prepared with soil plowing (80% of the area) and rice was cultivated as monocropping in about 70% of the fields.

The most spread weeds in the rice area were *Echinochloa* spp. present on about 87% of the farms. On almost half of the area of the considered farms, *Cyperus difformis* and *Heteranthera reniformis* were present, while weedy rice (*Oryza sativa*) infested about 40% of the rice area. According to the farmers, higher infestations of *Persicaria maculosa*, *Cyperus esculentus*, *Digitaria sanguinalis* and *Panicum dichotomiflorum* were observed in dry seeded rice fields. High presence of weeds typical of flooded environments were present, as expected, in the flooded seeded rice fields, such as *C. difformis*, *H.*

reniformis, *Alisma plantago-aquatica*, *Butomus umbellatum*, *Schoenoplectus mucronatus* and *Ammania coccinea*. Farmers noticed an increase in the infestations in the last five years of *Echinochloa* spp., weedy rice, and *C. esculentus*, while they observed a reduction in the presence of *A. plantago-aquatica* likely due to the introduction of florpyruaxyfen-benzyl, a herbicide highly effective against this weed.
The weed density asssesments highlighted a higher weed presence (about 66 plants m^{-2}) in flooded fields compared to the dry seeded ones (about 44 plants m^{-2}). The PCA showed that weed density was negatively correlated with soil sand content, especially for species found in flooded conditions; in these areas, in fact, seeding in flooded fields was the most applied practice. Moreover, weeds typical of dry environments were found in sandy or loamy sand soils where dry seeding was the most prevalent technique.

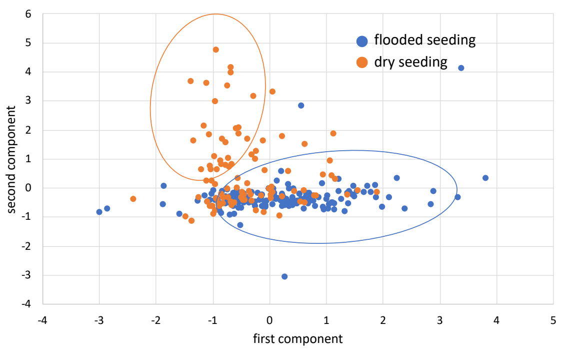

Figure 1. PCA showed that the first component was mainly correlated with weeds typical of flooded seeding, while the second component with weeds found in dry seeding.

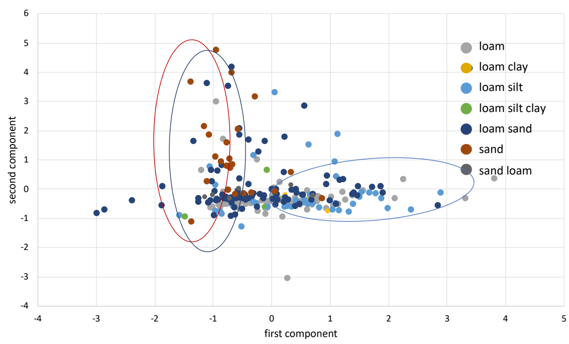

Figure 2. PCA highlighted a positive correlation with silt and clay soil content. Second component mainly correlated with sand content.

The cluster analysis showed that the seeding method was the most important predictor for the cluster formation. Three clusters were built, one constituted by 93% of the sites with seeding in flooded fields and with high density of weeds typical of flooded conditions, such as *H. reniformis*, *Echinochloa* spp., and *C. difformis*. Cluster 2 comprised 74% of the sites with dry seeding and with weeds typical of both flooded and dry seeding, while cluster 3 included 92% of the sites with dry seeding having weeds typical of this conditions.

Conclusions
The study permitted to have an updated picture of the infestations of rice fields and highlighted that some agronomic practices, i.e. type of seeding, can strongly influence the presence of certain weed species. The results highlighted that the choice of the agronomic practices to be adopted for rice cultivation is strategic not only to achieve high productions but also to correctly manage rice weeds by taking into account the spread of the different weed species, which are in turn affected by the agrotechniques.

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What Is The Most Promising BAT That Reduces NH_3 Emissions From The Agricultural Sector? Results From Embedding The Spheres Of Sustainability Into A Bayesian Network

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Introduction

Concerns about ammonia (NH_3) emission from the agricultural sector have dramatically increased in recent years due to its contribution to atmospheric fine particulate matter formation ($PM_{2.5}$ and PM_{10} fractions). Several technological solutions have been proposed to mitigate NH_3 losses, to manage production and storage of excreted animal manure, and for the application of organic or mineral fertilizers in the field. However, the success of their application may be limited if a collaborative bottom-up approach that commits farmers and practitioners in the full technology valuation is missing. Bayesian Belief Networks (BBNs) are innovative tools to represent expert knowledge in any particular situation – e.g. in the agroecosystem– and to evaluate simultaneously potential effects of alternative management decisions (Dai et al., 2021). By creating cause-and-effect relationships, BBNs can provide both diagnosis and prognosis under specific variable conditions, aiding the decision-making process.

Here, a Bayesian inference approach was used to embed quantitative experimental data and quali-quantitative perceptions from stakeholders into a single BBN model. The aim was to identify the Best Available Technologies (BAT) that combine the effectiveness in reducing NH_3 emissions from livestock management and N fertilizer application, with economic and socio-cultural acceptability by farmers and practitioners.

Materials and Methods

A semi-quantitative BBN causal model was built using Genie Academic 3.0 (BayesFusion LLC, USA). The model consisted of a set of variables with probabilistically defined dependencies (probability nodes), which representend the management variability of the livestock sector (swine, cattle and dairy cows) and the pedo-climatic and management practices for main spring and winter cereal cultivations (maize, winter wheat, barley) in the Veneto Region.

For cereal cultivation, cause-and-effect probability nodes were linked with the aim to describe NH_3 emissions from N fertilizer application technologies (e.g., closed slot injection or surface distribution of urea or ammonium nitrate, N fertilizer use under conservation tillage) in the different pedo-climatic conditions of the Veneto region. Estimates of NH_3 losses came from the integration of experimental, literature, and modelling data by using the modified version of DNDC v.CAN biogeochemical model, that was already tested in the field (Mencaroni et al., 2021). For the livestock sector, key technologies included in the BBN model affecting NH_3 emissions were a set of management practices related to feeding (e.g., precision feeding, a.a. integration), overcrowding (e.g., breeding density), healthcare (e.g., infirmary spaces), hygiene and cleaning (e.g., stable ventilation) and manure storage (e.g., fixed or floating covers). The contribution of livestock and fertilizer application from different areas of the Veneto region were integrated in the model, which allowed: 1. the selection of site-specific most impactful BATs; 2. the identification areas where actions were most urgent.

Stakeholders from different sectors (e.g., farmers, consultants, breeders) were engaged in the evaluation of the proposed technologies. In particular, perceptions about technological (i.e., the technical potential application) and economic (i.e., the perceived technical potential application) attractiveness were asked, and the results were introduced in the BBN as utility nodes to determine BAT.

Results

Results showed that both the livestock sector and the agronomic use of fertilizers have large room for improvements in reducing NH_3 emissions. Regarding N fertilizer application, the deep incorporation of both organic or mineral fertilizers were among the most effective tools, with NH_3 emissions that were always <30% compared to surface broadcast urea distribution (reference method). Pedo-climatic conditions were minor factors affecting the BAT selection, being soil pH-driven NH_3 emissions similar over *ca.* 70% of the regional area. However, stakeholders perceived it as costly and complicated the use of new machinery for the efficient injection of mineral N in both spring and winter crops, downplaying the impact of new technologies in reducing NH_3 losses. Regarding the livestock sector, improved healthcare conditions and reduced overcrowding were the most promising BAT, whose highest priority was peculiar for some regional areas (e.g., Verona province) due to social and environmental issues.

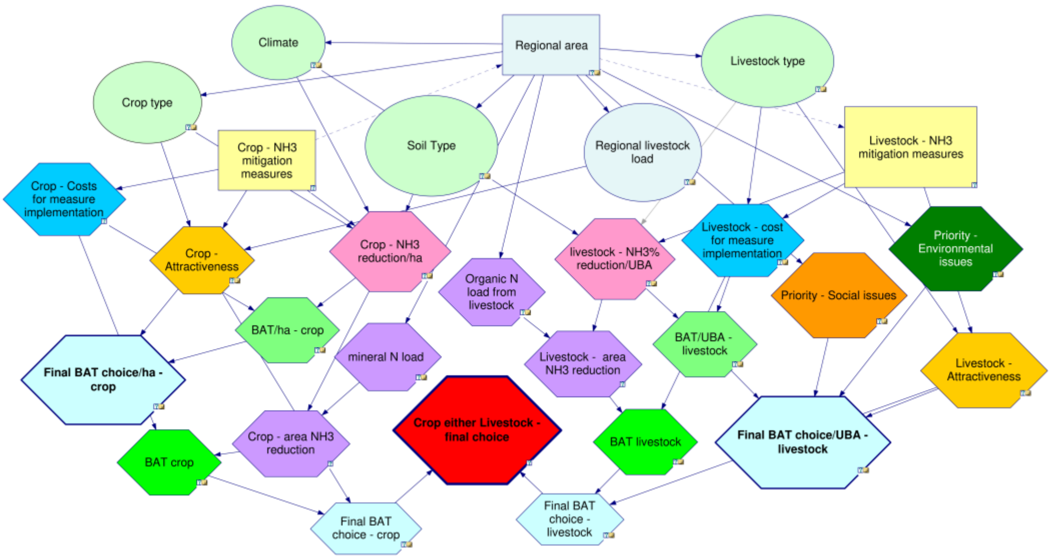

Figure 1. The constructed Bayesian belief network to identify most promising BAT reducing NH_3 emissions from livestock and N fertilizer management in the field.

Conclusions

The BBN model was able to embed into a single network quantitative results from technical solutions with quali-quantitative perceptions by farmers and practitioners. In fact, by combining social and economic valuation provided by stakeholders with the technical potential of NH_3 reduction, the BBN acted as a effective decision support tool capable of giving indications about the most promising BAT that should be supported. In this context, the greatest room for improvement was in most efficient ways of the livestock supply chain, from the stable management to the manure distribution in the field.

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Predicting The Canopy Nitrogen Content Of Mediterranean Forage Crops: A Remote Sensing Approach

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Introduction

Grassland cover about 25% of Earth's surface and 70% of the total agricultural terrestrial area (Conant, 2010). Nitrogen is one of the most important chemical elements contributing to successful forage crop productivity and quality as crude protein content. In grassland agroecosystems, remote sensing can provide diagnostic information on crop N status more quickly and in a spatial context than destructive sampling techniques (Wachendorf et al., 2018). It is not always possible to directly assess canopy N concentration with remote measurements. Factors such as water stress, percentage of canopy cover, and soil reflectance effects influence the vegetation indices' outcome. Nevertheless, using remotely sensed indices for estimating the canopy N content (g m^{-2} of N) instead of N concentration in rainfed environments might represent a solution to overcome these limitations (Cammarano et al., 2011). The hypothesis of this study was that remote sensing allows for the estimation of the N canopy content in Mediterranean forage systems under different management intensities. This study aimed to provide evidence on the ability to predict the canopy N content of forage crops under rainfed conditions through vegetation indexes derived from the combination of both remote sensing and ground data.

Materials and Methods

The study site was the UNISS experimental farm of Santa Lucia (Sardinia, IT, 39°58' N, 8°37' E, 15 m a.s.l.). The site is characterized by a Mediterranean climate, with an average yearly rainfall of about 500 mm, and clay-loam soils. The effects of forage crop mowing intensity – simulated grazing events and final harvesting (PP) *vs* ungrazed crop, cutting forage once at the end of the season (P) – were tested on the ability to predict canopy N content through remote sensing. Aboveground biomass (g m^{-2} of DM) and N content (%) were measured in 28 plots on five dates from 2021 to 2022. A the same time, remote sensing data were acquired through multispectral sensors placed on a drone collecting reflectance in the red (660 nm), red edge (725 nm), and NIR (850 nm) bands. The experimental design was set by following the approach proposed for wheat by Fitzgerald et al. (2010). For each measured data, the Canopy Nitrogen Index (CNI) was calculated from the N dilution curves (CNI = [(N%-Nmin)/(Nmax-Min)], Eq. 1, Fig. 1A). The Chlorophyll Content Index (CCCI) was calculated based on remotely sensed data through the relationship between the NDVI and the NDRE indices (Fig. 1B). For a given point in Fig. 1B, the CCCI is calculated as the vertical difference between any point and the lower line (minimum) as a fraction of the total distance between the upper (maximum) and lower (minimum) lines. The parameters of the linear model between CNI and CCCI (Fig. 1C, Eq. 2) allowed for predicting the N content from the CCCI by substituting the CNI of Eq.2 with the CNI of Eq.1. The expected N content was then multiplied by the DM to obtain the canopy N content (g/m^2). For both P and PP, the significance of linear regression between measured and predicted data, the R^2, and the RMSE were calculated to assess the ability to predict the canopy N content.

Results

Significant relationships (P<0.001) between measured and predicted N content were observed for both P and PP (Fig. 1D). The model used in this study showed a better ability to estimate N under PP (R^2=0.86, RMSE=1.48) than P (R^2=0.70, RMSE=3.47). The regression's residuals dispersion under P use revealed limitations in estimating the canopy N content at the end of the cropping cycle, with the highest forage availability, when a higher dilution of N in biomass is expected. This limitation can be related to the saturation of the multispectral information from both NDVI and NDRE. Furthermore, a share of uncertainty in the prediction can be explained by the different legume content in mixtures that were used in the experiment.

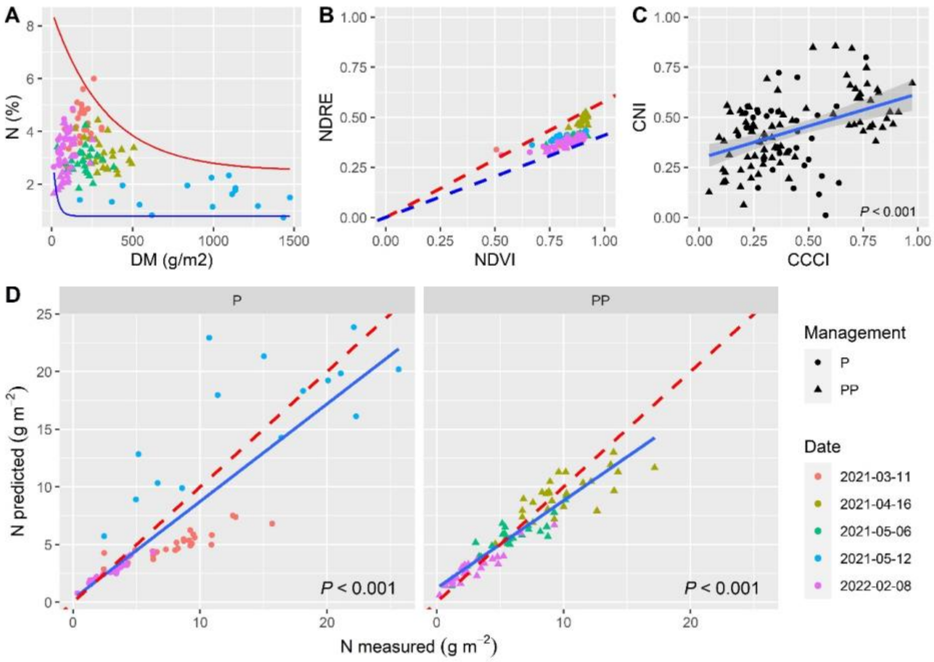

Figure 9. A: Relationship between canopy N concentration and biomass that allows the derivation of the Canopy Nitrogen Index (CNI). B: Relationship between NDVI and NDRE used to calculate the Canopy Chlorophyll Content Index (CCCI). C: Relationship between CCCI and CNI. D: Relationship between measured and predicted canopy N content in P and PP management options.

Conclusions

The preliminary results of this study suggested that the canopy N content of Mediterranean forage crops can be satisfactorily predicted through the CCCI index derived from remote sensing. These results indicated that the approach proposed for durum wheat could be adapted and replicated in a more complex intercropped system such as the forage species mixtures at a different intensity of use. Further insights are needed to assess the predictive ability in relation to the relative abundance of legumes in mixtures. The results can represent the basis for developing decision support tools for livestock farmers aiming to perform a real-time field estimation of the forage quality in extensively managed grasslands.

Literature

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Soil Olsen P And Maize Crop Responses To Phosphorus Starter Fertilisation

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Introduction

Low phosphorus (P) solubility limits its concentration in soil solution and crops may acquire insufficient P, resulting in retarded growth and, in maize, the typical purpling of leaves (Plénet et al., 2000). Farmers localise mineral P at sowing to stimulate the early plant growth, hovewer the use of mineral P is questionable where animal manures are distributed at rates sufficient to meet the annual P crop needs and/or the soil P status is high (Schröder et al., 2015).

The objectives of this work were to test the crop response to starter P fertilisation in a soil at different enrichment levels due to long-term (LT) fertilisation using mineral fertilisers or manures, and to derive a crop response curve to soil available P.

Materials and Methods

A field experiment was carried out in NW Italy during the 2019 and 2020 growing seasons on selected plots of the LT experiment of Tetto Frati (44°53'N; 7°41'E; 232 m a.s.l.) of the University of Turin. The trial compared sub-surface placement of NP (as diammonium phosphate; 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}) or N alone (ammonium nitrate; 27 kg N ha^{-1}) at sowing, in bands close to the maize seed furrows, in differing long-term (LT) fertilisation managements: two doses of urea (Min-L and Min-H), two doses of bovine slurry (Slu-L and Slu-H) or two doses of farmyard manure (Fym-L and Fym-H). The two rates, low (L) and high (H), corresponded to 170 and 250 kg N ha^{-1} $year^{-1}$ respectively, in all fertilisation systems. At the start of the experiment, the six systems had different soil P contents, since they were the result of LT fertilisation managements. The soil Olsen P concentrations before the experiment start showed the highest value in Fym-H (91 mg kg^{-1}), followed by Fym-L (52 mg kg^{-1}), the lowest values in both Min treatments (c. 14 mg kg^{-1}), and intermediate values in Slu (c. 29 mg kg^{-1} of Olsen P).

In both years, the crop development was assessed through different parameters (crop height, biomass, NDVI, Leaf Area Index, date of flowering). At maturity, maize grain yield, humidity, mycotoxin content and plant total P uptake were assessed. The soil was sampled at 50 days after sowing (DAS). Three 0-30 cm deep soil cores were collected with an auger along the central rows of each plot and pooled together to obtain a representative sample for the plant-available P determination, using the Olsen method. A linear-plateau model was used to interpolate soil Olsen P vs the true soil available P for the crop, as assessed by the plant uptake at harvest.

Results

Compared to the N only treatment, the starter NP fertilisation at sowing did stimulate the plant growth in early stages. Differences were more pronounced in the mineral systems than in the manured systems, and were more evident in the cooler year, 2019. However, differences in crop growth between NP and N starter fertilisations levelled up at the flowering stage (that occurred 1 day sooner in NP treatments, on average) and were detectable at harvest as yield, grain humidity or sanitary traits only in Min systems, but not in Slu or Man systems (data not shown; Battisti et al., 2022).

The P starter fertilisation influenced the available P as assessed by soil analysis during the early growth phases of maize growth, in interaction with the LT fertilisation. The soil Olsen P concentration at 50

DAS was consistently increased in the NP treatment compared to N, in Min-H e Slu-H treatments, while this trend was observed in Min-L and Slu-L in only one of the experimental years (Table 1). Conversely, when LT fertilisation included farmyard manure, no significant differences were found in soil Olsen P concentration as a consequence of NP starter fertilisation compared to N.

The total plant P uptake at harvest, that represents a true indicator of soil P availability, showed a linear-plateau response to soil Olsen P measured near roots at 50 DAS (Figure 1). The plant P uptake increased linearly up to the threshold of 39 mg P kg^{-1} of Olsen P, then stabilised, as luxury consumption of P is not typical in maize.

Table 3. Effect of starter fertilisation on soil Olsen P. Asterisks denote significant differences (* p <0.05; ** p <0.01; *** p <0.001) between means in long-term fertilisation × starter fertilisation × year interaction (p= 0.010), separated through a Bonferroni post hoc test.

P Olsen (mg kg^{-1})		N	NP	Sig. *p*
2019	Min-L	9.3	15.9	*
	Min-H	6.4	27.6	***
	Slu-L	27.4	30.1	
	Slu-H	26.5	37.6	**
	Fym-L	50.8	61.4	
	Fym-H	74.7	77.5	
2020	Min-L	8.8	13.9	
	Min-H	6.7	14.6	*
	Slu-L	25.8	37.8	**
	Slu-H	23.1	35.1	***
	Fym-L	46.6	50.4	
	Fym-H	80.1	82.0	

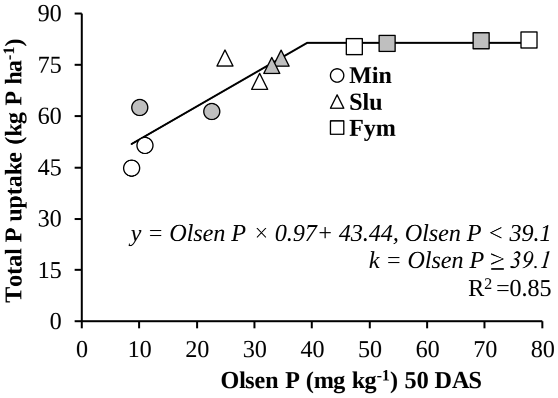

Figure 10. Total above-ground plant P uptake at harvest vs soil Olsen P concentration at 50 Days After Sowing, averaged over the two years (n=6). Open symbols = N starter fertilisation, closed symbols = NP starter fertilisation.

Conclusions

The starter NP fertilisation at sowing did not affect maize yield, grain humidity or sanitary traits, although an initial stimulation of plant growth was observed in P medium-enriched soils. Consequently, the starter NP fertilisation at sowing is recommended in soils with a low available P content, and should be avoided in rich soils, such as the ones that received farmyard manure. The situations where slurry was supplied, that had a soil P content that was considered high (20-30 mg kg^{-1} of Olsen P) were intermediate, and the benefit of starter NP fertilisation on crop growth depends on weather conditions, and in particular on temperature. In the framework of a changing climate, starter fertilisation could help ensuring high yields in unfourable conditions. In additions, thresholds above which a suspension of P fertilisation is recommended should be revised, as the maize plant P uptake was reduced below 39 mg kg^{-1} of Olsen P, which is far above the thresholds normally used to decide about fertilisation suspension.

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POSTERS

Carbon Flux As Affected By Different Winter Cover Crops

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Introduction

The composition of the environment we are living in is greatly influenced by agricultural activities. The process of sequestration of atmospheric gasses and release of GHG's into the atmosphere through agricultural activities hold a significant role in shaping the future environmental conditions. The CO_2 sequestration through sustainable agriculture practices is imperative to the maintenance of the ecosystems and agroecosystems for the wellbeing of all living things. The use of winter cover crops in the Mediterranean environment has many beneficial roles in improving agroecological conditions through the release of essential nutrients and CO_2 sequestration with other atmospheric gasses. The use of cover crops can ultimately increase the carbon sinks in the soil and this phenomenon will help in mitigating the effects of climate change and global warming (Mancinelli et al., 2019). The most common and effective cover crops in use include: vetch (*Vicia sativa* L.), phacelia (*Phacelia tanacetifolia* Benth.), and mustard (*Brassica juncea* L.). All these cover crops are rapidly growing high biomass plants that improve soil health, reduce soil erosion, suppress weeds, add nutrients, etc. The objective of this study was to evaluate the contribution of these cover crops in the carbon stock during growing cycle.

Materials and Methods

The research was conducted at the experimental farm of the University of Tuscia located in central Italy during 2012 and 2013 cropping seasons. The average temperature of the area is 14.5 °C. The soil of the experimental area is of volcanic origin and classified as Typic Xerofluvent. The soil total organic C and N content on average was 1.07% and 0.12%, respectively and pH of the soil was 7.1.

A 2-year cover crop study was carried out in order to study the carbon flux as affected by winter cover crops. The treatments consisted of four cropping systems: (a) conventional (b) vetch (c) phacelia and (d) mustard. The treatments were replicated three times according to a randomized complete block design. Winter cover crops were grown in two consecutive years and data related to carbon flux was collected periodically every year. The data for fluxes of CO_2 emissions from all experimental treatments was measured during both years with a portable dynamic closed-chamber infrared gas analyzer system (EGM-4, PP Systems). In both growing seasons, the aboveground biomass was collected in a sampling area of 1 m^{-2} in the central area of each plot just before its mechanical termination. The dry weight of collected sub-samples was measured. Dried sub-samples of the cover crop biomass were homogenized using a mill for biomass, then carbon (C) content was measured with an elemental analyzer.

ANOVA was performed by JMP statistical software package 4.0. It was conducted for the 2 years period applying a randomized complete block design with three blocks. Means were compared adopting the Fisher's protected least significant difference (LSD) at $p < 0.05$.

Results

In Figure 1 the Soil CO_2 emissions by soil temperature during the cover crop cycle are reported. The soil CO_2 emissions by soil temperature during the cover crop cycle were highest in vetch cover crop (R^2 = 0.314) followed by phacelia (R^2 = 0.3302), mustard (R^2 = 0.3288) and conventional (R^2 = 0.1935), respectively. However, the soil CO_2 emission trend by the temperature is similar among the three cover crops which are different to the conventional one that in addition resulted be not significant regression.

In Table 1 the cover crop biomass, C in cover crops, and C in cover biomass / C in soil CO_2 rate are reported. The cover biomass during 2012 and 2013 was highest in vetch (1036 g DM m^{-2} and 744 g DM m^{-2}) followed by phacelia, mustard and conventional respectively. The significant difference between vetch and other crops was also higher in 2012. However, there was no significant difference between vetch and phacelia in 2013 but they showed significant difference from other cover crops.

Table 1. Cover crops biomass, C in cover crops, and C in cover biomass / C in soil CO_2 rate. Levels not connected by same letter are significantly different, for the same parameter.

Cover crops	Year	Cover biomass (g DM m^{-2})		C in cover biomass (kg C ha^{-1})		C-Biomass / C-CO_2 rate	
C	2012	0	d	0	e	0.000	d
P		579	c	2275	cd	0.421	bc
M		482	c	2119	d	0.590	ab
V		1036	a	4392	a	0.721	a
C	2013	0	d	0	e	0.000	d
P		693	b	2738	bc	0.509	ac
M		482	c	1999	d	0.306	c
V		744	b	3084	b	0.441	bc

Furthermore, the C in cover biomass in 2012 and 2013 was highest in vetch (4392 kg C ha^{-1} and 3084 kg C ha^{-1}) followed by phacelia, mustard and conventional, respectively. The cover crop vetch also showed a significant difference from other crops. Mustard and conventional showed significant differences from each other and rest of the crops. The C in cover biomass / C in soil CO_2 rate in the year 2012 was highest in vetch (0.721) followed by mustard, phacelia and conventional, respectively. The results from 2013 showed the maximum C-Biomass / C-CO_2 rate in phacelia (0.509) followed by vetch, mustard and conventional, respectively. The C in cover biomass in 2012 and 2013 was highest in vetch (4392 kg C ha^{-1} and 3084 kg C ha^{-1}) followed by phacelia, mustard and conventional, respectively. The cover crop vetch also showed a significant difference from other crops but there was no significant difference between phacelia and mustard during 2012. Mustard and conventional showed significant differences from each other and rest of the crops. The C in cover biomass / C in soil CO_2 rate in the year 2012 was highest in vetch (0.721) followed by mustard, phacelia and conventional, respectively. The results from 2013 showed the maximum C-Biomass / C-CO_2 rate in phacelia (0.509) followed by vetch, mustard and conventional, respectively. However, there was no significant difference observed between phacelia, mustard and vetch but they all showed significant difference from conventional

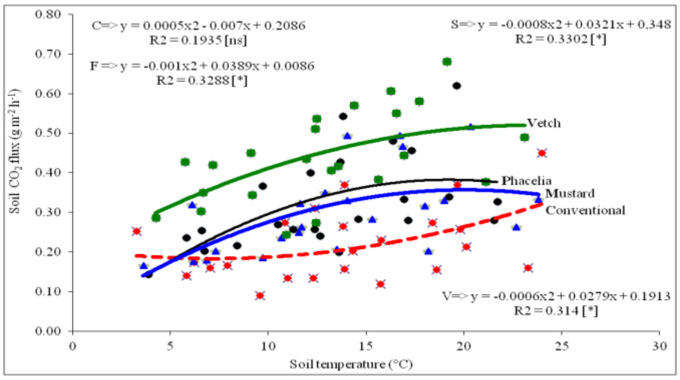

Figure 1. Soil CO_2 emissions by soil temperature during the cover crop cycle. *: significant for $P \leq 0.05$; n.s.: not significant

Conclusions

To conclude it can be said that growing cover crops is the most efficient method for alleviating the effects of global warming through carbon sequestration. The results show that vetch cover crop has the maximum ability in the sequestering of carbon in soil and plant biomass. After vetch, the cover crop phacelia as shown the maximum capacity of sequestering atmospheric carbon dioxide.

Literature

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Enlarged Row Spacing To Reduce Manual Weeding In Organic Sugar Beet Cultivation

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Introduction

Organic sugar beet is increasingly being grown in Italy since a few years. The containment of biotic threats is a challenging task under the organic crop protocol. Especially weeds are difficult to control without herbicides, and all sugar beet growers rely on manual weeding to complement the activity of mechanical weeders. This work, funded by the Emilia-Romagna 2014-2020 Rural Development Programme, tests the option of a wider row spacing as means to reduce the burden of manual weeding, while limiting losses in yield potential. In the sugar beet crop, row spacing has been recently surveyed under warm climates as it concerns weed control (Bayat et al., 2018) and productivity (Malik et al., 2015).

Materials and Methods

In 2020 and 2021, six experimental fields were set up in three farms in the Ferrara, Italy, floodplain (average position, 44° 47’ N, 11° 55’ E, 5 m asl). Three inter-row spacings were compared in 80 m^2 sugar beet plots with three replicates: single (45 cm), single/double (45+90 cm) and double spacing (90 cm) between rows. The two larger spacings were obtained by eliminating one third of the rows (the 2^{nd} and 5^{th} row in a 6-row drilling) (45+90 cm), and every other row (90 cm) after seedling emergence. Accurate weeding was ensured by hand passes, while the rest of crop husbandry reflected standard practices.
During crop growth, the percent canopy cover of the soil was assessed through the mobile phone app Canopeo® at intervals of 1-2 weeks. At advanced growth stages (June-July), the normalised difference vegetation index (NDVI) was determined through the GreenSeeker hand held device. At harvest (July 20-23 across the two years) sugar beet samples were taken, brought to the lab of Co.Pro.B. sugar factory in Minerbio (BO), washed, weighed, analysed for sugar content and noxious elements (Na, K and amino-N) concentration. Based on these data and the related beet prices, raw sugar yield (t ha^{-1}), gross and net margin (€ ha^{-1}), and internal beet quality (% juice purity) were assessed.

Results

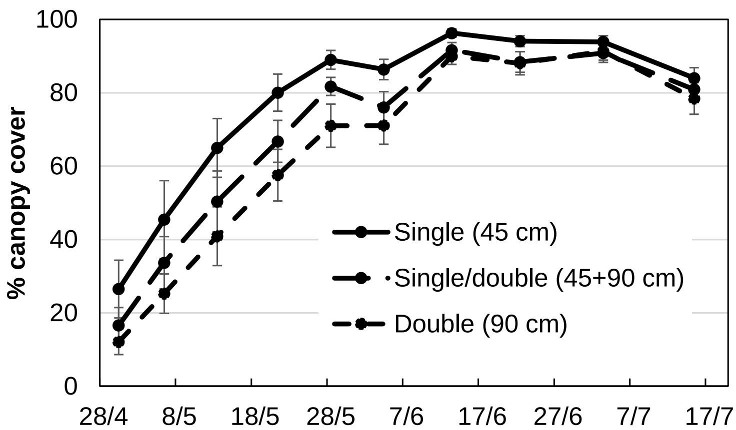

Figure 1. Soil canopy cover in the three row spacings in the average of the six trial fields (vertical bars, ±SE; n = 6).

The canopy cover was quite differentiated among the three row spacings in the early crop stages (Fig. 1).
Later on, the differences were reduced, as was the variation among the six trial fields at each date (error bars). It is evidenced that, in the short growing season due to organic beet harvesting at the beginning of the sugar campaign, the crop maintained a ~90% canopy cover for approximately one month. In this period, the single spacing maintained a slight advantage over the two wider spacings.

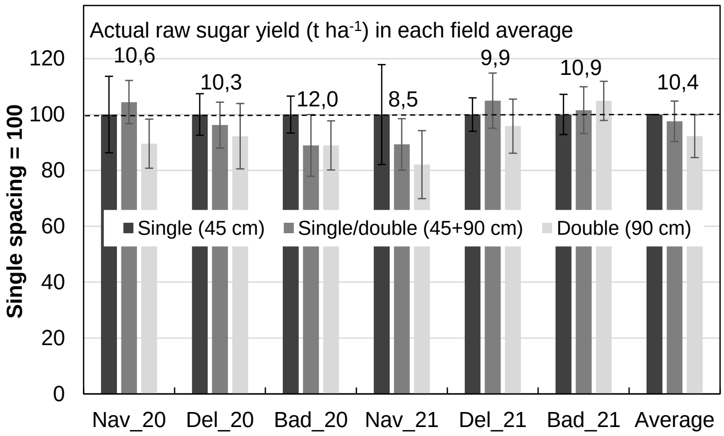

Figure 2. Relative raw sugar yield in the three row spacings across the six trial fields (vertical bars, ±SE; n = 6).

The NDVI exhibited modest, insignificant differences with a slight downward trend from June to July (data not shown). Therefore, it is perceived that the wider row spacings, beside involving a later soil cover in the early stages, did not determine a better growth status in the late stages, in contrast to what expected.

The different canopy cover modestly reflected in the final yield: in the average of the six fields, the single/double spacing and the double spacing lost only 2.4% and 7.7% raw sugar yield, respectively, vs. the single spacing (Fig. 2).

Beet quality was slightly yet negatively influenced by wider spacings, as the likely consequence of less beets/m² (due to selective row elimination) getting more saturated with impurities: average juice purity was 92.7%, 92.2% 91.4% in the three respective spacings.

The gross margin echoed the yield differences: in the average of the six fields, -2.8% and -8.9% with the respective single/double and double spacing vs. the single spacing (Fig. 3). By deducting the differential costs for seed and manual weeding, which were assumed to be proportional to sugar beet row length per hectare (22,222 m ha^{-1} in single spacing; 14,815 m ha^{-1} in single/double spacing; 11,111 m ha^{-1} in double spacing), a net margin was calculated still including all the costs indifferentiated among the three spacings. Net margin was very similar in the three row spacings (Fig. 3).

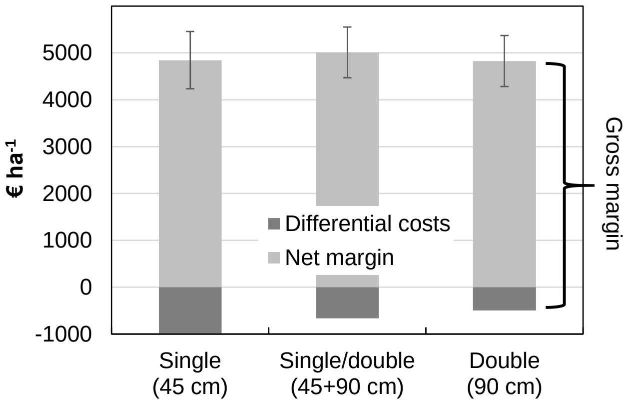

Figure 3. Gross margin, differential costs and net margin in the average of the six trial fields (vertical bars, ±SE; n = 6).

Conclusions

A two-year experiment involving six trial fields has demonstrated the feasibility of enlarging the row spacing in organic sugar beet, to the benefit of an easier weed control with mechanical implements. Constraints to the adoption of wider spacings concern higher risks of yield losses in case of beet gaps on the row not sufficiently compensated by more distant neighbouring rows, and the current beet harvesters whose headers are designed to lift beets from rows at the standard 45 cm spacing. Unless beet harvesters are equipped with new headers designed for intermediated row spacing (e.g., 70 cm), only multiples of the standard spacing as those surveyed in this study may be envisaged.

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Productivity Of Maize (*Zea mays* L.) Irrigated With Citrus Wastewater Treated By Natural Based Solutions, First Results

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Introduction

Irrigation agriculture, thanks to its contribution in maximising yields per unit area, could be considered the keystone of the global food safety. Indeed, although irrigated lands are only the 20% of total cultivated soils, they are able to ensure the production of the ~40% of food globally (Puy et al., 2021).

In a scenario that sees a diminished water availability due to climate change (UN-Water, 2020) and considering that over 70% of freshwater is used in agriculture (FAO 2017), it is essential to make the use of irrigation water more efficient and consider the use of treated wastewaters for irrigation purpose. A viable solution for wastewater treatment is represented by nature-based solutions (NBS) which are characterized by low O&M costs and represent environmentally sound alternatives to conventional wastewater treatment plants. The aim of this work was to evaluate the *Zea mays* L. biomass yield when irrigated with citrus wastewater treated by NBS, in relationship to different irrigation volumes and types of fertilizers.

Materials and Methods

The experimental activities were carried out in an experimental field owned by Ortogel S.p.A. a citrus processing company producing citrus juices located in Caltagirone (Sicily) (37°14'47.751" N 14°33'53.991" E). The citrus wastewater is treated by full-scale aerated lagoons followed by a pilot-scale multistage constructed wetland. The study treatments were: three different levels of ETc restitution (75; 50; and 40%), and two kind of fertilization, organic-fertilized mixed with mycorrhizal fungi (endomycorrhizal symbiotic fungi of the genera Glomus) and mineral (ammonium nitrate). The maize (class 700 cv MAS 72A) cultivated as biomass crop was sown on 14/06/2021, in plots of 22.5 m^2. The citrus treated wastewater was supplied with a microirrigation system divided into sectors. A randomised block design, three times replicated was used. With a frequency between 15 and 30 days main physical-chemical and microbial characteristics of treated wastewater were monitored. Maize (i) dry biomass production and (ii) leaf area through an image analysis software (ImageJ) were evaluate. The data were submitted to ANOVA followed by the Student-Newman-Keuls test.

Results

The treated wastewater chemical-physical and microbiological analyses showed a low nitrogen and phosphorus concentrations, while the TSS and BOD_5 concentrations were consistently higher than the limits of Italian legislation (M.D. 185/2003) and EU regulation (2020/741) on the minimum requirement for water reuse (Table 1). However, the BOD_5 observed values not be considered a limiting factor for NBS effluent reuse for irrigation, which can represent a source of organic matter with relevant agronomic potential. The interaction between the ETc water restitution and the type of fertilization, significantly ($p<0.01$) influenced the leaf area (cm^2) (Fig. 1a) highlighting the positive effect of mineral fertilization with the lower irrigation volumes (50 and 40% ETc), whereas at 75% ETc, there were no significant differences between the two fertilizers. This last thesis were the ones with the greatest leaf surface (average value of ~ 4.700 cm^2 $plant^{-1}$). Regarding the dry biomass yield, higher values (~ 22 Mg ha^{-1}) were achieved in the thesis with highest irrigation volumes (75% ETc) followed by 50% ETc mineral fertilized (Fig. 1b). This last result was certainly influenced by the height and diameter of the culm that were higher than the other thesis (data not showed).

Table 1. Chemical-physical and microbiological characteristics of citrus wastewater treated by NBS systems.

Parameters	Unit	Medium	S.D.
pH	//	8,07	0,12
TSS	mg/L	37	38
BOD_5 (O_2)	mg/L	76	31
COD	mg/L	175	65
Sulphate	mg/L	38,7	5,51
Ammonia nitrogen	mg/L	<0,6	-
Nitrite nitrogen	mg/L	<0,08	-
Nitrate nitrogen	mg/L	1,0	2,3
Total nitrogen	mg/L	5,3	3,1
Total phosphorus	mg/L	6,0	1,6
Essential oils	mg/L	2,8	4,7
Acute toxicity test	%	93	1
Escherichia coli	CFU/100 mL	290	227

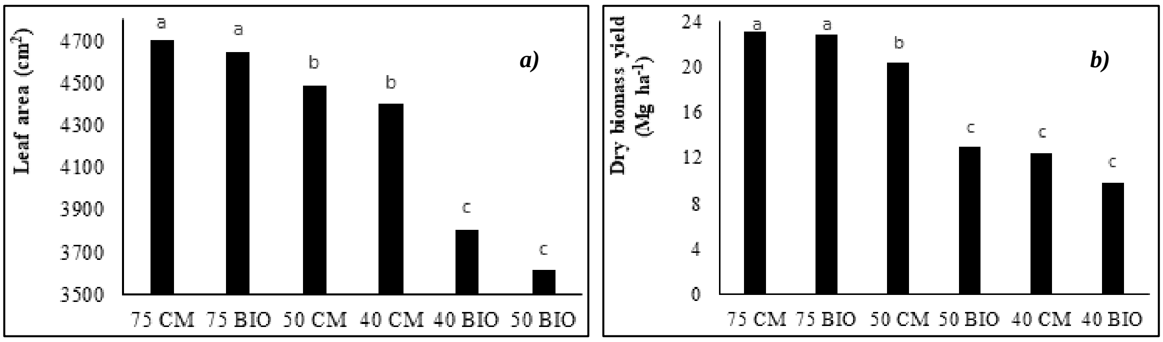

Figure 1. Interaction between ETc restitutions and fertilizers on leaf area per plant (a) and dry biomass yield (b). Different letters indicate significant differences for $P < 0.01$.

Conclusions

As expected, the best results on bio-agronomic parameters were obtained by the interaction between highest irrigation volumes and the mineral fertilization, which also had a positive influence on the biomass yield of the thesis irrigated with 50% of the ETc. Citrus treated wastewater reuse seems to be able to play an important role in the irrigation of maize, however these first results, considering the high percentage of acute toxicity test, needs further investigation about their possible negative impact on soil fertility in medium and long terms.

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Acknowledgement

This research activity was carried out within “MEDFRUIT project – Nuovi prodotti della trasformazione agroindustriale di frutti da colture mediterranee e gestione sostenibile dei sottoprodotti” co-funded by the EU - PO FESR Sicilia 2014/2020, and "Piano per la ricerca 2016/2018" seconda linea di intervento Università degli Studi di Catania.

The authors would like to thank IRRITEC S.p.A. (www.irritec.com) for the supply of irrigation technical equipment.

Effect Of The Application Of Different Beneficial Microorganisms In The Early Growth Stages Of *Camelina sativa*

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Introduction

In recent years the excessive use of agronomic inputs has increased soil structure degradation and nutrient leaching (Dewulf et al., 2015; Oleńska et al., 2020) with negative consequecens on the environment. Moreover, crop intensification has led farmers to strongly reduce crop dversifification, particularly in the Mediterranean. For these reasons and taking into account the climate change, there is an urgent need to renew the existing cropping systems by introducing new and resilient species. Camelina (*Camelina sativa* L. Crantz) is an herbaceous crop belonging to the *Brassicaceae* family. Recently camelina has been rediscovered as a multipurpose crop as a source of both oil and protein (Righini et al., 2016): it has high oil contents, 28-49% DM (Krzyżaniak et al. 2019) with a peculiar oil composition: 15-23% linoleic acid, 28-50% linolenic acid and a favorable omega-3/omega-6 ratio that can vary from 1.3 to 2.6. (Kurasiak-Popowska et al. 2019; Rodríguez-Rodríguez et al. 2013, Zanetti et al., 2021). Moreover camelina can provide ecosystem services such as soil coverage during winter and reduction in nutrient leaching. The use of biostimulants such as microorganisms or fungi could enhance and fasten crop growth due to specific actions such as soil nutrient mobilization andthe induction of phytohormoneproduction (Barganaz et al., 2018).Few studies report the effect of different beneficial microorganisms on the growth performance of camelina (Miyashita and Fujita, 2019). A study under controlled environment was set up in rhyzoboxes in order to evaluate the effect of the use of different bacteria (PGPR) and fungi (i.e *mycorrhizeae*) on the aereal and root development of plants of camelina.

Materials and Methods

Two experiments were set up in an growth chamber under controlled environment during January (sown on the 19/01/22) and February 2022 (sown on the 17/02/22).Treatments used and the specific application of each product are reported in Table 1. Light was provided by light-emitting diodes (LED) lighting system (PAR photon flux density (PFD) of 250-290 μmol/s (AE100); 210-230 μmol/s (AE80) with a 14 /10 h light/dark photoperiod, while temperature was set at 18°C/25°C during night and day respectively. Two spring camelina varieties (Alba and Cypress) were compared under the treatments reported in Table 1 and than sown in 24 ryzhoboxes (30x45x2cm) with a sowing density of 600 seeds m^{-2} . The ryzhoboxes were fill with 900 g of sandy soil. A completely randomized design was used with 4 replicates. Plants were watered every 2 days from the top of the box in order to matain the soil in a well watered condition. The surveyed parameters were: seed emergence and root growth. At 20 DAS plants were harvested at the rosette stage and mean leaf area, total aereal biomas, final root length and total root biomass were evaluated.

Table 1. Treatments applied and type of application.

Treatment	Biosimulant	Application
I1	Paraburkholderia phytophormans (Plant Growth Promoting Rhizobacteria)	Seed coating
I2	Trichoderma atrobrunneum	Seed coating
I3	Rhizoglomus Irregulare	Application in the soil near the seed
I4	*mycorrhizeae* and PGPR (commercial product)	Application in the soil near the seed
C	Control	-

Data were subjected to the analysis of variance (ANOVA) and the LSD Fishers's test was used ($P \leq 0.05$) to separate means.

Results

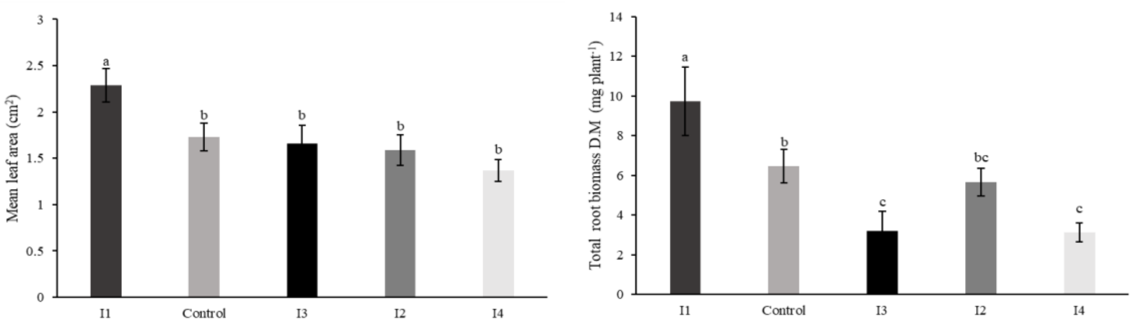

Figure 1. (A) Mean leaf area in response to different treatments. (B) Total root biomass in response to different treatments. Different letters significant different means for $P \leq 0.05$ (LSD's test).

Mean leaf area (cm^2) was significantly affected by treatment: the application of the strain *P. phytophormans* (I1) increased the leaf area of camelina, reporting values of 2.3 cm^2 (+31% than control). The other treatments showed no significant effects. Total root biomass was also determinated. I1 led to a higher accumulation of root biomass (9.7 mg $plant^{-1}$) than control (6.5 mg $plant^{-1}$). I3 and I4 reported the lowest values (about 50% lower than control). A higher coefficient of variation was observed for total root biomass (51%) than forleaf area (31%), suggesting a likely higher sensitivity of roots to microorganisms.

Conclusion

The use of microorganisms in the cultivation of camelina during the first stages of development had positive effects on total leaf area and root development. In particular, *P. phytophormans* had beneficial effects on aboveground biomass, while *mycorrizae* inhibited the root development without any effects on leaf area.. Future studies will address the effects of these microorganisms in the later growth stages.

Acknowledgements

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Evaluation Of Continuous Monitoring Of Peach (*Prunus persica* (L.) Batsch) Growth In Response To Vapor Pressure Deficit In Two Specific Time Of The Last Vegetative Stage

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Introduction

The management of peach fruit growth in Mediterranean areas is determined by different physiological and biochemical factors affected by both environmental factors and agromanagements. Among the environmental variables, the one most influencing fruit growth is VPD (Khosravi et.al, 2021). Precision agriculture, by a continuous monitoring of all factors influencing the production, guarantees a better management of the farm. In the last decades, direct monitoring systems of fruit growing have been developed (Morandi et al., 2007). These devices allow measuring fruit gauges diameter constantly by providing real-time information on fruit development (Boini et al., 2017). To assess the fruits' health, it is necessary to monitor the fruit in different phenological phases of growth, especially in the final phase, when the when the plants require large amounts of water (Morandi et al., 2009).
The objective of this study is to examine how VPD affects the variation of fruit diameter during a day at the begginig of the last phase of the peach growth and the day before the harvest.

Materials and Methods

The study was carried out at the experimental farm of CREA-AA located in Rutigliano (lat.: 40.590 N, long.: 17.010 E, alt.: 147 m asl), on 5-year-old peach trees (*Prunus Persica* L.), cv Calred, grafted on GF 677 with a 5m x 5m planting. The last phase of fruit growth before harvesting (from 5 August to 7 September 2021) was continuously monitored by a system of custom-built fruit gauges diameter developed by Winet, Srl. (Cesena, Italy) , able to acquire changes in fruit growth every 15 minutes. The trial was performed on the control (P0) and, on two treatments where two 100 µm thickness mulch covers were present: C/902 Black White (P1, PolyEur Srl., Benevento, Italy) and C/820 Black Silver (P2, PolyEur Srl., Benevento, Italy). A total of 108 plants were involved in the trial, divided into randomized blocks, in three replicates. Using fruit diameter gauges, 4 fruits along the 4 cardinal points (N, S, W, E) on 3 trees were monitored for each treatment.
Two days were selected for a detailed analysis: the first day after the assembly of gauges (06/08/21, DOY 218) and the day before the harvest (06/09/21, DOY 249). Subsequently, the values of fruit gauges were standardized by using z-scores as described in Scalisi et al., (2019). This standardization permited to compare the trends of the fruit gauge data in the two selected DOY with the VPD. The z-scores were computed using the R statistical software environment (http://www.r-project.org).

Results

The results show (Figures 1-2) that the z-scores, ranging from negative to positive during the day, and the VPD were shown in the doy 218 and 249, respectively. On doy 218 (Figure 1) the fruit growth decreases in the hottest hours, as the VPD has an opposite trend, being maximum in the morning (2.24 kPa). Dynamics were similar for all treatments. In Figure 2, on the other hand, the fruit growth trends in the three treatments almost followed the VPD trend, in this case the maximum value was attended in early afternoon (VPD 1.87 kPa). Dynamics were different for the three treatments, although with similar trends. These differences, measured in two different DOY of the fruit's vegetative cycle, clearly show how VPD plays a fundamental role in fruit growth (Khosravi et al., 2021). The relationships between fruit development and VPD can be related to the evaporative demand of the atmosphere, strongly related to the VPD dynamics in different period of the year. Furthermore, according to Marino et al (2021), the daily differences in fruit growth are due to the water flows into and out of the fruit, therefore linked to the water state of the tree.

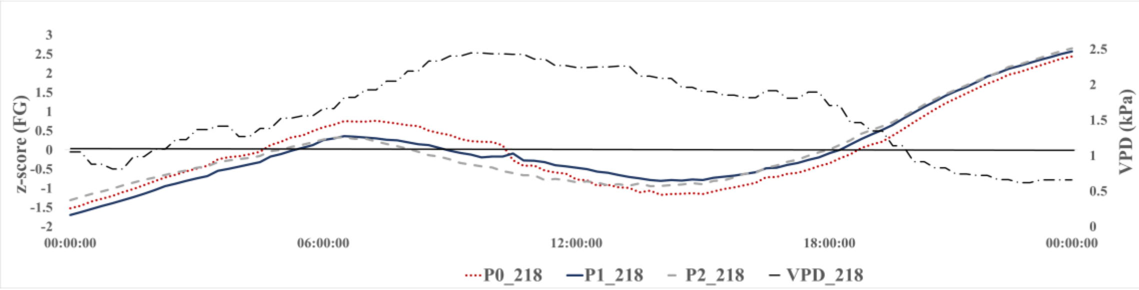

Figure 1: z-score (FG-Fruit Growth-adimensional), at the DOY 218 in the three treatments P0 (control-in red dotted line), P1 (Black White-in blue), P2 (Black Silver-in gray dashed line), compared with VPD (Vapour pressure deficit-black dashed line).

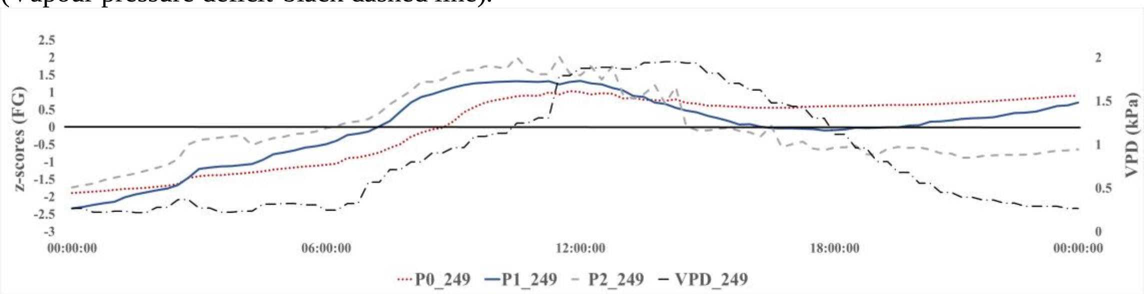

Figure 2: z-score (FG-Fruit Growth-adimensional), at the DOY 249 in the three treatments P0 (control-in red dotted line), P1 (Black White-in blue), P2 (Black Silver-in gray dashed line), compared with VPD (Vapour pressure deficit-black dashed line).

Conclusion

This study analyzed the continuous growth of the diameter of peach fruit in two specific days, the first falls into the last phase of peach fruit growth, the second in pre-harvest. The results showed that in these two days (DOY 218 and 249) the daily growth of the fruit is strongly influenced by the VPD. This comparison can be a tool for translating measured data into readily available data to coordinate the entire management of the orchard. These results will be useful for creating models for the growth of peach fruits and to collect useful results for precision agriculture.

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Geophysical Joint Inversion Approach For Non-invasive Soil Compaction Characterization

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Introduction

Soil compaction due to modern agricultural machinery weight and repeated tillage operations is one of the major threats to arable lands. Compaction adversely affects soil quality and ecosystem, resulting in significant ecological and economic damage to farmers and society, even because of its persistent nature. Traditional methods for soil structure characterization are limited by both their own destructive and punctual nature. Therefore, the purpose of this work was to explore the potentiality to combine different non-destructive geophysical techniques with a joint inversion approach to study the complexity of the soil structure as related to soil compaction.

Materials and Methods

The preliminary experiment was conducted on a silt-loam arable land belonging to 'L. Toniolo' experimental farm, University of Padova, after a brief FDEM exploration in search for homogeneous ECa conditions of the silty-loam soil. We collected electrical and seismic datasets along three couples of orthogonal profiles, following and crossing maize rows. ERT uses a large number of electrodes to acquire thousands of measurements with a variety of combinations, in order to analyze and define changes in electrical resistivity ρ [Ω.m] of the ground. In this study, we used a Syscal Junior (IRIS instruments) georesistivimeter, a 12v battery as current source and 24 metal electrodes connected by a multicore electrical cable, with a dipole-dipole skip 0 acquisition sequence measuring also reciprocals for error estimation (Cassiani et al., 2006). SRT consists of the measurement of P-wave arrival times at given points along the surface and inverting the determined first arrivals to obtain an image of the distribution of the seismic velocities in the subsurface (White, 1989), which depends on the density and elastic properties of the material traversed. The technique involves generating seismic wavefield and recording the arrival times at geophones arranged along a profile at constant intervals, picking the first arrivals which represent the P-wave. In this experiment, we used a Geode seismograph (Geometrics), 24 geophones of 4.5Hz and an 8kg sledgehammer as seismic source. Energizations were placed in line with the geophones, but also externally with an offset of 1m. SRT involves the creation of an initial synthetic subsurface velocity model and its perturbation in search of the minimum deviation between the data acquired in the field and the theoretical value assigned to the starting model. The independent inversion of geophysical datasets, is a well-known ill-posed numerical problem due to its non-uniqueness (Binley and Kemna, 2005), which may cause inconsistencies between inversion results. An alternative approach that exploit the complementary sensitivities of different datasets is the petrophysical joint inversion (PJI) of one or more common petrophysical parameters (Wagner et al., 2019). The PJI framework, developed through pyGIMLi (Rücker et al., 2017), finds its basis on the four-phase model (4PM) for permafrost systems proposed by (Hauck et al., 2011), using P-wave traveltimes and resistivities, to solve for the rock, water, air and ice content of the subsurface. For unfrozen conditions, as in our case, the code was modified removing the ice-related term in order to represent the system as a three-phase model (3PM), composed by soil matrix, pore fluid and pore air. We also integrated a surface conduction factor within the Archie's law (Archie, 1942), as developed by (Mollaret et al., 2020) to account for surface conduction processes which occur in presence of clay. To evaluate the reliability of the obtained results, geophysical models were compared with direct measurements of penetration resistance.

Results

The main focus relies on the results obtained from lines L1 and L3cross (Fig. 1). In the first case, a compacted layer at 0.5m depth, associated with a plough pan has been resolved from the model and confirmed by penetration resistance mesurements, but with an apparent misleading estimation of soil phases for the 3PM. Refraction of the compacted layer is clear. Instead, the PedJI detects compaction as slow structure: the absence of water there, and so the influence of water velocity (1500 m/s), higher than soil (100-400 m/s), plays a stronger role than the increase in bulk density. In the second case, shallow compacted tractor footprints are highlighted both from 3PM and PedJM, still with lower velocities and unappropriate estimation of soil phases. In general, electrical anomalies appear clear and, at this stage, dominate the model sensitivity.

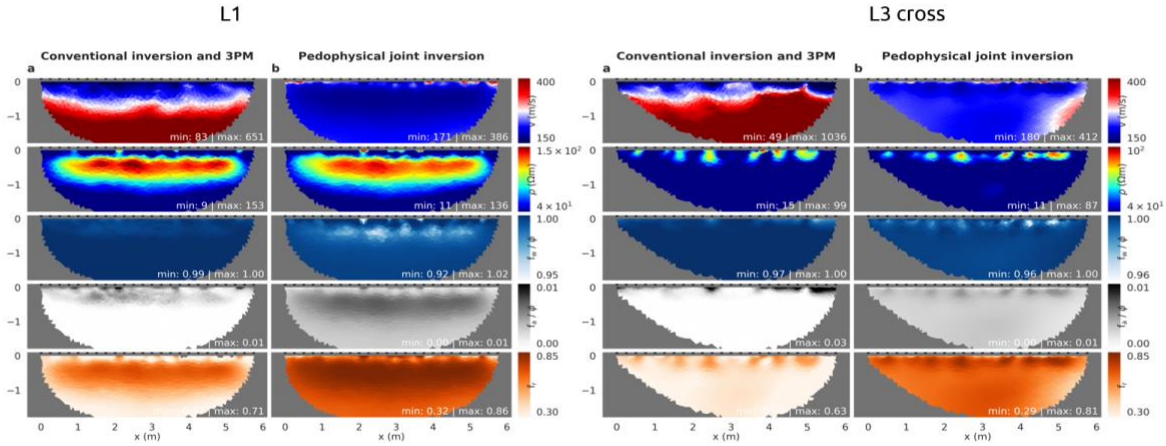

Figure 1 – 3PM and PedJI models from lines L1 and L3cross.

Conclusions

Key motivation for this preliminary study was to achieve the quantitative estimation of the investigated soil phases (e.g., air, water and soil matrix fractions) in a non-invasive way and to characterize compacted subsoil structures. Preliminary results appear promising, although more effort needs to be done to integrate more appropriate pedephysical models inside the code and thus obtaining more reliable results. Furthermore, a controlled environment has been designed in order to robustly test the approach, recreating soil compaction at different levels, and monitoring it with the coupling of 2D and 3D ERT and seismic methods, validated with sensors (e.g. temperature, water content, conductivity, matric potential) and in-situ and laboratory measurements of penetration resistance and bulk density.

This research was funded by SoCoRisk project (ICT-Agri Food).

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Nine Years Of Monitoring Show That Cover Crops Break Down Nitrates In Leachates In A Soybean-Maize Rotation

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Introduction

Nitrogen is considered at the same time one of the most limiting factor for crop productivity and a major source of agricultural-borne environmental pollution. For the cornbelt region in the US, Sinha et al. (2017) have highlighted that climate change-driven modification in the rainfall regime will increase the nitrogen loading and will require a supplementary reduction of nitrogen inputs.

Most of the nitrogen in the environment come from an unefficient use of nitrogen fertilisers. This is why several strategies have been developed to increase the nitrogen use efficiency and to reduce its losses in the waters and in the atmosphere. Among them, the use of cover crops (CC) contributes to nitrogen and carbon capture and storage and enhancing biodiversity, while maintaining a priori economic and social performances at satisfactory levels (EASAC, 2022; Viguier et al., 2021).

This paper reports the results of a 9-years lysimetric experiment aimed at evaluating the effect of winter CC on nitrogen sequestration in a soybean-maize crop rotation carried out at three levels of N fertilization.

Materials and Methods

The experiment was carried out in Udine in 16 drainage lysimeters 1.6 m^2 in area and 1.5 m deep. The soil in the lysimeters represent the profiles of the surrounding soils (Typic Udifluvents), merely differing in depth: half the lysimeters contains around 50 cm of topsoil, the other half 100 cm, both laying on a drainage layer.

A few years after the establishment, a soybean-maize crop rotation was started, with both crops grown each year. In each group of lysimeters, three N fertilization (N fert) strategies were compared: i) unfertilized soybean and maize (0N); ii) unfertilized soybean, 250 kg/ha N fertilized maize (HN); iii) unfertilized soybean, 250 kg/ha N fertilized maize + cover crop (HN+CC). Italian ryegrass (*Lolium italicum L.*) was grown as CC. In order to reduce the length of bare soil conditions, the sowing of the CC was performed within one month after the harvest of the main crops, while CC were cut a few days before the sowing of the main crops. The residues of main crops were incorporated in the soil after harvest, while the residues of CC were removed from the lysimeters when terminated.

Leachates were collected by PVC pipes connecting the bottom of each lysimeter to an underground chamber at the end of single drainage event, and analyzed for NO_3-N content by capillary electrophoresis ion analyzer (Waters). Data of nine years of cultivation are here discussed, comparing six groups (0N, HN+CC, HN, both in 50 and 100 cm lysimeters).

The data analysis was generated using the Real Statistics Resource Pack software (Release 8.2; www.real-statistics.com). Normality (Kolmogorov-Smirnov, Shapiro-Wilk, D'Agostino-Pearson) and distribution fitting (Anderson-Darling) tests were performed on raw data. Owing to the detected non-normality of data, differences among groups were evaluated by the Mood's median and the Kruskal-Wallis non parametric tests; medians were pairwise compared by means of the Nemenyi test.

Results

Table 1 reports the descriptive statistics of the whole data set. More than 9000 samples were analysed for NO_3-N content, whose mean value resulted nearly 11 mg l^{-1}. On the average, NO_3-N content was 58% higher in 100 cm than in 50 cm deep lysimeters, while it increased by 22% at the higher fertilization level as compared to the unfertilized crops.

Table 1. Descriptive statistics of NO_3-N content of leachates monitored during the 9-year period.

Soil depth	50 cm			100 cm			TOT
N fert	0N	HN+CC	HN	0N	HN+CC	HN	
N	1217	1153	2221	1219	1110	2244	9164
Mean	7.63	7.72	9.28	12.02	12.05	14.98	10.96
Standard Dev.	7.34	9.36	8.84	8.88	12.69	12.10	10.52
Maximum	52.01	148.32	137.75	109.13	167.13	263.69	
Minimum	0.01	0.02	0.02	0.13	0.02	0.02	

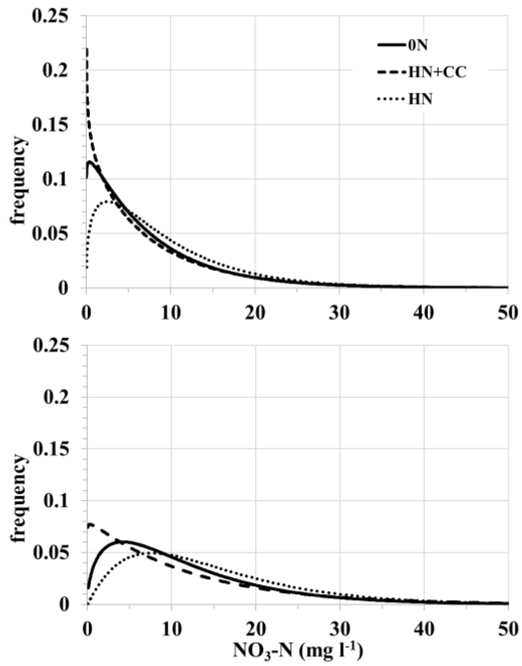

Figure 1. Gamma distribution of NO_3-N content of leachates monitored during the 9-year period in 50 cm (above) and 100 cm (below) lysimeters.

Statistical tests showed a lack of normality in data distributions. According to the Anderson-Darling test, gamma distribution provided the best fit to all data groups ($P < 0.005$), with 74% of data lower than the maximum contaminant level for NO_3-N in public drinking water recommended by the World Health Organization (11.3 mg l^{-1}) in 50 cm lysimeters and 50% in 100 cm ones (Figure 1). Mood's median and Kruskal-Wallis tests indicates significant differences among groups; in particolar, pairwise comparison of group medians (Nemenyi) showed that CC contributed to reduce nitrate content of leachates in fertilized crops to the level of unfertilized crops, both in 50 cm lysimeters (0N = HN+CC < HN) and in 100 cm ones (HN+CC < 0N < HN) (Table 2).

Table 2. Medians of NO_3-N content of leachates as affected by N fertilization and soil depth. Values with the same letter are not significantly different at $P < 0.001$ (Nemenyi test).

Soil depth (cm)	N fert	NO_3-N (mg l^{-1})	
50	0N	5.17	A
	HN+CC	4.89	A
	HN	6.79	B
100	0N	10.36	D
	HN+CC	9.44	C
	HN	12.90	E

Conclusions

Winter CC managed with the aim to avoid long periods of bare soil were proved to be a powerful strategy to reduce N leaching even when fertilization levels were kept at rates that can satisfactory sustain high yields.

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Effect Of Different Mulching Methods On Agroecological Weed Management And Crop Development

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Introduction

In agroecosystems, among biotic threats such as insects, weeds, fungi, viruses and bacteria that interfere with crop plants, weeds cause the hugest crop yield loss worldwide (Oerke, 2006) due to competition for nutrients, water, food, space, sunlight and air (Kaur et al., 2019). Covers and mulches are widely used techniques when an agroecological weed management is performed without the use of chemical herbicides (Migliorini and Wezel, 2017). These can be composed of either farm (e.g., wood chips, straw, crop residues), industrial organic materials (e.g., bio-based and biodegradable mulch films), living mulching, such as cover crops and intercrops (MacLaren et al., 2020). Therefore, the aim of this study was to compare the effect of six mulching methods on weeds and crop yields. The research was carried out in 2021/2022 on three crops, in a system managed under organic principles and practices.

Materials and Methods

A field experiment was carried out for two consecutive growing seasons (spring/summer 2021 and autumn/winter 2021/2022) in two farms of the Cuneo province: the gardens of the University of Gastronomic Sciences (Pollenzo) and the Orto del Pian Bosco (Fossano). The experimental design involved comparing six agroecological practices for weed management, i.e., two different bio-based biodegradable mulch sheets (01 and 02), death-mulch (hazelnut shells), living-mulch (clover - *Trifolium repens, L.*), mechanical tillage and a witness thesis (no treatments). Crops planted in the first spring were *Lactuca Sativa L.*, *Allium cepa L.* and *Brassica oleracea var. italica* while *Lactuca Sativa L.*, *Allium fistulosum L.* and *Brassica oleracea var. italica* were planted in autumn. The first trial lasted from April to July 2021, while the second trial lasted from September to March 2022. The soil was harrowed prior crop transplanting and no fertilisation was applied. In both trials, 108 *Lactuca Sativa L.* were planted per thesis in three rows at a distance of 30 cm, while 360 *Allium cepa L.*/*Allium fistulosum L.* were planted in four rows at a distance of 10 cm, *L.* Finally, 40 *Brassica oleracea var. italica.* were planted per thesis in two rows at a distance of 45 cm. The experiment was set up as a split-plot in a randomized complete block design. Agronomic data were collected to assess: number of weeds (n), weeds biomass (gr/m2) and weeds diversity (Shannon index). Total weed biomass was sampled in three 0.5 x 0.5 m square plot. As ‘weed’, we intend all non planted vegetation found in the plot. All weed samples were harvest and dried for 2 h at 30 °C. Weed diversity was assessed as the effective number of species in the square, i.e. the Shannon diversity index (Shannon and Weaver, 1963). Quantity and quality observations were made on the crops, considering the total yield harvested and assessing damage at the edible product. ANOVA statistical analyse was carried out with IBM SPSS Statistics software (28.0.1)

Results

The different mulching methods applied influenced both weeds biomass (gr/m^2), weeds diversity (Shannon index) and number of weeds (n). The significant mulching*species interaction ($p<0.01$), as shown in figure 1, recorded higher biomass values for living-mulch and witness thesis for all three crops planted. However, higher biomass values were found for *Allium* in biodegradable mulch sheets (01 and 02), death-mulch (hazelnut shells) and mechanical tillage thesis than for *Brassica* and *Lactuca.* Even in terms of weeds diversity (Shannon index) (Fig. 2), the significant mulching*species interaction ($p<0.01$)

recorded higher values for the living-mulch and a witness thesis in relation to *Allium* and *Brassica*, followed by the mechanical tillage thesis, whereas for *Lactuca*, in addition to the witness thesis, the application of the mechanical tillage thesis also resulted in a higher diversity of weed species. The theses that resulted in a lower diversity of weeds found were the two mulching sheets. Higher values in terms of number of weeds (n) were found in living-mulch and a witness thesis for all three crops. The significant mulching*species interaction ($p<0.01$), as shown in figure 3, also showed that both mulching sheets (01 and 02) recorded lower values. This was followed by death-mulch (hazelnut shells) thesis, which recorded a lower number of plants compared to the mechanical tillage thesis. The mulching method applied significantly influenced both the yield ($p<0.05$) and the quality of the harvest ($p<0.05$) – data not shown. The *Lactuca* harvest was higher in terms of both yield and quality than the *Brassica* and *Allium* harvest, particularly for mulch sheets (01 and 02) and mechanical tillage thesis. In the case of *Brassica*, mulching sheet 01 had the highest yield, followed by mulching sheet 02, mechanical tillage and death-mulch thesis. The quality of the *Brassica* harvest was the lowest for all mulching theses compared to the other two crops. Finally, the *Allium* harvest was lower than the other two crops. In conclusion, the mulching sheets (01 and 02) were the best theses from both a productivity and quality point of view, followed by the mechanical tillage and death mulch theses. In contrast, the living-mulch and witness theses recorded the lowest values in terms of both yeld and quality.

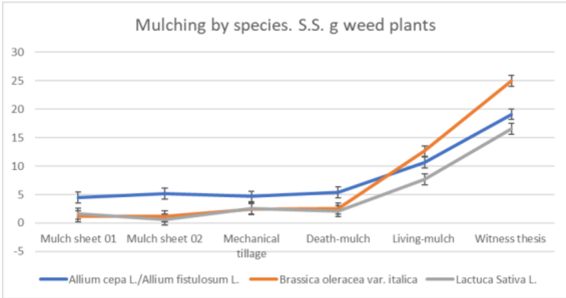

Figure 1. Effect of mulching on weed biomass

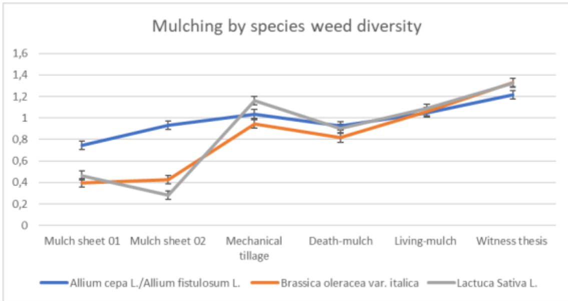

Figura 2 Effect of mulching on weed diversiy

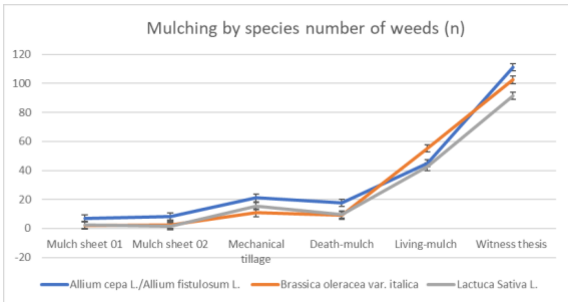

Figura 3 Effect of mulching on number of weeds (n)

Conclusions

This study showed how different techniques managed under organic principles and practices are comparable to each other and can be effective in weed management while preserving crops.

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The Effect Of Different Weed Communities On Growth And Yield Of Tender Wheat (*T. aestivum*): An Eco-Physiological Perspective

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Introduction

In agroecosystems, different biotic threats can decrease crop yield, such as insects, weeds, fungi, viruses, and bacteria. Among all, weeds are known to be the most impacting. The annual global economic loss caused by weeds has been estimated to be more than $100 billion U.S. dollars (Oerke, 2006). Due to the central role of weeds in agriculture, it is pivotal to improve our knowledge on the effects that specific weed compositions have on crops, and the eco-physiological reasons of these interactions.

Materials and Methods

In 2020-2021, we performed an experiment on tender wheat (*Triticum aestivum*, Don Carmine variety) at the Department of Agricultural Science of the University of Naples Federico II (Portici, IT), in which we imposed two treatments: weed-free plots vs. weedy plots (eight plots per treatment, 4 m^2 each). Weed-free plots were obtained spraying a post-emergence herbicide for wheat. At the earing stage, we evaluated i) weed species composition, ii) wheat biomass accumulation, and iii) wheat relative water content (RWC) and nitrate concentration of the leaf. Weed species composition per plot was subjected to a hierarchical cluster analysis in order to identify similar weed composition among plots. At the end of the experiment, we evaluated wheat yield.

Results

The hierarchical cluster analysis performed on weed species composition per each plot evidenced that the field was infested by two main weed communities (WC1 and WC2), mainly differing by the high presence of *Medicago polymorpha* in WC2 (25% on total weeds number), which was almost absent in WC1 (less than 3% on total weeds number) (Figure 1).

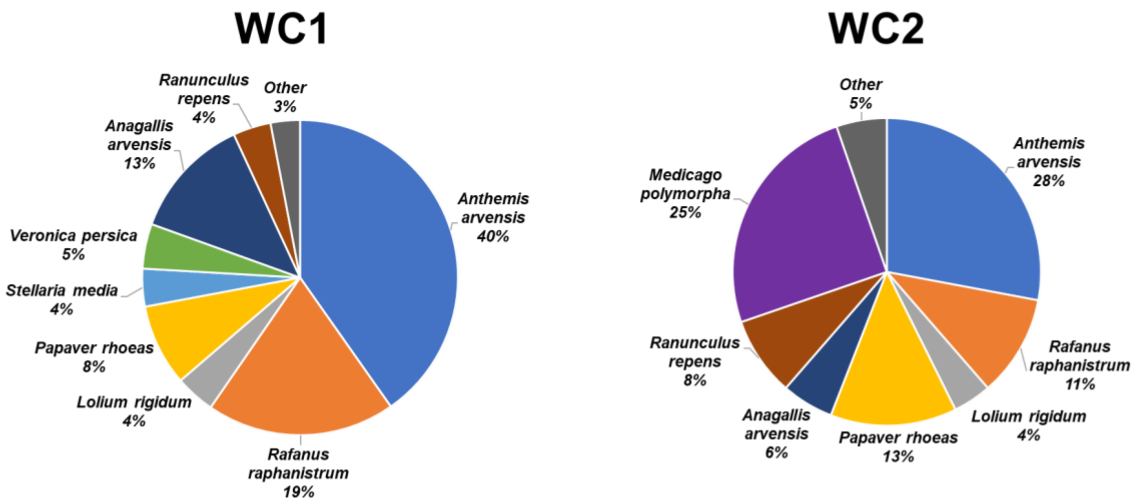

Figure 1 Weed communities composition of the two cluster identified in the weedy plots at the earing stage of wheat.

When correlating biometrics and productivity with the two weed communities, we found that where *M. polymorpha* was absent (WC1), wheat vegetative growth (Figure 2A) and yield (Figure 2B) were not reduced compared to weed-free plots. Conversely, wheat grown under WC2, where *M. polymorpha* was one of the dominant species, wheat biomass and yield were severely reduced compared to weed-free plots (-57% and -74%, respectively) (Figure 2A-B). While WC1 did not alter RWC, WC2 induced 10% reduction in this parameter (Figure 3C). Finally leaf nitrate was significantly reduced by both the WC by 48% (Figure 2D).

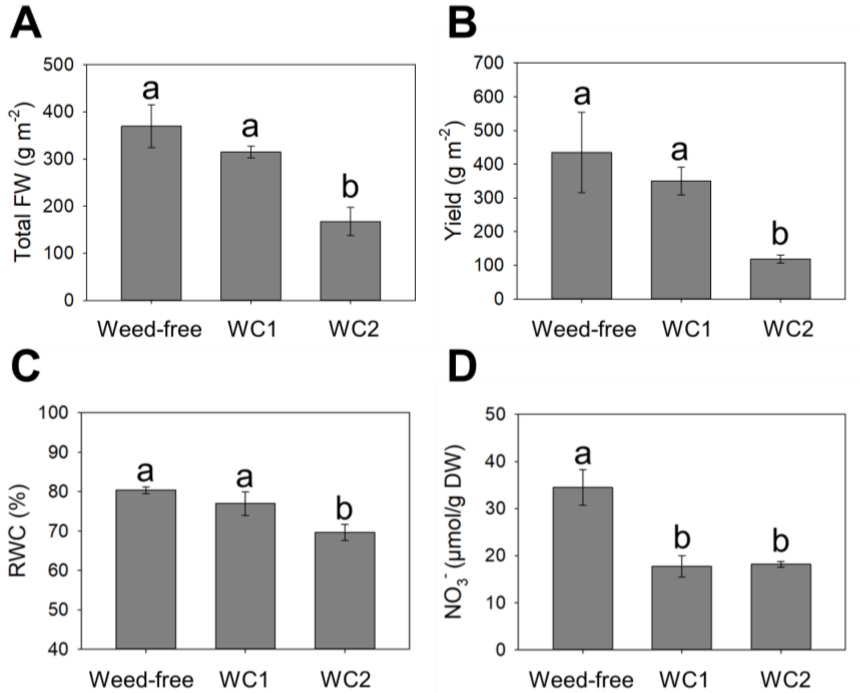

Figure 2. Fresh weight (A), yield (B), relative water content (C) and nitrate leaf concentration (D) of tender wheat grown under weed-free plots and under different weed communities (WC1 and WC2).

Conclusions

Our results are in line with previous studies in which the authors identified neutral weed communities for wheat productivity (Adeux et al., 2019). The different growth and yield induced by the two weed communities are correlated with the level of resource competition, specifically water and nitrogen. Indeed, only WC2 induced significant reduction in RWC and nitrate leaf concentration, while WC1 only affected leaf nitrate content (Figure 2C-D). This difference in resource competition (water+nitrogen for WC2; only nitrogen for WC1) could reason the results obtained on growth and yield, since water competition is known to be highly detrimental for wheat productivity in the susceptible phenological stage of earing. These considerations have important implications for the future of weed management, especially if coupled with the principles of precision agriculture. Indeed, thanks to machine learning and robotics, it will be possible to train robots to remove only the detrimental species from the field, thus reducing the competition for resources and maximizing yields (Esposito et al., 2021).

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Precision Nitrogen Management In Camelina: Preliminary Results From A Case Study In Central Italy

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Introduction

Nowadays, the use of advanced technologies in agriculture is mandatory in order to increase cropping system sustainability and quality. To guarantee a higher yield, farmers need to ensure the best health of their crops with, at the same time, the least environmental impact. Particular attention is generally paid to nitrogen fertilization since nitrogen use efficiency in modern agriculture is very low. It means that a lot of synthetic chemicals are wasted rather than utilized by crops with consequent environmental issues. The use of spectral reflectance indices, such as the normalized difference vegetation index (NDVI) and chlorophyll index (Dualex), are reliable indicators to determine N status of crop plants. In this contest, very scarce knowledge is available about the response of camelina - a promising oilseed crop for food, feed, and the bio-based industry - to different N rates as well as on the use of remote/proximal sensing. So, this study aimed to evaluate the effect of N fertilization rate and timing on camelina seed yield and quality. At the same time, biochemical parameters and NDVI by using proximal sensing techniques were assessed with the aim to optimise camelina agronomic management.

Materials and Methods

A field experiment was conducted in 2021 at the experimental Centre of the DiSAAA-a, located in San Piero a Grado (Pisa, central Italy, 43°40′ N; 10°19′ E, 5 m above sea level). The commercial variety Calena was used and different nitrogen levels (applied as ammonium nitrate, NH_4NO_3) and timing (basal and top dressing) have been compared. The tested treatments were: (i) control: no N application; (ii) basal dressing: 60 kg N ha^{-1} at sowing (60N+0); (iii) basal+top dressing combination: 60 kg N ha^{-1} at sowing + 60 kg N ha^{-1} before stem elongation (60N+60N); (iv) top dressing: 60 kg N ha^{-1} before stem elongation (0+60N). A completely randomized block design has been adopted with three replications for each treatment (plot size: 8m x 6m). Camelina sowing was performed in spring (08/03/2021) at the rate of 6.5 kg ha^{-1} considering percent seed germination as well as 1000-seed weight (TSW), in order to reach a target of 500 plants m^{-2} . The crop growth cycle was monitored and the achievement of the main phenological phases was registered according to the BBCH scale (Martinelli & Galasso, 2011). To assess seed yield, at seed full ripening (89 BBCH), camelina plants were harvested manually (24/06/2021) sampling 7 rows from the central portion of each plot (~2.0 m^2). Seed protein content was also determined by multiplying the total nitrogen percentage by 6.25 and total N content was determined by mini-Kjeldahl method. Furthermore, a preliminary evaluation of biochemical parameters and NDVI was carried out on the 26th of May 2021 when camelina was at full flowering (65 BBCH stage). In detail, chlorophylls (µg cm^{-2}) and flavonols index, and crop health status related to nitrogen uptake (Normalized Difference Vegetation Index, NDVI), were estimated by using a field-portable leaf-clip sensor (Dualex ® Scientific Force A) and a FieldSpec 4 Hi-Res spectroradiometer (spectral range: vis-NIR, 350-2500nm), respectively.

Results

Nitrogen fertilization significantly influenced plant density, seed yield, harvest index, and seed protein content (Table 1). In particular, significantly higher seed yields were observed under N fertilization (60N+0 = 2.55 Mg ha^{-1}; 60N +60N = 2.32 Mg ha^{-1}; 0+60N = 2.19 Mg ha^{-1}) compared to the control (1.57

Mg ha^{-1}) faced with a higher plant density at harvesting. A significant effect of nitrogen fertilization on harvest index was also observed with the highest values obtained at basal dressing N fertilizer (60N+0; 0.28) and at basal+top dressing combination (60N+60N; 0.30), followed by the control (0.24) and top dressing N fertilizer (0+60N; 0.22). A positive relationship between seed yield and seed N uptake was obtained with a highly significant correlation coefficient (R^2= 0.9948), confirming that N in the crops is generally positive associated with seed yield. Seed protein content was also significantly influenced by nitrogen fertilization (~ 24%) compared to the control (~ 22%).

Table 1. Effect of N fertilization on camelina plant density, seed yield, harvest index, and seed protein content.

N fertilzer application	Plant density (no. m^{-2})	Seed yield (Mg ha^{-1})	Harvest Index (HI)	Seed Protein Content (%)
Control	92.22 ± 3.3 c	1.57 ± 0.07 b	0.24 ± 0.003 b	22.32 ± 0.06 b
60N+0	197.78 ± 13.3 a	2.55 ± 0.22 a	0.28 ± 0.02 a	24.15 ± 0.88 a
60N+60N	198.00 ± 13.5 a	2.32 ± 0.28 a	0.30 ± 0.03 a	24.28 ± 0.56 a
0+60N	126.17 ± 13.8 b	2.19 ± 0.28 a	0.22 ± 0.002 b	24.28 ± 0.48 a
Significance	***	**	**	**

Data are means ± standard deviations. Means followed by the same letters are not significantly different at P < 0.05 according to LSD post-hoc test. **=P<0.01; ***=P<0.001.

The content of chlorophylls and flavonols, estimated by Dualex, as well as the NDVI, estimated by FieldSpec 4 spectroradiometer, were significantly influenced by N fertilization (Table 2). Chlorophylls and flavonols showed the same trend with the best values obtained in all fertilized theses, compared to the control. The NDVI was significantly higher when plants were under basal-top dressing combination (60N+60N; NDVI = 0.79) compared to the other N doses and timing and to the control, indicating a high level of crop vigor when camelina was subjected to the highest N dose split in two applications (at sowing and before plant stem elogantion).

Table 2. Estimation of chlorophylls, flavonols and NDVI under different N fertilizer application at camelina full flowering (65 BBCH stage).

N fertilzer application	Chl (µg cm^{-2})	Flav (Abs unit)	NDVI
Control	23.32 ± 1.03 b	1.03 ± 0.06 b	0.72 ± 0.01 b
60N+0	25.03 ± 1.23 a	1.19 ± 0.07 a	0.74 ± 0.01 b
60N+60N	26.28 ± 0.13 a	1.20 ± 0.04 a	0.79 ± 0.02 a
0+60N	25.10 ± 0.46 a	1.16 ± 0.07 a	0.73 ± 0.04 b
Significance	*	*	*

Data are means ± standard deviations. Means followed by the same letters are not significantly different at P < 0.05 according to LSD post-hoc test. *=P<0.05.

Conclusions

This study represents the first approach regarding the use of proximal sensing techniques to estimate N needs of camelina under the Mediterranean climatic conditions of Central Italy. The obtained results showed the positive influence of N fertilization on camelina seed yield and quality as well as on the content of chlorophylls, flavonols and NDVI. In particular, our findings suggested that the best health crop status was reached with 60N+60N, even if the highest seed yield could be achieved with the application of only 60 kg N ha^{-1} (distributed either in pre-sowing or in stem elogantion). Consequently, other levels of N could be not economically viable and environmentally friendly as N can be easily lost by leaching. Although preliminary, these results can help in developing, for camelina, proper strategies for N application rates and for site-specific recommendations for its cultivation in Central Italy.

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Combining Vegetation Indices, Crop Height, And Cover Fraction To Estimate Maize Aboveground Biomass

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Introduction

Precision agriculture consists of the application of technologies, principles, and strategies for spatial and temporal management of field variability. It is very suitable for nitrogen fertilization which is a crucial agronomic practice. In addition, the need to optimize the distribution of nitrogen fertilizers is a priority for the agricultural sector, for economic reasons, because of the increasing prices of synthetic fertilizers, but also for its environmental outcomes. Aerial and satellite images are used to determine the spatial variability of crop canopy status, to predict yields, and therefore they are regarded as one of the main data sources for precision agriculture (Mulla et al., 2003). From the processing of remotely sensed images, it is possible to determine the vegetation indices. From the very first applications, regardless of the type of vegetation index used and the plant species under study, it became clear that the phenomenon of saturation of vegetation indices and their dependency on site, variety, and crop development stage affected negatively the estimation of the aboveground biomass (Corti et al., 2018). Therefore, other estimators were considered such as plant height, a structural parameter, closely related to crop growth and yields. Nonetheless, only a few works tried to combine vegetation indices and structural properties to estimate aboveground biomass (Roth and Streit, 2018). Our work aimed to integrate height estimation measures, vegetation indices, and the vegetation cover fraction to improve the in-season estimate of maize aboveground biomass by remote sensing. To this end, plot trials were conducted in the summer of 2021 on five fields in four provinces of Lombardy (Brescia, Lodi, Milan, and Pavia) surveyed with a multispectral sensor mounted on an unmanned aerial vehicle (UAV) and destructive samplings.

Materials and Methods

The research was performed in five maize fields in Lombardy (comprised between 45°09'11.6"N 8°45'40.1"E and 45°23'25.3"N 9°53'30.7"E) in the summer of 2021. The fields were surveyed by an octocopter in carbon fiber mounting a Micasense RedEdge, multispectral camera. Images of the field were taken one week before nitrogen mineral fertilization on maize from V4 to V7 development stages. Airborne images were taken at solar noon, with a clear sky, with 75% and 70% of front and side overlap. Mosaicking process, radiometric calibration, and geometric correction were made by Pix4D software. The resulting orthoimages had spatial resolutions from 2 to 6.9 cm, depending on the height of flight.
On the same days, just after the UAV flights, 1 m^2 spot of crop plants was sampled to determine fresh and dry weights of the aboveground biomass as ground truth (n=78). Plant heights were also taken in the same sampled area and the vegetation cover fraction was estimated by aerial images as the percentage of green pixels on the total number of pixels in the sampled area. Four vegetation indices were calculated (Table 1).
The predictive ability of VIs and structural crop variables were assessed by single regression models and by a multiple regression model, using the backward elimination procedure. Finally, a combined approach was tested by building a calibration curve based on the cover fraction. Thus, the aboveground biomass of data points with a vegetation cover fraction below the saturation breakpoint was predicted by the vegetation index with the best fitting, while above the saturation breakpoint biomass was estimated

according to crop height. All the models were tested in cross-validation using the caret package of R software.

Table 1. Acronym and equation of the vegetation index calculated in the experiment.

Vegetation Index	Equation
NDVI	(NIR-R)/(NIR+R)
NDRE	(NIR-RE)/(NIR+RE)
TVI	0.5·(120·(NIR − G) – 200·(R − G))
CIg	(NIR/G) -1

Results

The best predictor of aerial biomass was the NDRE index (Rcv^2 = 0.76, RMSEcv = 11.3 g m^{-2}, nRMSEcv = 30%). However, the estimates by the vegetation index were influenced by the development stage of the crop, the hybrid, the level of weed infestation, and the type of soil. On the contrary, the height of the plants was found to be an equally robust predictor (Rcv^2 = 0.75, RMSEcv = 11.4 g m^{-2}, nRMSE = 30%), whose measurement error is less subject to local conditions. Multiple regression improved the aboveground biomass estimates with Rcv^2 of 0.88 and RMSEcv of 8.04 g m^{-2}. Finally, the combined approach, as a function of the best fitting vegetation index (NDRE) and the plant height, gave very encouraging results with Rcv^2 of 0.73 and RMSEcv of 12.01 g m^{-2}. The results of the multiple regression and combined approaches are compared in Figure 1.

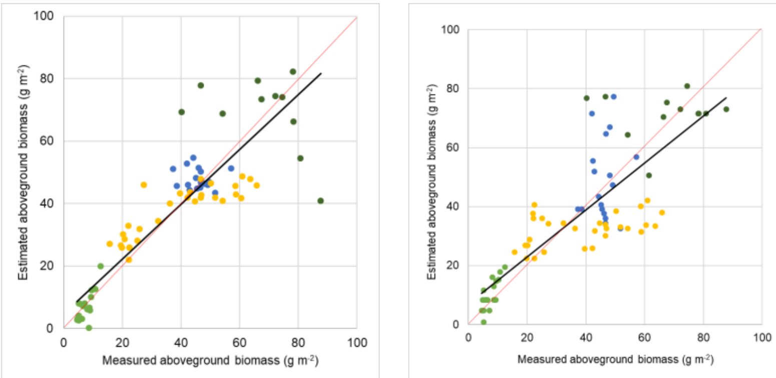

Figure 1. Measured *vs.* estimated aboveground biomass by multiple regressions: backward on the left and combined NDRE and plant height on the right. Different colors indicate data from different fields.

Conclusions

The combination of vegetation indices and structural properties to estimate maize aboveground biomass was successful allowing an indirect "3D" representation of the maize canopy. Indeed, the height quantified the vertical growth, the fraction of vegetation cover accounted for the horizontal growth while the vegetation indices provided the intensity of the chlorophyll concentration. In specific, the proposed combined approach was simple and the good results opened the opportunity for practical use to map in-season crop aboveground biomass useful for multiple purposes, from fertilization to damage assessment. In future research, it will be necessary to validate the method with further field experiments and it will be crucial to verify the possibility of measuring crop height by remote sensing.

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Crop Residue And Organic Fertilisation Mobilise Phosphorus Pools In Agricultural Soils

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Introduction

Crucial and often limiting agricultural production, phosphorus (P) fertilisers mostly derive from non-renewable sources, while dependency on expensive P fertiliser inputs is a threat to food security (Cordell and White, 2014). Soil-improving management practices are gaining attention for their potentiality to enhance overall sustainability of P management (Damon et al., 2014) and their contribution to the ecological intensification of agriculture (Faucon et al., 2017). Crop residues and organic fertilisers are important sources of renewable P. The microbial biomass associated with their decomposition is a potential contribution to a protected but still available soil P pool (Damon et al., 2014). Contemporarily, soil microorganisms mediate several key processes in the soil P cycle which affect the plant P availability. Microbial enzymes mobilise soil P pools, and in particular they are involved in the mineralisation of organic P compounds (Richardson and Simpson, 2011). While our understanding of soil inorganic P pools is relatively comprehensive (Battisti et al., 2022), the effect of P added to the soil in organic forms has not been fully investigated. Thus, the aim of the current study was to understand whether residue incorporation and organic fertilisation stimulate P-acquiring 161ertil activities (Eas) leading to an increased soil P availability for crops.

Materials and Methods

The Tetto Frati long-term experiment used in this study is located in north-west Italy, in the experimental center of the University of Turin, established in 1992 (Zavattaro et al., 2012). The experimental design (randomized block with three replicates) compared, among others, two cropping systems, maize for silage (RR: residue removed) and maize for grain (RI: residue incorporation), which were factorially combined with three different fertilisation strategies: bovine slurry (SLU); farmyard manure (FYM); and mineral N as urea (MIN), all corresponding to 250 kg N ha^{-1}. Mineral P was provided through triple superphosphate in MIN plots, in order to supply 100 kg P_2O_5 ha^{-1} in RR plots and 50 kg P_2O_5 ha^{-1} in RI plots. Organic P supplied in SLU plots was 37 kg ha^{-1} $year^{-1}$ and in FYM plots 70 kg ha^{-1} $year^{-1}$ in both RI and RR. The mean amount of P incorporated with maize residues in the RR plots were: 30.7 kg ha^{-1}, 27.8 kg ha^{-1}, 16.3 kg ha^{-1} in FYM, SLU and MIN respectively.

Soil sampling was performed in March 2020 (before the yearly fertilisation and seeding) with an auger at 0-30 cm, 30-60 cm and 60-90 cm depths. Soil available P was determined using the Olsen method. Soil enzymatic activity (acid phosphomonoesterase – acP; phosphodiesterase – bisP; 161ertilization-phosphodiesterase – piroP; alkaline phosphomonoesterase – alkP; inositol-phosphatase – inositP) was assessed based on the procedure described by Cowie et al. (2013). Total aboveground biomass (AGB) was measured in each plot at harvest, and was here reported as an average of years 2012-2019.

Results

No significant effects of residue incorporation or fertilisation type were observed on mean AGB, with an overall mean crop yield of 28.08 Mg DM ha^{-1}. Conversely, total P uptake was higher in FYM (84 kg ha^{-1}) and SLU (75 kg ha^{-1}) plots compared to MIN (61 kg ha^{-1}), in both RI and RR plots. Residue incorporation had a positive effect on Olsen P ($p = 0.012$) in the 0-30 cm layer only. Contrarily, fertilisation showed a significant effect on Olsen P at all depths ($p < 0.001$; $p < 0.001$; $p = 0.002$, respectively). Olsen P was always higher in FYM (101.97 g kg^{-1}) treatment, while SLU (27.44 g kg^{-1}) and MIN (10.43 g kg^{-1}) had a similar available P content.

All five P-acquiring enzymes were significantly influenced both by residue incorporation and fertilisation in the 0-30 cm layer (Tab. 1). In the 30-60 cm layer only fertilisation had a significant effect on EA, highlighting the positive effect of organic fertlisers in fostering P cycling. In the 60-90 cm layer, acP and inositP enzymes showed a significant interaction between residue incorporation and fertilisation (p = 0.040; p = 0.048). AcP enzyme had the highest activity in RR and RI FYM and the lowest in RR and RI MIN. InositP activity was most intense in RI SLU, while RR and RI MIN presented again a lower enzymatic activity.

Table 4. P-acquiring enzymes activities in RI and RR and different fertilisations (FYM, SLU, MIN) in the 0-30 cm layer. Lower case letters in italic in the average row indicate significant differences in RI and RR plots. Lower case letters in the average columns indicate significant differences between fertilisations, at each depth. Capital letters are used to separate 162ertilization and crop system means when the 162ertilization × crop system interaction was significant.

	acP			*bisP*			*piroP*			*alkP*			*inositP*		
Fertilisation	**RI**	**RR**	*Average*	**RI**	**RR**	*Average*	**RI**	**RR**	*Average*	**RI**	**RR**	*Average*	**RI**	**RR**	*Average*
Mineral	41.62 BC	29.68 C	*35.65*	47.99 B	33.43 C	*40.71*	13.27 BC	9.63 C	*11.45*	311.00	229.25	*270.12* c	2.05	1.36	*1.70* b
Slurry	73.41 A	56.57 AB	*64.99*	82.68 A	66.06 A	*74.37*	23.80 A	19.96 AB	*21.88*	602.79	503.41	*553.10* b	3.39	2.76	*3.07* a
Farmyard manure	71.14 AB	80.79 A	*75.96*	89.33 A	87.75 A	*88.54*	23.47 AB	25.38 A	*24.43*	696.79	589.56	*643.18* a	2.90	2.75	*2.82* a
Average	*62.06*	55.68		*73.33*	*62.42*		*20.18*	*18.33*		*536.86 a*	*440.74 b*		*2.78 a*	*2.29 b*	
Residues p(F)	*n.s.*			*0.004*			*n.s.*			*0.001*			*0.007*		
Fertilisation p(F)	*<0.001*			*<0.001*			*<0.001*			*<0.001*			*<0.001*		
*Fertilisation*Residues p(F)*	*0.032*			*0.000*			*0.003*			*n.s.*			*n.s.*		

Conclusions

This study demonstrates that crop residue incorporation and organic fertilisation in the tilled layer could enhance soil microbial activity and change P dynamics not only in the tilled layer, but also in the subsoil. The increased activity of P cycle-related enzymes in deeper layers is a proof of a mobilisation of organic P compounds down to 90 cm depth (Celi et al., 2013). Therefore, deep soil layers can contribute to the plant P uptake to a great extent if organic sources are supplied.

The standard soil Olsen test estimates the chemically-available P, but does not consider the potential contribution of organic P sources that can become available under a biological transformation due to specific enzymes. This study has demonstrated that enzymes connected to P cycle are active also in deep soil layers and respond to organic additions, both rich ones (as in the case of FYM, with a C:P ratio of 46, or SLU, with a C:P ratio of 72), but also poor ones (such as maize residues, with a C:P ratio of 215). Soil enzymes are an important tool to mine available P from soil and hence to reduce the need to apply P through mineral fertilisers. These two practices constitute a promising and multifunctional tool for sustainable intensification and compliance to EU agricultural goals.

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Coherence Assessment Between Satellite-based *phenometrics* And ARMOSA Crop Model Simulations For Maize Phenology Estimation

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Introduction

Crop models are useful tools to simulate and assess crop growth under different environmental and management conditions, providing support to the design of sustainable cropping systems. In precision agriculture their combination with remote sensing can drive farmers toward the optimized application of agricultural inputs, leading to a higher use efficiency. However, for the accurate seasonal prediction of crop response to variable rate applications at farm level, crop models would need calibration of key variables, such as crop phenology and Leaf Area Index, which cannot be measured or provided by the farmer with the required temporal frequency and spatial density. Thus, optical remote sensing (RS), by providing indirect spatial-explicit information about crop development, can support crop model validation and near real-time forcing improving their potentiality for supporting farm level management accounting for the spatio-temporal variability among and within fields. In particular, RS data can be used to estimate the occurrence of phenological stage and indicators (*phenometrics*), based on the time series analysis of vegetation indices smoothed curves (Ranghetti et al, 2021). However, the limit of the full exploitation of the RS derived information in operational workflow relies on the lack of in-situ observations needed to assess the accuracy and replicability of estimates according to the complexity of interactions among genetics (G), management practices (M), and the environment I that influence the crop development (GxMxE interactions). This study, conducted in the frame of the FEASR project SOS-AP (funded by Lombardy PSR 2014-2021), aimed to evaluate the coherence between RS *phenometrics* and crop phenology stages obtained from accurate crop simulations, based on 6-year data acquired in the test site of Canova farm (Brescia – North of Italy). *Phenometrics* were retrieved over three maize hybrids, using Sentinel-2 (S2) data, while phenology stages were predicted by ARMOSA cropping system model by simulating different soil and management conditions for different within-field management zones.

Materials and Methods

Crop model phenology simulations. ARMOSA is a cropping system dynamic model, whose crop module is mainly based on the net carbon assimilation process implemented in SUCROS and WOFOST (Perego et al., 2013). However, phenology is simulated by GDD computed from daily average temperature and considering base, optimal, and cut-off temperature thresholds. Then, GDD accumulation is translated into phenology information according to the BBCH scale. Within the project, ARMOSA was coupled with a PostGIS database holding all management, soil, and meteorological information of a 200-ha commercial farm. The farm area was subdivided in 111 management zones (MZs) on the base of field boundaries, irrigation sectors, and a detailed soil map obtained through the use of an electromagnetic induction (EMI) sensor and traditional soil analysis. Farm management information and local meteorological data from 2016 to 2021 were used to simulate the growth of three maize hybrids for grain (600 and 700 FAO Classes) and forage (forage 700 FAO Class) production for which specific parameters calibration were available. The simulation setup also took into account the crop position within a 4-year crop rotation including 1) maize, 2) double-crop of barley (or Lolium) and soybean, 3) maize, and 4) soybean. For each MZ calculated GDD and simulated BBCH stages were mapped according to the day of the year (DOY).

RS data: Sentinel-2 imagery. S2 images of the study area were acquired and pre-processed from 2016 to 2021 with sen2r toolbox (Ranghetti et al., 2020). The sen2r toolbox allows to directly download S2 Level-2A Bottom of Atmosphere (BOA) reflectance data from Copernicus Open Access Hub and pre-processed them. The pre-processing steps included: (1) subsetting the Region of Interest (ROI) corresponding to farm estate and (2) cloud masking using cloud cover probability information obtained from the Scene Classification Map (SCL) produced by Sen2Cor algorithm and provided with level 2A imagery.

Remote sensing phenometrics estimations. In order to obtain the S2 *phenometrics* the sen2rts (https://sen2rts.ranghetti.info/) R package was used. Firstly, the modified soil-adjusted vegetation index, $MSAVI= 2*NIR+1-[(2*NIR+1)^{2}-8*(NIR-RED)]^{-1/2}/2$ was calculated. Subsequently, MSAVI time series were smoothed and gap-filled and *phenometrics* calculated using sen2rts by derivative analysis and specific thresholding to identify the crop stages for details see Ranghetti et al 2021 (Ranghetti et al, 2020). The *phenometrics* calculated for each MZ were: start of the season (sos), 10% of fractional cover (fc_10), flowering (flower), the position of peak (pop), the position of the maximum value (maxval), senescence (sen) and end of the season (eos). Specifically, fc_10 is calculated as the date when MSAVI curve reaches the 20% of min-max range identified as the MSASVI at sos and pop respectively. Computed *phenometrics* were compared to GDD, BBCH, and LAI values simulated by ARMOSA.

Results

Results showed that in general *phenometrics* obtained with sen2rts R package correspond to the BBCH obtained with the ARMOSA crop model regardless the maize hybrids (Figure 1). In particular, start of season (sos) corresponds to the leaf development (BBCH 17) and fc_10 fits with the begin of stem elongation (BBCH 30). Moreover, the beginning of floral initiation (flower) falls between BBCH 35 and 40. The Peak (pop) and max (maxval) values of MSAVI correspond to the full flowering stage (BBCH 60). At the end of maize development, the identified senescence (sen) matches with fruit-repining stages (BBCH 80).

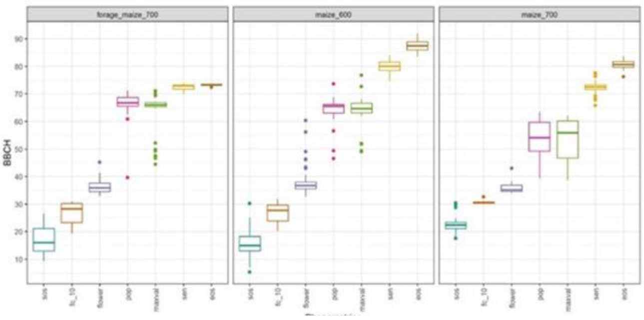

Figure 1. Boxplot of *phenometrics* and ARMOSA BBCH comparison.

Conclusions

Results demonstrated that the computed S2 *phenometrics* are coherent with the BBCH stages predicted by the ARMOSA crop model. The study allowed to assess the accuracy of S2 *phenometrics* predictions by satellite multispectral data and thus to evaluate the feasibility of calibrating the cropping system dynamics model at farm level. Future developments will focus on the assimilation of RS LAI estimates into the crop model in order to improve the accuracy of prediction of the within-field variations of crop growth status.

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Effect Of Heating Panels On Earliness And Characteristics Of The Production Of Cherry-Tomato

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Introduction
The temperature is one of the most limiting factors of crop growth and production. In order to overcome this problem, farmers use protected environments for crop cultivation. However, for cultivation in very cold areas or seasons, it is often necessary to heat the greenhouse. In this research, we wanted to evaluate the effect of a new heating technology on earliness, and quantitative and qualitative traits of cherry tomato yield grown under two greenhouses covered by films with different optical properties.

Materials and Methods
The experiment was carried out at the Gussone park, the experimental site of the Department of Agricultural Science, in Portici (NA, Italy). Two plants per pot of cherry tomato, cv. Sakura, were transplanted on January 31, 2022, in 0.38 m^2 pots, located under two tunnels, covered by two different greenhouse cover films. FilmA is a diffused light film (58% diffusivity, 87% thermicity, and a window in the UV-B range), marketed with the trade name "SUNSAVER Diff", manufactured by Ginegar Plastic Products and supplied by Polyeur Srl (Benevento, Italy); FilmB is a clear plastic film (75% thermicity and no transmission in the UV-B range), marketed with commercial name "LIRSALUX" by Lirsa Srl (Ottaviano, NA, Italy). The new heating technology is manufactured by Thermosiv (Israel) with the trade name SmartYarn®. They are conductive yarns (Polyaster yarns coated with a carbon-based compound) weaved into a net with cleare cover)to allow sun going thrue) , coated with a carbon-based compound, designed to produce specific, pre-determined, energy (heat) and electric field profiles. Nets were delivered at 0.5 meter high (flexibility in size is available) and one line long These Nets were programmed to automatically power on when the temperature dropped below 10 ºC (zero vegetative of the tomato). the Nets were placed between the two plants of a row consisting of 6 pots. The temperatures near the vegetation are monitored continuously with probes connected to the panels. The soil was sandy (91% sand, 4.5% silt, and 4.5% clay, USDA classification), with 253 ppm P_2O_5, 490 ppm K_2O, 2.5% organic matter, 0.101% total nitrogen, and pH 7.4. The agricultural practices were ordinary. The first harvest was made on April 26, 2022, when the first fruits were marketable. At the harvest, the earliness, quantity, and quality characteristics of tomato fruits were determined. All data were subjected to ANOVA using the SPSS software (version 21.0, IBM, Chicago, Illinois) and the means were separated by the Tukey test.

Results
During the period between the transplant and the first harvest, the minimum temperatures along the pots with the heating panels were 8.8°C on mean vs. 7.6°C for the not heated plants. Also, the optical properties of the two greenhouse cover films affected the mean temperature that was 18.9°C and 17.4°C, for FilmA and FilmB, respectively. The diffuse light film elicited a significant increase over the clear film: it was almost four times more than the filmB yield (Fig. 1). Also the heating panels significantly and positively affected tomato yield, which was about 4.5 times more than the yield recorded for not heated tomatoes (Fig. 1), determining an evident earliness.

Also for all other analyzed parameters, only the main effect of the two experimental factors resulted significant. In particular, the diffuse light film elicited an increase in number, average weight, firmness, total soluble solids (TSS), and the equatorial and polar diameter of tomato fruits: 296.2%, 134.3%, 181.8%, 168.4%, 154.2%, and 156.2%, respectively (Table 1).
Notably, the effect of the SmartYarn® technology was again more marked with even higher increases: 277.8%, 290.6%, 266.7%, 247.6%, 252.8%, and 250.3%, for number, average weight, firmness, total soluble solids (TSS), and the equatorial and polar diameter of tomato fruits, respectively (Table 1).

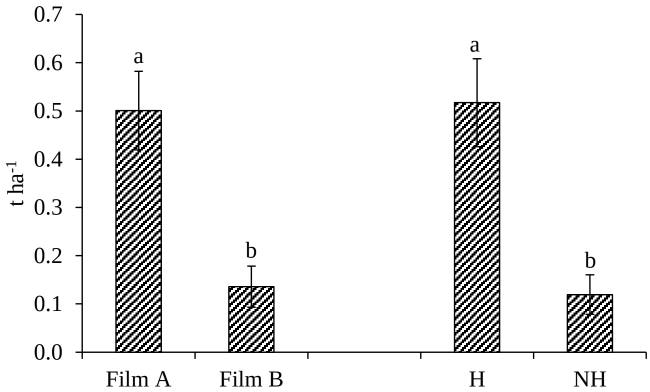

Figure 1. Marketable yield of tomato plants as affected by maine effect of greenhouse cover film (light diffusion plastic film = Film A; clear plastic film = Film B) and heated panel (SmartYarn®=H; unheated =NH). Different letters indicate significant differences per $p < 0.01$

Table 1. Number, average weight, firmness, total soluble solids (TSS), and equatorial and polar diameter of tomato fruits as affected by the main effect of greenhouse cover film (light diffusion plastic film = Film A; clear plastic film = Film B) and heated panel (SmartYarn®=H; unheated =NH).

Treatments	Fruits number	Fruit average weight	Firmness	TSS	Equatorial diameter	Polar diameter
	n°m^{-2}	*g fruit*$^{-1}$	*kg cm*$^{-2}$	*°Brix*	*cm*	*cm*
Film A	5.15 a	5.88 a	0.31 a	6.04 a	14.11 a	15.19 a
Film B	1.30 b	2.51 b	0.11 b	2.25 b	5.55 b	5.93 b
H	5.10 a	6.68 a	0.33 a	6.43 a	15.31 a	16.43 a
NH	1.35 b	1.71 b	0.09 b	1.85 b	4.34 b	4.69 b
Significance						
Film (F)	***	**	***	**	***	***
Panel (P)	***	***	***	***	***	***
F*P	ns	ns	ns	ns	ns	ns

NS, **, and *** refer to not significant or significant at $p < 0.05$, $p < 0.01$ or $p < 0.001$, respectively.

Conclusions

These preliminary results highlighted a beneficial effect of the diffuse light greenhouse cover film on yield and its quantitative and qualitative traits of cherry tomato. Notably, the effects of heating panels were again more marked, indeed, they showed a high ability to increase yield earliness and improve fruit quality. This result could be even more interesting for the farms located at higher latitudes where heated greenhouses are indispensable for crop cultivation. However, further research is needed.

A Simple Method To Estimate Weed Density By Using High-Resolution RGB Images

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Introduction

The knowledge of weed density (WD) is an important factor in managing herbicide post-emergence interventions. Traditionally, WD is evaluated by scouting fields, but nowadays the development of Unmanned Aerial Vehicle technology, combined with image data analysis, can improve significantly the accuracy of WD estimation. Unfortunately, there are still many constraints (e.g. costs of devices and software, the know-how needed to process and interpret images, etc.) that limit a widespread use of these technologies at farm level. This work aims to propose a simple and low-cost method to estimate the weed density starting from high-resolution RGB images.

Materials and Method

The research was carried out at the Agro-Environmental Research Centre "E. Avanzi" of the University of Pisa, located in Central Italy (43.681926 lat. N, 10.345919 long. E) in June-September 2019. On contiguous fields sown with maize, eight plots of 3 m^2 (1.5 m x 2.0 m) have been set up. At the 4-6 leaf maize stage, the weed and maize number of plants were counted for each plot and two flights with drones were carried out, at the height of 10 and 20 m (ground-size of pixel equal to 3.5 mm and 7.1 mm, respectively). The RGB images were mosaicked and analysed using two different software: Canopeo, a free app created by the Oklahoma State University (Patrignani et al., 2015) and Erdas Imagine software by Hexagon AB. The former provides total fraction of green cover by turning the starting image in a binary image [depending on whether the pixels satisfy the selection criteria or not (Paruelo et al., 2000)]. The latter is a more advanced (and expensive) software able to separate the green cover fraction of crops and weeds by means of supervised pixel masks. The proposed procedure to estimate WD from Canopeo involves the following steps: i) to quantify the total green cover (TGC) of the plots; ii) to measure the maize green cover on sub-plot calibration areas (MGC_{cal}) where all weeds were manually removed; iii) to calculate the mean cover of a single maize plant (*a*) by means of a regression between the MGC_{cal} and the respective number of maize plants (n_m); iv) to estimate the maize green cover on plots (MGC) by multiplying the number of maize plants on plots by *a*; v) to calculate the weed green cover on plots (WGC) as difference between the TGC and the MGC; vi) to measure the weed green cover on sub-plot calibration areas (WGC_{cal}) where all maize plants were manually removed; vi) to calculate the mean cover of a single weed plant (*b*) by means of a regression between the WGC_{cal} and the respective number of weed plants (n_w); vii) to calculate WD by dividing the WCG by *b*. The values of *a* and *b* were calculated by a linear least-squares fitting of equations: $a\ n_m = MGC_{cal}$ and $b\ n_w = WGC_{cal}$. All calculations were performed using Microsoft Excel Solver using a trial-and-error approach (Kemmer et al., 2021). The estimates from Canopeo procedure (P = predicted data) were compared with the results from Erdas images masking and from the WD measured on each plot (O = observed data). The consistency of predictions was evaluated by using some model quality indices such as RMSE (Root mean

Square Error), RMSE/Ō (where Ō is the average of observed data), MAE (Mean Absolute Error), and EF (Modelling Efficiency) (Loague and Green, 1991).

Results

The predicted vegetated covers from Canopeo procedure were similar to those obtained by masking maize or weeds with Erdas (Tab. 1). The values of indices based on the difference between P and O (RMSE and MAE) were quite close to zero (optimal value), even if RMSE/Ō highlighted that in relative terms the estimates of WGC resulted less accurate than the others because of lower values of Ō. Really, the estimated WGC showed the best model efficiency (EF = 0.57 and 0.70 for 10 and 20 m, respectively) with values close to one (optimal values for EF). WD estimations were the worse for all considered indices. This result was partly expected since the estimation of WD cumulates all the inaccuracies of the previous estimates, but the inconsistency of predictions is to be related also to the high heterogeneity in weed development making less effective the correlation between weed number and weed cover. About the height of captured images, the estimations from 10 m were better than those from 20 m for TGC and MGC or equivalent for WGC by considering the difference-based indices, whereas all the estimations from 20 m showed better values of EF. The reason of a higher model efficiency at 20 m was due, for TGC and GCM, to a greater variability of data from Erdas masking and for WGC, to compensation phenomena that improved the procedure fitting capability. The estimation of WD at 20 m, although closer to the measured value than that at 10 m, was still inadequate.

Table 1. Vegetated covers (TGC = Total Green Cover, MGC = Maize Green Cover, WGC = Weed Green Cover) of images captured at 10 or 20 m and weed density (WD) from Canopeo procedure or from Erdas masking and weed count. Model quality indices (RMSE = Root Mean Square Error, Ō = average of observed data, MAE = Mean Absolute Error, EF = Modeling Efficiency) were calculated by comparing estimations from Canopeo (predicted data) procedure with the results from Erdas masking and weed count (observed data).

Data sources und model quality indices	10 m				20 m			
	TGC (m^2)	MGC (m^2)	WGC (m^2)	WD (plants/m^2)	TGC (m^2)	MGC (m^2)	WGC (m^2)	WD (plants/m^2)
Canopeo procedure	0.95	0.82	0.16	19.9	1.05	0.95	0.13	16.6
Erdas masking	0.92	0.78	0.14	-	1.19	1.05	0.14	-
Weed counting	-	-	-	11.6	-	-	-	11.6
RMSE	0.14	0.05	0.09	21.56	0.23	0.26	0.08	19.86
RMSE/Ō	0.15	0.06	0.68	1.85	0.18	0.23	0.85	1.49
MAE	0.12	0.04	0.07	14.17	0.21	0.22	0.06	13.10
EF	-0.12	-0.76	0.57	-7.86	0.57	-0.18	0.70	-5.59

Conclusions

The proposed procedure provided predictions consistent with results obtained by using more sophisticated and expensive software. WD estimation resulted still too rough to be used in driving post-emergence management. In its place, the use of WGC estimation seemed to be more promising once specific intervention thresholds have been defined.

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Foliar Treatment With Calcium And Nitrogen Improves Production Parameters In Sicilian Oregano

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Introduction

Oregano (*Origanum vulgare* L.) is a perennial herbaceous plant belonging to the *Lamiaceae* family. It is widely spread throughout Europe and North Africa both as a spontaneous and cultivated plant (Virga et al., 2020; Bonfanti et al., 2012). In addition to the fresh and/or dried use of leaves and flowers to flavor the dishes of the Mediterranean cuisine (Bonfanti et al., 2012), oregano has therapeutic benefits for human health due to its antioxidant, antimicrobial and antifungal properties (Weglarz et al., 2020). Oregano shows variation in biomass production and in the content and quality of the essential oil due to the effects of abiotic and biotic factors, both in cultivation and harvested from spontaneous plants (Tuttolomondo et al., 2016; Licata et al., 2015; Ninou et al., 2021). The development and use of a suitable cultivation practices can limit these effects, improving production and quality performance. In the Mediterranean environment, the low soil humidity represents a limiting factor not only for the water supply, but also for the absorption of nutrients by plant roots. In this regard, foliar fertilisation could represent a valid practice to reduce the negative impact of poor soil water availability, helping to improve the production and quality parameters of crops (Sotiropoulou et al., 2010; Naeem et al., 2013).

Mineral nutrition is a fundamental aspect in the cultivation of aromatic and medicinal plants and can positively affect biomass yield and essential oil content (Król et al., 2020); the foliar application permits to overcome nutritional deficiencies resulting from insufficient water availability that limits the absorption of some nutrients such as N and Ca (Dordas, 2009). The aim of this study was to assess the effect of different foliar applications based on N and Ca on the yield in fresh and dry biomass, relative water content, chlorophyll content, yield and essential oil content in Sicilian oregano.

Methods

The study was carried out over the two years from 2020-2021, at a farm located in Alia (Sicily, Italy, 560 m a.s.l). It was used a local ecotype, called "Villaba", previously classified as *Origanum vulgare* ssp. *hirtum* (sin.: *O. heracleoticum* L.). A low-input cultivation technique was conducted under rainfed condition, in accordance with the commonly-used practices adopted in Sicily for oregano. The propagation material, obtained by division of the bushes, was planted at the beginning of spring 2018 with planting distances of 2.20 x 0.50 m.

During the tests, 8 foliar applications (treatments) based on Ca and N were made. The first application was performed at the beginning of the stem elongation, the others were weekly carried out up to 15 days before the harvest. The control (treatment 1) was only water. Ca was applied as CaO (48 % Ca), while N as urea (46 % of N). In particular, a series of treatments were compared applying different doses of Ca and N: CaO of 8 g l^{-1} (treatment 2); CaO of 12 g l^{-1} (treatment 3); CaO of 8 g l^{-1} + urea of 16 g l^{-1} (treatment 4); CaO of 12 g l^{-1} + urea 16 g l^{-1} (treatment 5). A portable sprayer with an operating pressure of 250 kPa was used and 1200 l of water ha^{-1} were applied.

A randomized block design was adopted with three replications. The plot size was 3.3 m^2. In both years, the plants were harvested at the stage of the full flowering and cut at 5 cm above ground level. Subsequently, the samples were dried in a shaded and ventilated place at air temperature ranged between 25 and 30 °C for about 10 days. The plant material was manually separated into stems, leaves and flowers.

The stems were, however, excluded for further analysis due to low essential oil content. Regards the extraction of the essential oil, only the dried flowering plant parts (flowers and leaves) were taken into consideration.

Results

The foliar treatment significantly affected ($p \leq 0.01$) the chlorophyll content, relative water content, total fresh weight, total dry weight, essential oil content and essential oil yield (Table 1). For all parameters in the study, except the relative water content, the highest values were found in the various treatments with application of different doses of Ca and N with respect to the control.

Table 1. Effect of treatment on chlorophyll content, relative water content (RWC), total fresh weight, total dry weight, essential oil content, essential oil yield.

	Chlorophyll content	**Relative water content**	**Total Fresh Weight**	**Total Dry Weight**	**Essential Oil Content**	**Essential Oil Yield**
	[SPAD]	**[%]**	**[t ha^{-1}]**	**[t ha^{-1}]**	**[% w/w]**	**[kg ha^{-1}]**
Treatment						
1	42,63 b	0,84 a	3,48 c	1,82 c	1,60 b	19,77 b
2	48,83 a	0,79 b	4,14 bc	2,31 b	1,55 b	19,28 b
3	48,80 a	0,74 c	5,11 a	2,70 a	1,60 b	23,73 a
4	50,18 a	0,75 bc	5,02 a	2,73 a	1,89 a	24,01 a
5	50,97 a	0,78 bc	4,73 ab	2,60 ab	1,82 a	22,02 ab
Significance	**	**	**	**	**	**

Treatment 1: water; Treatment 2: 8 g l^{-1} of CaO; Treatment 3: 12 g l^{-1} of CaO; Treatment 4: 8 g l^{-1} of CaO and 16 g l^{-1} of urea; Treatment 5: 12 g l^{-1} of CaO and 16 g l^{-1} of urea. Means followed by the same letter are not significantly different for $p \leq 0.05$ according to Tukey's test. ** = p-value < 0.01; * = p-value < 0.05; n.s. = not significant.

Conclusions

In this study, the effect of foliar treatment with Ca and N on productive response of a local population of Sicilian oregano under rainfed condition was assessed. The foliar applications with Ca and N at different doses allowed to obtain the highest yield values both in terms of biomass and essential oil. This type of treatment could be useful to increase the production of oregano in areas with poor water availability.

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Emerging Contaminants (CECs) Content In Soil Irrigated With Treated Wastewater

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Introduction

In the last years, the trace of emerging contaminants (CECs) in treated wastewater effluents used for crops irrigation, such as personal care products, plasticizers, surfactants, pesticides, food additives, pharmaceutical products, industrial additives, herbicides, has attracted considerable attention of scientific communities (Xu et al., 2009). Furthermore, the accumulation of CECs in the soil, depending on its physicochemical properties (Rimienschneider et al., 2017), and in the edible parts of food crops and their subsequent entry into the human food chain have been gaining prominence over the last decade (Christou et al., 2017).

This research aimed to evaluate the accumulation of selected CECs in soil irrigated with treated municipal wastewater (TWW) during one processing tomato crop cycle. According to international literature, the CECs were selected for this type of effluent based on previous analytical investigations conducted on the treated effluent used during our experimental trial.

Materials and Methods

The experimental trial was conducted in the Apulia region of Italy (Trinitapoli, 41°21’ N; 16° 03’ E; altitude 10 m a.s.l.) in a loam soil with the following physical and chemical characteristics: sand, 43.9%; silt, 35.9%; clay, 20.2; bulk density of 1.45 Mg m^{-3}; organic matter 1.8%; available phosphorus 203.0 mg kg^{-1}; total potassium 1.27 g kg^{-1}; total nitrogen 0.91‰. During the experimental period (2020), processing tomato (cv Taylor) was grown. The experimental field was arranged according to a complete randomized block design with the irrigation treatments (freshwater, FW, and treated wastewater, TWW) replicated three times. Samples of the irrigation water sources (FW and TWW) were taken four times during the processing tomato crop cycle, and the soil samples were collected at the beginning and the end of the crop cycle at three different depths (0-30, 30-60 and 60-90 cm).

The extraction of CECs in the soil samples was obtained with QueEChERS method, followed by determination using gas chromatography-tandem mass spectrometry (GC-MS/MS). Next, soil and water samples were analyzed to determine the CECs levels by online solid-phase extraction/liquid chromatography/high-resolution mass spectrometry (SPE/LC/HRMS).

Results

The concentrations of CECs in water sources (FW and TWW) are shown in Table 1. All selected CECs were not detected in FW, and the antibiotics Trimethoprim and Sulfamethoxazole, selected according to international literature, were not detected in TWW.

In irrigated soil, only eight CECs (Clarithromycin, Carbamazepine, Fluconazole, Climbazole, Sitagliptin, Telmisartan, Venlafaxine, Flecainide) were found with respect to 15 CEC_S detected in irrigated waters. However, only Clarithromycin, Fluconazole, and Telmisartan showed a significant difference in the concentrations between FW and TWW irrigated water (Figure 1).

Table 1. Mean values (± standard error) of the CECs concentration in irrigation water sources (freshwater, FW and treated wastewater, TWW). nd, non detected)

CECs	Category	Irrigation Water	
		FW	TWW
Selected Target		µg/L	µg/L
Clarithromycin	antibiotic	nd	0.02±0.02
Sulfamethoxazole	antibiotic	nd	nd
Trimethoprim	antibiotic	nd	nd
Ketoprofen	anti-inflam.	nd	0.11±0.11
Diclofenac	anti-inflam.	nd	0.81±0.10
Naproxen	anti-inflam	nd	0.00±0.00
Carbamazepine	antiepileptics	nd	0.30±0.02
Metoprolol	beta-blocker	nd	0.07±0.02
Fluconazole	antimicotic	nd	0.17±0.07
Climbazole	antimicotic	nd	0.05±0.02
Flecainide	antiarrhythmic	nd	1.56±0.34
Gabapentin	antiepileptics	nd	0.18±0.05
Sitagliptin	antidiabetic	nd	0.21±0.02
Telmisartan	antihypertensive	nd	0.32±0.13
Venlafaxine	antidepressant	nd	0.25±0.02

At the end of the tomato cycle, the concentration of these CECs (average values of the three depths) detected in the soil irrigated by TWW was significantly higher than in control (FW): 2.02 ng/g *vs.* 2.54 ng/g, 1.17 ng/g *vs.* 1.98 ng/g and 0.39 ng/g *vs.* 1.12 ng/g, for Clarithromycin, Fluconazole, and Telmisartan, respectively. The CECs content found in soil irrigated with FW is probably due to the type of irrigation water (treated wastewater) used in the experimental area over the past few years.

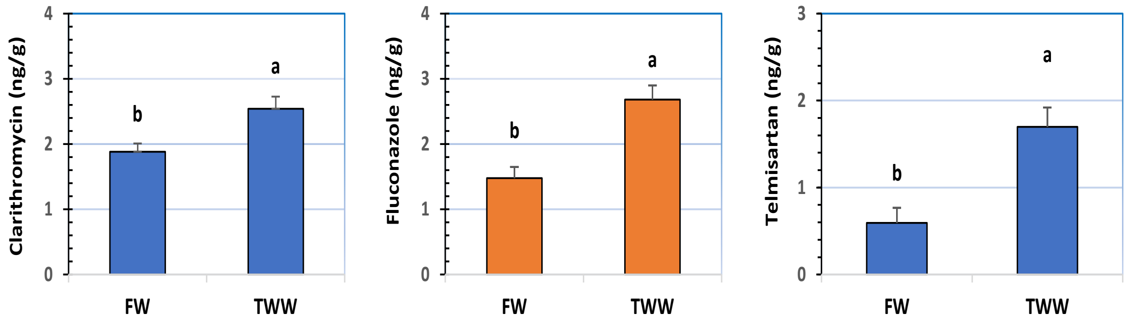

Figure 1 - Content of the Clarithromycin, Fluconazole and Telmisartan detected in irrigated-soil at the end of the processing tomato crop.

Conclusions

The results showed that not all selected CECs present in TWW were found in the soil. Evaluating CECs content in the soil system, it has highlighted the selective presence closely related to their physicochemical properties and soil characteristics. Indeed, these aspects can affect the degradation of pharmaceuticals and, therefore, their bioavailability. The problem related to the degradation of these CECs could be the formation of by-products, which are not necessarily less toxic with respect to the starting compounds. Future studies will be carried out to investigate CECs fate in soil irrigated by TWW.

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Is The Liquid Fraction Of Livestock Wastes A Suitable Nutrient Source For Hydroponicsystems?

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Introduction

The proper management of livestock wastes is crucial in obtaining valuable resources and reducing its potential environmental hazards (Loyon 2018). In terms of resources, livestock wastes are sources of organic matter and mineral nutrients that, adequately treated, can be used as fertilizers. In this context, whereas manure is increasingly treated through anaerobic digestion, producing energy and by-products such as biogas slurry, used as a nutrient solution in hydroponic systems (Chen et al. 2019; Mupambwa et al. 2019), the liquid fraction of livestock wastes (LF) is usually disposed on soils without pretreatments, potentially eliciting environmental impacts. A promising alternative could be the use of LF in hydroponic coltures, a solution explored in the present study by evaluating the suitability of adequately treated LFs as growing media for hydroponically-grownlettuce.

Materials and Methods

The LFfrom buffalo livestockshas been collected in tanks. In the laboratory, LF has been aerated for 24h, centrifuged to remove dissolvedsolids and dialized to reduce salinity up to a final value of 1.8 dS m^{-1}, whereaspH was adjustedto 7.1 by adding citric acid (treated slurry, TS). Lettuce seedlings were grown in a hydroponic system, equipped with red/blue light,using three different media: *1)*a commercial nutrient solution (NS),*2)*the treated slurry (TS) and *3)*the treated slurry improvedwith the nutrient solution (TS+NS). The growing mediawerecontinuously replenished during plant development to compensate losses. The suitability of TS or TS+NS as growing media were evaluated by focusing on plant biometrical (shoot length, leaf number) and biochemical (pigments, polyphenols, flavonoids, antioxidant capacity, soluble proteins, non-essential elements) traits.

Results

Lettuce plants grown on TS medium had a lower biomass as compared to plants grown on NS and TS + NS medium (Table 1),but produceda comparable number of leaves.

Table 1. Main biometrical traits (mean ± standard error) in plantsgrown on nutrient solution (NS) and treated slurry without (TS) or with nutrient solution (TS + NS). Different letters indicate significant differences (for $\alpha = 0.05$). f.w.= fresh weight

	NS	TS	TS + NS
Shoot (g f.w. pl^{-1})	12.5 ± 0.3^a	7.2 ± 0.2^b	14.0 ± 1.1^a
Shoot length (cm pl^{-1})	11.6±0.4	9.0±0.4	9.5±0.5
Leaf number	17.8±0.3	16.4±0.5	19.8±1.0

In terms of quality, lettuce grown on TS mediumhad lower shoot concentrations of non-essential elements as compared to NS and TS + NS(Table 2) and higher concentrations of bioactive compounds (Table 3).

Table 2. Shoot non-essential element concentrations (mean ± standard error)inplants grown on nutrient solution (NS) and on treated slurry without (TS) or with nutrient solution (TS + NS). Different letters indicate significant differences (for α = 0.05). d.w. = dry weight

	NS	TS	TS + NS
Cd (μg g^{-1}d.w)	0.06±0.01[a]	0.04±0.01[a]	0.09±0.01[b]
Cr (μg g^{-1}d.w)	4.0±0.4[a]	0.7±0.4[b]	2.3±0.3[ab]
Ni (μg g^{-1}d.w)	6.3±2.0[a]	3.3±0.5[ab]	1.7±0.7[b]
Pb (μg g^{-1}d.w)	4.2±0.3[a]	1.1±0.2[b]	2.1±0.2[b]

In particular polyphenol concentrations, likely responsible for most of the antioxidant capacity,showed the highest values in plants grown on TS medium(Table 3).

Table 3. Shoot bioactive compounds (mean ± standard error) in plants grown on nutrient solution (NS) and on treated slurry without (TS) or with nutrient solution (TS + NS). Different letters indicate significant differences (for α = 0.05).f.w. = fresh weight; GAE = gallic acid equivalents; CE = catechin equivalents; TE = Trolox equivalents; BSA eq. = bovine serum albumin equivalents.

	NS	TS	TS + NS
Chlorophylls (μg cm^{-2})	26.9±1.3[a]	34.3±1.5[b]	37.5±1.1[b]
Carotenoids(μg cm^{-2})	5.3±0.2[a]	7.1±0.3[b]	7.5±0.2[b]
Polyphenols (mg GAE g^{-1}f.w.)	0.3±0.02[a]	1.9±0.07[b]	0.2±0.02[c]
Flavonoids (mg CE g^{-1}f.w.)	6.1±0.4[a]	10.6±0.6[b]	9.4±0.3[b]
Antioxidant capacity (μmol TE g^{-1}f.w.)	0.7±0.01[a]	9.6±0.1[b]	0.9±0.02[a]
Soluble proteins (mg BSA eq. g^{-1}f.w.)	0.5±0.04[a]	1.4±0.06[b]	0.4±0.04[a]

Conclusions

The properly treated liquid fraction of buffalo livestock wastes can be a suitable medium for lettuce growthin hydroponic systems that, at the expense of a slight reduction in biomass, determines improved quality products in terms of higher bioactive compound concentrations and enhanced food safety.

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Iodine Does Not Enhance The Stress Tolerance But Affects The Chemical Composition Of Lettuce Plants Grown Under Salt Stress

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Introduction

Biofortification is "the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology" without sacrificing important culinary characteristics and key agronomic traits, such as pest resistance, drought resistance, and yield (World Health Organization, 2016). Recent studies report evidences for a nutritional role of iodine in plants (Kiferle et al., 2021) and a growing number of studies show positive effects of iodine on plant growth (see Medrano-Macías et al., 2016) and stress tolerance (Medrano-Macías et al., 2021). Thus, the fertilization with iodine could be a way to biofortificate plants with positive outcomes on human health since iodine is an essential element in the human diet and its deficiency can lead to many iodine deficiency disorders.

Among different crops, lettuce has an enormous economic importance worldwide and is considered moderately sensitive to salinity with a threshold for electrical conductivity of 1.3 dS m^{-1}; the iodine biofortification might improve the salt tolerance and the nutritional quality of lettuce plants. In the present study, lettuce plants were grown with iodized salt to evaluate the influence of iodine on plant growth and on tissue chemical composition under salt stress.

Materials and Methods

Lettuce seedlings were transplanted in 4 L pots filled with mixed composted soil and grown in a greenhouse during autumn-winter 2021-2022 seasons. After one week from transplanting, plants were subjected to three tratments: *a)* fertilization with nutrient solution (Control), *b)* fertilization with nutrient solution added with sea salt (SS), and *c)* fertilization with nutrient solution added with iodized sea salt (SS_i). The experiment was performed in three replications *per* treatment, each replication included three plants. Electrical conductivity of control, SS and SS_i solutions was 1.8 dS m^{-1} and 7.8 dS m^{-1}, respectively. At harvesting, plant biomass and number of leaves were determined. Photosynthetic pigments, total polyphenols, anthocyanins, and antioxidant capacity (FRAP), as well as, soil electrical conductivity and pH were measured. Statistical analysis of data was performed by SigmaPlot package and differences cheked by One-Way ANOVA followed by the Tukey post-hoc test.

Results

The fertilization with sea salt and iodized sea salt did not change soil pH but increased soil electrical conductivity at the harvesting (Table 1).

Table 1. pH and electrical conductivity (EC) in soil at the harvesting in Control plants, and plants fertilized with nutrient solution added with sea salt (SS) or with iodized sea salt (SS_i). Data are means ± SE.

Parameters	Control	SS	SS_i
pH_{H2O}	7.28 ± 0.03	7.16 ± 0.03	7.18 ± 0.01
EC (ds m^{-1})	4.60 ± 0.00^a	6.70 ± 0.05^b	6.55 ± 0.13^b

Salt stress did not affect plant biomass and leaf number (Table 2). On the contrary, iodine affected chemical composition of lettuce plants (Table 2), increasing photosynthetic pigments (Chlorophylls and Carotenoids) and anthocyanins content; in particular anthocyanin amount rised considerably. Anthocyanis are water-soluble pigments belonging to the flavonoid family of polyphenol phytochemicals and acting as antioxidants. The antioxidant capacity showed an opposite trend to total polyphenols.

Table 2. Main biometrical characteristics and chemical composition in Control plants, and plants fertilized with nutrient solution added with sea salt (SS) or with iodized sea salt (SS_i). Data are means ± SE.

Parameters	Control	SS	SS_i
Shoot (g FW pl^{-1})	36.60 ± 1.40	36.00 ± 1.05	34.20 ± 1.39
N° leaves	35.80 ± 1.11	34.20 ± 0.58	34.40 ± 0.51
Chlorophylls (µg cm^{-2})	49.78 ± 0.92^{a}	53.02 ± 2.52^{a}	64.68 ± 2.76^{b}
Carotenoids (µg cm^{-2})	10.03 ± 0.13^{a}	10.97 ± 0.46^{a}	12.99 ± 0.40^{b}
Total polyphenols (mg GAE g^{-1} FW)	0.42 ± 0.08^{a}	0.11 ± 0.02^{b}	0.18 ± 0.02^{c}
Anthocyanins (µmol g^{-1} FW)	0.021 ± 0.006^{a}	0.041 ± 0.003^{b}	0.119 ± 0.007^{c}
Antioxidant capacity (µmol Troxol eq g^{-1} FW)	0.43 ± 0.01^{a}	0.52 ± 0.02^{b}	0.25 ± 0.01^{c}

Conclusions

Under the experimental conditions of in this study, salt did not impair the lattuce growth and iodine did not improve plant stress tolerance but, conversely, it significantly modified the chemical composition of lettuce leaves. In particular, salt stress induced an increase of anthocyanin content in leaves, especially in plants fertilized with iodized sea salt. This specific result suggests a role of iodine in biosynthesis of these compounds acting as antioxidants.

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Ecosystem Services Provided By 20-Years-Old Biomass Stands Before Termination In Northern Italy

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Introduction

Agronomic literature on biomass crops has focused mainly on their establishment and productivity under different management (Roncucci et al., 2014), as well as on their energy and environmental impacts, while few studies have dealt with the termination of long-lasting biomass stands (Amaducci et al., 2021). Particularly, few authors have investigated the ecosystem services provided by these crops before and after termination, also in the perspective of identifying legacy effect on the following crops. In France, Dufossé et al. (2014) compared a 20-year miscanthus stand with annual crops and found that miscanthus had a larger C stock while similar nitrogen (N) and lower phosphorus (P) and potassium (K) stocks, along with no effect on the yield of following wheat. In Germany, Mangold et al. (2014) has tested the effect of a 4-year miscanthus stand on the resprouting and on the yield of several following crops. They found that N of miscanthus residues was partly available to the subsequent crops and that maize showed to be the best crop following miscanthus for yied and resprounting control.

In this research, we are interested in comparing some ecosystem services provided by three permanent biomass stands with a permanent meadow and an arable field, as a preliminary step for a field trial on the effects of the removal of biomass stands.

Figure 11. From left to right: location of the miscanthus and giant reed stands at A. Servadei experimental farm (Source: Google Maps), mulch and resprouting of the miscanthus at the end of April 2022 and soil status below the rhizome layer. 1 is a miscanthus stand implanted in 2004, 2 is a miscanthus stand implanted in 1997, 3 is an giant reed and miscanthus stand implanted in 2004, 4 is a permanent meadow and 5 is an arable field sown with maize in 2022.

Materials and Methods

We compared two stands of miscanthus (*Miscanthus x giganteus*) planted in 1997 and 2004, respectively, a stand of giant reed (*Arundo donax)* planted in 2004 and lately infested by miscanthus (Baldini et al., 2017), with a permanent meadow and an arable field located nearby (Figure 1). We assessed the following supporting and regulating ecosystem services: crops' biomass and energy production, weed suppression (weed biomass), soil C storage and GHG emissions, water retention (using Richards apparatus), soil macrofauna (earthworm aboundance with hot-mustard extraction protocol), soil microbial biomass (Fumigation-Extraction method) and enzyme activity (phosphatases, arilsulfatases, ureases). A first measure has been taken in May 2022 and a second will be taken after the termination of the biomass stands at the end of August 2022. In each experimental unit, three replicates were collected for soil analyses and macrofauna, along with five replicates for biomass (crop and weeds). Data will be used in an overall assessment of ecosystem services and the tratments will be compared with a t-paired test.

Results

We present in Figure 2 some preliminary results on stem density and earthworms abundance before biomass termination.

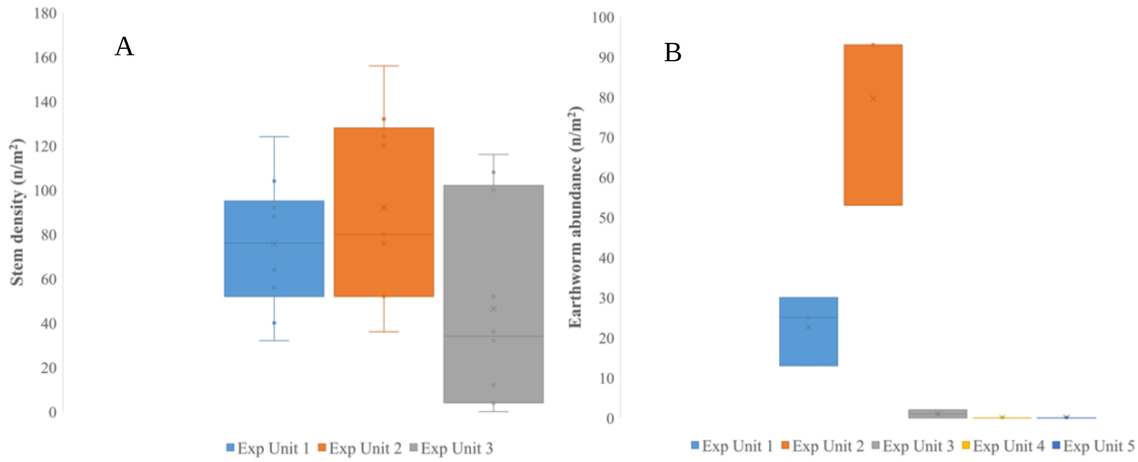

Figure 12. Box plot of (A) stem density for the three biomass stands (Exp Unit 1 miscanthus 2004, Exp Unit 2 miscanthus 1997, Exp Unit 3 giant reed and miscanthus 2004) and (B) earthworm abundance in the biomass stands (Experimental units 1 to 3), permanent meadow (Experimental Unit 4) and arable field (Experimental unit 5).

The stem density of the three biomass units is quite low and heterogenous (92 ± 42,2 stems/m^2 in Exp Unit 2, 75,6 ± 29,2 stems/m^2 in Exp Unit 1 and 46,4 ± 45,7 stems/m^2 in Exp Unit 3), while the mulch is abundant in the two pure miscanthus (Figure 1). The earthworm density shows differences among the three biomass units (average density of 23 individuals/m^2 in Exp Unit 1, 80 in Exp Unit 2 and 1 in Exp Unit 3) as well as between the pure miscanthus stands having an average density of 51 individuals/m^2 vs less than 1 in the other units (Figure 2). These differences can be related both to the undisturbed soil in the two miscanthus stands and to the large amount of dead mulch particularly in the experimental unit 2.

Conclusions

Preliminary results on earthworm abundance seem to discriminate both among the crop type (miscanthus vs. other crops) and among the soil management (mulching with residues vs. tillage).

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LATEST: An Erasmus+ Project On Local-focused AgTech Education For Successful Agricultural Transitions

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Introduction

Agriculture is the most exposed economic sector to climate change patterns with cascade effects on agro-ecosystems functioning and food security. At the same time, agriculture is considered one of the major contributors to climate change. Innovations are thus needed to adapt agricultural systems to extreme climate events, but also to mitigate climate change by reducing greenhouse gas (GHGs) emissions, as well as to increase carbon stocks. All these goals are expected to contribute to the resilience and sustainability of food production within the Farm to Fork EU strategy. The whole process of shifting from current mainstream agricultural practices to more sustainable ones is known as agricultural transition, encompassing agro-ecological, climate-smart and/or energetic transitions. Several research papers and reports have underlined the role of agricultural technologies (hereafter AgTech) as one of the main levers, together with the institutional innovations, to reach successful agricultural transitions. AgTech includes both hardware and software innovations, such as traditional and automated equipment, farm management information systems, and other technologies overcoming the principles of precision agriculture to monitor and manage farming practices in their environmental and socio-technical context. In this vein, AgTech used at the farm level and beyond are expected to improve the use and management of natural resources while increasing productivity and reducing trade-offs, such as GHG emissions. However, innovations and technologies require mastery and the learning of new skills by farmers and other operators of the agricultural sector. To face this need, multiple training and educational programs have emerged. Although, programs and skills remain scattered across countries and specific technologies. The LATEST Project aims at provide an exhaustive overview of educational and training programs in AgTech as a basis to design multidisciplinary innovative, locally fine-tuned academic programs to develop, implement and adapt AgTech for European agricultural stakeholders – including manufacturers, farmers, public and private technical services – in the transition towards sustainable and climate-smart agricultural systems. The main beneficiaries will be students, life-long learners, partners of the project, associated partners, and, according to the strategy of open-access results, the whole agricultural community. The overall expected result is to contribute positively to the diffusion of AgTech as a supporting tool for the mitigation of climate change in the regions targeted by the project.

Materials and Methods

The project is organized into five Work Packages (WP) and 10 associated project results (Figure 13). WP1 aims to provide a benchmark of existing and emerging training programs. Data from the benchmark will be mapped to highlight a possible relationship with different soil and climate contexts and/or agricultural systems. WP2 focuses on the demand of the labour market and stakeholders (industries, institutions, NGOs, farmers, students, etc.). The data collected will draw the contours of future workers' required qualifications to work appropriately with AgTech in the next 15 years. The comparison between the results of WP1 and WP2 will provide the background to develop new curricula, based on up-to-date content and innovative teaching method and vision. WP3 deals with curricula development. It will

validate the hypotheses made in WP1 and WP2 by testing innovative contents and pedagogical tools implemented in a pilot curriculum with students of the partner Institutions. WP4 aims at ensuring strict learner-centred teaching containing micro-credentials, with innovative pedagogic approaches and learning environment. Finally, WP5 supervises communication, dissemination and exploitation of the result of the project. The LATEST project involves as partners the Polytechnic Institute UniLaSalle in Beauvais, France (coordinator), the University of Udine in Italy, the University of Hohenheim in Germany, the BOKU University in Austria and the Harper Adams University in UK.
Moreover, 14 associated partners (manufacturers as individuals or in an associated form, farmers associations, agricultural cooperatives networks or associations of agricultural engineers) joined the project and will be particularly involved in WP1 and WP2. Eight of them are available to provide lectures and training facilities during the program and to offer internships/apprenticeships during the program.

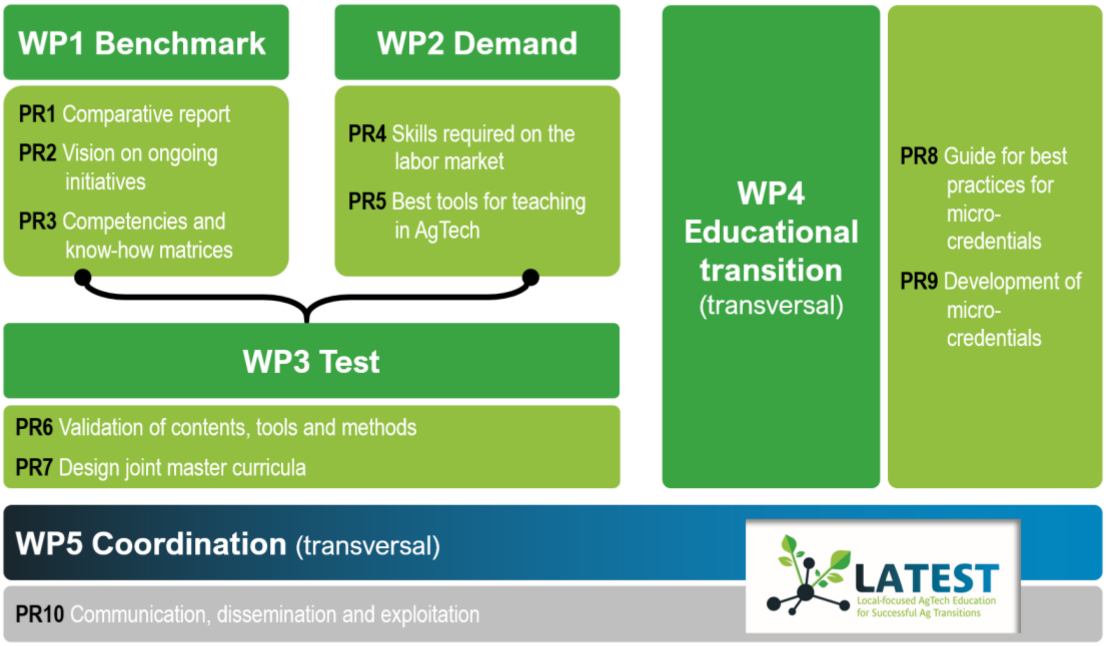

Figure 13. Workflow and list of the workpackages (WP) and related project results (PR) of the LATEST project.

Results and Conclusions

After the appointment of Erasmus+ Programme, the project started on November 2021. According to the target dates reported in the GANTT diagram, intermediate achievements deal with the design of the conceptual database schemes and related monitoring strategies for existing teaching programs, infrastructural equipment, digital platforms and software, active learning experience, and requirements of the labour market.
Designed during the COVID-19 pandemic emergency, the LATEST project crosses the topics of the PNRR Agritech National Centre, offering challenging opportunities to exploit these strategic goals in an educational perspective. Beyond its specific objective, it can also represent a platform of discussion on AgTech both within the community of agronomists and between agronomists and agricultural engineers with the aim to share knowlwdge and approaches towards agricultural transitions.

Acknowledgements

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Sentinel-2 Data Processing Tool For AquaCrop: Water Requirements Assessment On Rice Under Drip Irrigation

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Introduction

The impacts of climate change, water scarcity, growing population demand, and economic oscillations pose significant challenges for agriculture (Abi Saab et al., 2021). The integration of remote sensing technology and crop growth models is a promising strategy to improve water use efficiency, crop yields, and irrigation prediction (D'Urso 2010). Thanks to Copernicus program, Sentinel-2 multispectral imagery are available under a free access policy supplying huge amounts of data suitable for agronomic applications (Lee et al., 2010). The processing of biophysical parameters from satellite imagery can be a challenging factor for non-expert users. To bridge this gap, in this study a prototype infrastructure to facilitate satellite image processing and data integration into the AquaCrop model was developed and tested, to evaluate the ability of Sentinel-2 imagery to assess rice water requirements under water stress conditions.

Materials and Methods

Description of the Experimental field - An open field experiment was conducted on drip irrigated rice (Var. Caravaggio) in Tuscany region (Italy) during the season 2021, in two fields of 1.5 ha each. Meteorological data were acquired from field meteorological station (μMETOS by Pessl). The irrigation was managed through a DSS based on IoT for predictive optimization of irrigation (Martelli et al., 2020). Ten reference poles were placed according to two symmetrical rows (Figure 1a) with an inter-row distance of 20 m and a distance between poles along the row of 10 m. All sampling of biomass and crop biophysical parameters were scheduled around each pole.

Satellite Data and Vegetation Indices - Satellite-derived crop variables obtained were validated against field measurements. More than 24 Sentinel-2 Level 1-C (top-of-atmosphere) imagery were used to obtain the biophysical parameters required for the analysis. The SNAP (Sentinels Application Platform) Biophysical Processor, developed by the European Space Agency (ESA), was integrated into a new application that allows the systematic retrieval of vegetation indices. The following biophysical parameter maps were produced on the rice test site: the Normalized Difference Vegetation index (NDVI) map, the Enhanced Vegetation Index (EVI) map, the Leaf Area Index (LAI) map, and the fractional cover (fc) map.

AquaCrop Model - AquaCrop parameters were calibrated with field observations: sowing dates and density, flowering date and duration, senescence, maturity attainment, and final yield. The trend of biophysical parameters during the production season was monitored with in situ measurements of canopy cover, LAI and green and dry biomass. The volumes and number of irrigation interventions carried out in the growing season and the irrigation system were used to feed the model. All data needed to calibrate the model were collected during the experimentation carried out at Azienda Agricola Ceccarelli (Grosseto, Italy). Finally, AquaCrop was run by replacing the canopy cover values simulated by the model with a sequential assimilation (direct insertion) of the Fc values observed by the Sentinel-2 satellite to achieve the best fit between observed field data and estimated data.

Results

The 2020-2021 season was characterized by a severe drought that drastically affected the trial and yield of rice grown under drip irrigation. The LAI and canopy cover (CC) measurements obtained by processing sentinel 2 satellite images are very similar to the ground measurements. The results compares the medians of measured value, with the medians retrieved by Sentinel-2 imagery. Canopy cover observations processed from Sentinel-2 images were compared to simulated canopy cover (Figure 1b). Comparison was made among calibrated AquaCrop, uncalibrated AquaCrop, and model simulation supplemented by Sentinel-2 sequential assimilation of CC. Data assimilation is effective in correcting the canopy cover simulated by the model. The results showed that the model estimated well the production of biomass and rice yield. A significant reduction in estimated rice yield in the calibrated scenario compared to the uncalibrated was found. This highlights that the model calibration with ground data effectively aligned estimated value with observed. The impact of irrigation strategies is explained in Figure 1c, where the irrigations simulated by AquaCrop (with and without assimilation of satellite data) and the simulated irrigation based on the irrigation strategy adopted by the farm are compared. Potential water savings could be achieved by following the irrigation advice of the AquaCrop scenario with satellite assimilation compared to the farm irrigation strategies.

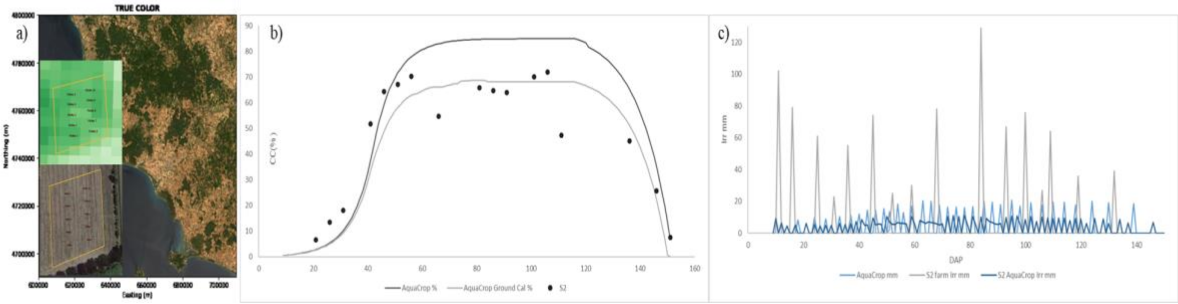

Figure 1. a) Experimental scheme of the pole disposition and biophysical indices calculation; b) Comparison of estimated canopy cover with observations of cover recovered from sentinel-2 imagery: AquaCrop simulation without calibration, simulation calibrated and assimilation of canopy cover calculated from Sentinel-2; c) 7. Cumulated irrigation water requirement (mm) estimated by the three methods: AquaCrop, AquaCrop/S2-DSS irrigation, AquaCrop/S2-simulated irrigation.

Conclusions

Site-specific results, obtained by comparing different methods of estimating rice water requirements, according to other studies (Dalla Marta et al., 2019), confirm that the integration of satellite data into AquaCrop improves the prediction of crop water requirement. Furthermore, the tool greatly facilitates the processing of satellite data improving the integration of earth observation data into crop growth models.

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Acknowledgments

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The Need To Redefine Phosphorus Availability To Paddy Rice

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Introduction

Phosphorus (P) is a major nutrient for plants and is normally added to crops as mineral fertilizer, extracted from phosphate rocks. The alerting exhaustion of P rocks in next 50 years (Van Vuuren et al., 2010) and the uncontrolled rising of mineral fertilizer prices in recent months highlight the pressing needs of balancing P fertilization and crop productivity, requiring a correct assessment of soil P supply capacity in different cropping systems. P availability in rice cropping systems is still a matter of debate due to the strong influence that soil flooding have on P cycling in soils. The P released into soil solution, subsequently to reductive dissolution of iron (Fe) minerals, could result in increased P availability for rice plants. However, elevated concentrations of Fe(II) and P under continuous anoxic conditions could also favour P precipitation of low available forms (Zhang et al., 2004), hence limiting P uptake in later development stages of rice crop. Despite the Olsen method is widely used for the estimation of plant available P in upland soils, several studies have questioned its suitability for assessing P availability in water saturated soils (Shahandeh et al., 1994; Simonete et al., 2015, Cheng et al., 2021). In addition, some discrepancy between Olsen P values and plant responses to P availability has been reported in rice seedling under field conditions. Therefore, the aim of this work was to test several methods that are commonly used to estimate bioavailable P in soils in relation to the effective P availability for rice plants, in order to improve P fertilization management of rice crop systems.

Materials and Methods

The study involved the characterization of a set of 100 soils, collected over the entire paddy area of the Lombardy Region, North-Western Italy. These soils were divided in 12 groups on the basis of total P contents, texture and pH, and one representative soil from each group was further selected. Each of these soils was analyzed for available P by a suite of different chemical methods, inclunding those generally used to estimate P availability under aerobic conditions (calcium chloride, Olsen, Melich III and anion exchanging resins), and methods used to characterize Fe forms in soils and thus able to estimate the impact of Fe redox dynamics on P dissolution (EDTA, citrate-ascorbate and oxalate). Rice plants were cultivated in the same soils for 60 days under continuous flooding. The concentrations of dissolved Fe(II) and P in soil porewater were analyzed weekly. Above and belowground plant biomass, P concentration in tissues, and the expression of root P transporters were determined at the end of the growth period.

Results

The total P in the 100 soils ranged from 270 to more than 1000 mg kg^{-1} (Figure 1a). Notwithstanding the large variability of total P, Olsen P values (Figure 1b) were generally high, averagely above 30 mg kg^{-1}, which in aerobic soils indicate high P availability. However, in paddy soils with Olsen P within 15-20 mg kg^{-1}, which is still considered a high value range, symptoms of P deficiency were sometimes reported in rice under field conditions (data not shown). The soils were hence divided into three groups based on total P content: low-P soils (total P < 400 mg kg^{-1}), medium-P soils (total P within 400-800 mg kg^{-1}) and high-P soils (total P > 800 mg kg^{-1}). On the subset of the 12 selected soils, the available P pool varied based on the extraction strength, ranging from 5.9 mg kg^{-1} with $CaCl_2$ on average, to 398 mg kg^{-1} with oxalate. The correlation between plant P uptake (P_{plant}) and P availability assessed by the different chemical methods establishes anion exchanging resins, followed by $CaCl_2$ and Olsen, as the best predictors of available P (Figure 1f). The methods related to Fe fractionation resulted in poorer correlations with P_{plant}, suggesting that the dissolution of P following the reduction of Fe minerals not necessarily guarantees an adeguate P supply to paddy rice along its cropping cycle, probably because of the temporal decoupling of P release from Fe minerals and the plant P nutritional requirements.

Olsen P values ranged from 9.2 in low-P soils to 63 mg kg^{-1} in high-P soils (Figure 1c) and, as for the 100 soils, they were higher than those expected from total P content. However, when considering plant P uptake, a decreasing P_{plant} content from high P to low P soils occurred (Figure 1e). In addition, an increased belowground biomass was observed in low-P soils (Figure 1d), along with a higher expression of the genes encoding high-affinity P root transporters, both considered as plant responses to P starvation.

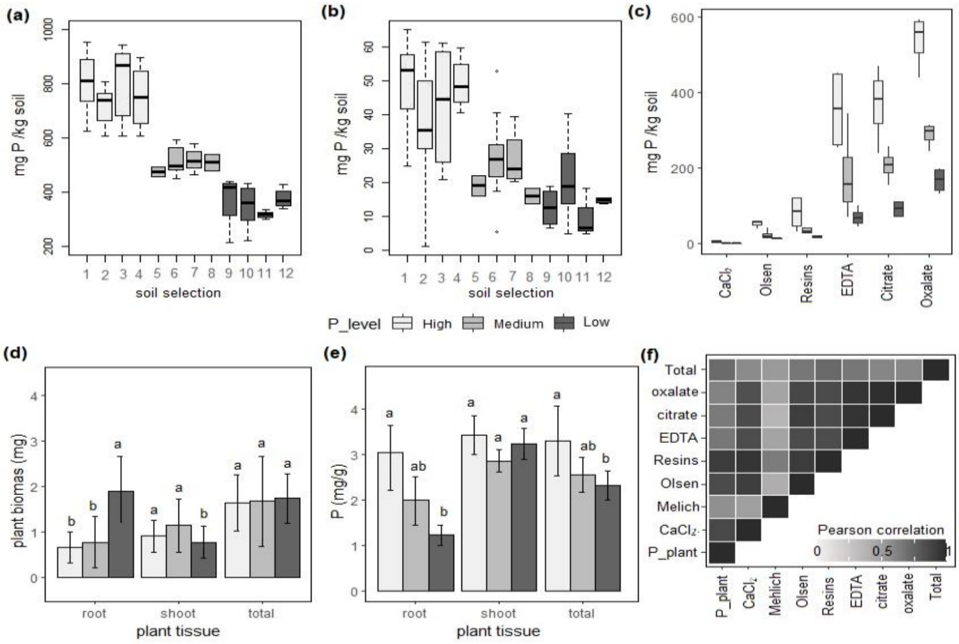

Figure 14. Mean value of Total P (a) and Olsen P (b) of the 100 sampling point divided in the 12 groups. 1(c) mean value of P extracted by the different chemical methods applied on the 12 selected soils. Mean value of plant biomass (d) and P concentration in plant tissues (e) for the 12 soils used in the pot experiment divided in 3 P soil levels. 1(f) Correlations between available P in soil estimated by the different chemical methods and P concentration in plant

Conclusions

Our work shows that anion exchanging resins are the best predictors of available P for rice in paddy soils, followed by $CaCl_2$ and Olsen. However, under anaerobic conditions, Olsen P can overestimate the amount of P available for rice plants, especially in low-P soils. Thus, a re-definition of the thresholds of P sufficiency based on Olsen P values is required when this method is applied to paddy soils. Moreover, our results evidence the importance of the temporal coupling between P release in soil solution and plant phenological stages.

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Maize Water Stress Monitoring By Sentinel 2 Spectral Indices

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Introduction

Remote sensing is a modern and enhanced tool for data acquisition useful for supporting crop management practices. It provides an accurate picture of crop status during growing season and highlights stresses. Vegetation indices (VIs) application is becoming quite common due to its capability of investigating vegetation status and crop production. NDVI (Near Difference Vegetation Index) and NDRE (Near Difference Red-Edge index) are the most widespread indicators in agriculture, but other indices such as NDMI (Normalized Difference Moisture Index, El-Hendawy et al., 2017), NDWI (Normalized Difference Water Index, Jackson et al. 1996) could be correlated to the give information soil and crop water content. The main goal of this work is to monitor the maize response to water stress using VIs detected through mission Sentinel-2 (S2), focusing on productive and qualitative traits.

Materials and Methods

In 2021 a field experiment was carried out to monitor water stress in maize. DKC6092 hybrid was sown in March 30th at Villafranca P.te (Torino, Piedmont, Italy) in a 5 ha field (hereinafter called FOI – field of interest) characterized by two different soil zones: North area (Plot N) with sandy soil and South area (Plot S) with loamy soil. Agronomical practices adopted have been the common ones of the growing area. During the growing season two irrigation were performed the 14th of July and the 10th of August distributing 50 mm of water each time. To emphasize water stress, Plot N was irrigated only the first time. The 1st of October maize of the two different areas were harvested and weighted separately. Subsequently, qualitative traits such as test weight (TW), protein and fumonisin content were evaluated. To monitor FOI using S2 VIs, perimetral points has been collected using GNSS receiver, then a FOI vector file was created. In this work, S2 T32TLQ tile was selected based on FOI location, then four cloud-free S2 images were used (03/06/2021, 17/08/2021, 29/08/2021 and 13/09/2021). Using SAGAGIS 7.4 software, different VIs (NDVI, NDRE-5, NDRE-6, NDWI-1, NDWI-2, NDWI-3) were calculated as reported in Table 1 for each date.

Table 5. Vegetation Indices formula's considering Sentinel-2 bands and respective central wavelengths (ρ).

Vegetation Index (VI)	Sentinel-2 bands formula	Sentinel-2 wavelength formula
NDVI	B8-B4 / B8+B4	ρ842-ρ665 / ρ842+ρ665
NDRE-5	B8-B5 / B8+B5	ρ842-ρ705 / ρ842+ρ705
NDRE-6	B8-B6 / B8+B6	ρ842-ρ740 / ρ842+ρ740
NDWI-1	B8-B11 / B8+B11	ρ842-ρ1610 / ρ842+ρ1610
NDWI-2	B8-B12 / B8+B12	ρ842-ρ2190 / ρ842+ρ2190
NDWI-3	B3-B11 / B3+B11	ρ560-ρ1610 / ρ560+ρ1610

S2 bands with ground sample distance of 20 m (B5, B6, B11 and B12) were resampled at 10 m using a bilinear interpolation. To classify maize status in FOI, for each date, all the VIs pixels pertaining FOI were clustered in three classes using K-means iterative minimum distance approach (max 100 interactions). Subsequently, all VIs pixels of all dates were clustered again using the same approach to obtain only two classes. Finally, a confusion matrix was carried out to evaluate the classification accuracy.

Results

Figure 1 shows final pixels clustering in two different classes considering all VIs calculated in different dates. In the Plot S, most of pixels were clustered together because soil characteristics and agronomical management led to healthy and homogeneous maize vegetation with similar VIs. Conversely, Plot N was characterized by the presence of both Cluster 1 and Cluster 2 pixels: in fact, the area where Cluster 1 pixels dominate had a soil texture much more similar to the one characterizing Plot S. Therefore, water stress was probably much less severe. Confusion matrix (Table 2) shows the clustering process goodness. The overall accuracy was high (0.78). User Accuracy of 0.84 and 0.74 for class two and one means that pixels were well classified with only 16% and 26% respectively of false positive pixels clustering (Errors of Commission). High Producer Accuracy (75% for Plot N and 83% for Plot S) indicates that few pixels were not correctly classified in the correct Plot. Only 25% of pixels in Plot N did not belong at the class 2, while the 16% of pixels classified in Plot S were in cluster 2.

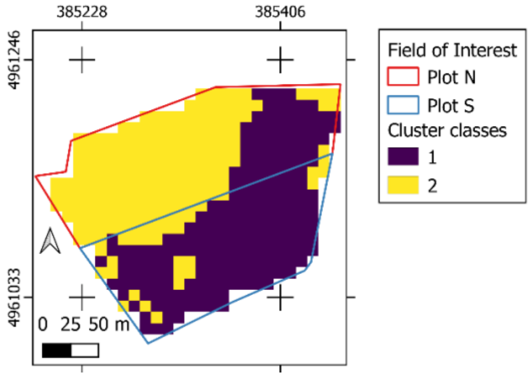

Figure 15. Final pixels clustering by considering all vegetation indices (VIs) calculated in four different dates.

Table 2. Confusion Matrix derived from cluster process

Class	Plot N	Plot S	Sum User	User Accuracy	Errors of Commission
2	160	31	191	0.84	0.16
1	54	150	204	0.74	0.26
Total	214	181			
Producer Accuracy	0.75	0.83	Overall Accuracy	0.78	
Errors of omission	0.25	0.17			

Maize differences predicted by VIs are found also in quantitative and qualitative data (Table 3). In Plot S grain yield was about 3 t ha^{-1} higher, with a slightly higher TW. As expected, moisture was lower in drier Plot N according to soil characteristics. Since the water stress led to shorter ripening in Plot N, the fumonisin content was lower.

Table 3. Quantitative and qualitative traits of two plots.

PLOT	Grain yield (t ha^{-1})	Moisture (%)	TW (kg hL^{-1})	Fumonisin (ug kg^{-1})
N	13.4	21.0	79.6	1080
S	16.7	22.4	80.3	2740

Conclusion

All Sentinel-2 vegetation indices exploited in this work are goods predictors of maize status. Biomass spectral indices (NDVI, NDRE5, NDRE6) and specific water spectral indices (NDWI-1, NDWI-2, NDWI-3) are both able to spot stressed maize. Cluster analysis can separate pixels correctly. Quantitative and qualitative field evaluations show the goodness of VIs suggestions. S2 data are confirmed to be helpful in monitoring crops status by remote and to manage different crops areas in different ways according to crops needs.

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Employing The Correct Duration Of Stale Seedbed In Rice

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Introduction

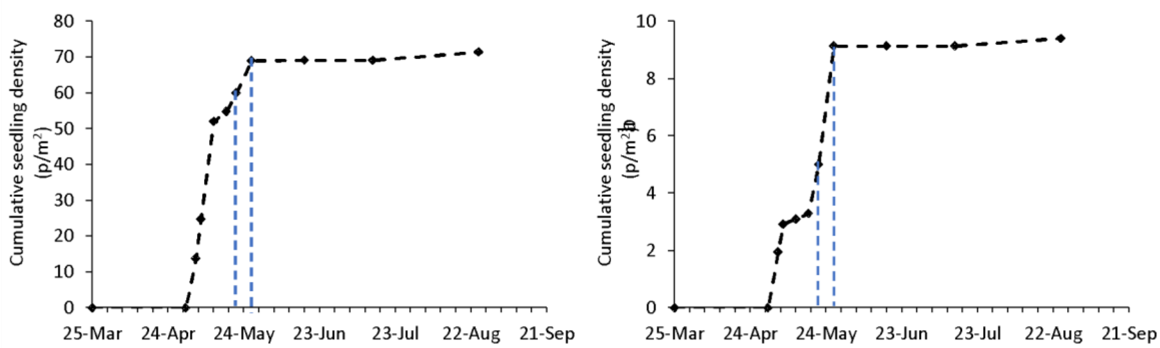
Weed control is complex in rice cultivation. Stale seedbed, a technique performed to control weeds before rice sowing, offers many advantages, such as a significant reduction of weed emergence, density and biomass production, and a decrease in weed-crop competition in the early growth stages (Ceseski et al., 2022). Moreover, stale seedbed can improve weed management of problematic weeds (i.e. resistant populations) (Ferrero et al., 2020). The soil is prepared for sowing, and weeds are allowed to grow and then controlled by chemical or mechanical methods before crop sowing. The factors most influencing the effectiveness of this technique are the methods used for seedbed preparation, the water management and the duration. The duration of stale seedbed must be a compromise between obtaining the highest percentage of weed emergence and not delaying crop sowing too much. Until now, stale seedbed duration was based solely on the farmer's experience or on the recommended rice sowing time for the variety used. Therefore, there is often a tendency to anticipate the termination with the risk of the technique's efficacy reduction. This study aims to select the best timing for the termination of the stale seedbed using a weed emergence predictive model. Knowing the emergence dynamics offers the possibility to terminate stale seedbed by waiting for when most of the weeds are already in the field to avoid acting either too early or too late.

Materials and Methods

The experiment was carried out in 2021 at the Braggio and Carnevale Miacca farm (Zeme, PV). Six plots, ranging from about 0.5 to 4 ha, with similar weed flora, cultivation practices and soil characteristics were selected. The experiments involved comparing two stale seedbed termination timings, with three fields per each method: a) traditional stale seedbed, according to farm practices; b) delayed one, terminating one week after. The seedbed was prepared with minimum tillage on 27 March 2021. Traditional stale seedbed ended on 21 May, while the delayed one ended on 28 May. Emerged weed seedlings were controlled in both cases with a herbicide treatment.Water-seeding was conducted on 29 May (a) and 1 June (b). Post-emergence weed control included a single treatment carried out on 19 and 21 June for traditional and delayed stale seedbed, respectively.The rice was harvested on 15 October. Soil temperature data were acquired during stale seedbed using sensors placed at a depth of 5 cm in the fields, while weed emergence was monitored every 3-4 days in each plot casting 30×30 cm squares 10 times and noting the seedling number for each species. After the termination of stale seedbed, the infestation dynamic was monitored to assess the efficacy of the weed control strategy.

Results

Rice yield did not differ between the two compared termination timings, although sowing was delayed by one week in the case of delayed termination. The weed emergence data showed an infestation made by about 85% by *Oryza sativa* var. *sylvatica* (ORYSA) and by about 3% by *Echinochloa crus-galli* (ECHCG). Figure 1a shows the evolution of the cumulated density of ORYSA over time. At the time of the traditional termination timing (21 May), the density was about 60 plants/m^2, corresponding to 86% of the final emergence (Figure 2a). At the survey on 27 May, before delayed termination timing, cumulated emergence had already reached almost 100% (about 70 plants/m^2). Figure 1b shows the emergence dynamic of ECHCG, which was much less aboundant than ORYSA, with a density of about 10 plants/m^2. At the traditional termination timing, ECHCG was still at about 50%, while at the delayed timing, the species had reached 100% emergence. If the density of ECHCG had been higher than 10 plants/m^2, the early termination of stale seedbed in traditional date would have had a much less efficacy on this species than the delayed termination. These results confirm that the second date would be the best one. Using an emergence predictive model for the two weed species (ORYSA and ECHCG) would allow to know the percentage of emergence in advance and choose the correct date of intervention. If such a model had been available as early as 2021, it would suggest waiting until at least 80-90% of the ECHCG emergence before terminating the stale seedbed.



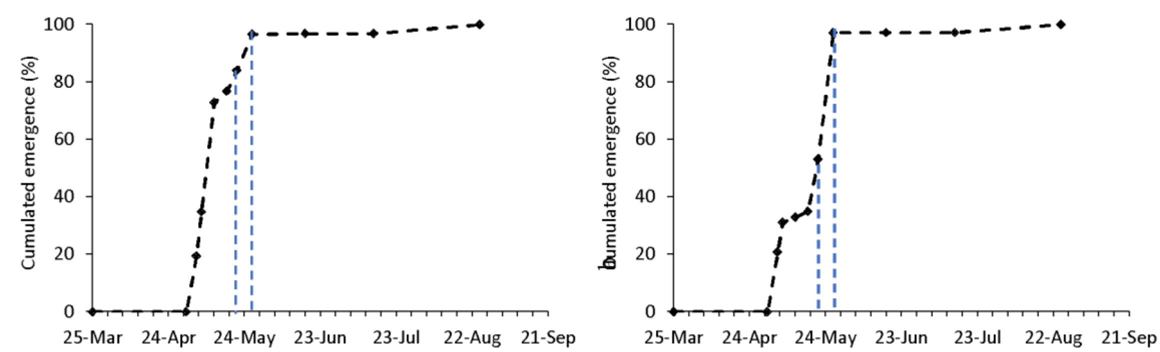


Figure 1. Cumulated density (plants/m^2) of *Oryza sativa* var. sylvatica (a) and *Echinochloa crus-galli* (b) during rice cultivation in 2021. Vertical lines showed the date of traditional and delayed stale seedbed.

Figure 2. Cumulated emergence (%) of *Oryza sativa* var. sylvatica (a) and *Echinochloa crus-galli* (b) during rice cultivation in 2021. Vertical lines showed the date of traditional and delayed stale seedbed.

Conclusions

Stale seedbed was an effective technique for weed control, and water-seeding and the use of a late sowing variety probably favoured the technique's success. The delayed termination date of the stale seedbed allowed for more effective weed control, particularly of ECHCG. Although this did not result in higher yields in the experiment due to the low infestation density of this species in the experimental fields, it is to be expected that in the case of higher densities, good post-emergence control would have been crucial to avoid yield losses with the traditional timing of termination. A comparison of the emergence dynamics of ORYSA and ECHCG in the field showed that the two species have different timing of emergence and that the best time of control has to be defined to achieve high emergence rates for both. Predicting their emergence with a model could guide the farmer in identifying this timing and further improve the efficacy of this technique.

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Camelina And Pea Intercropping For Weed Control In Organic Farming

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Introduction

Weed management is a cornerstone for organic farming (Bond and Grundy, 2000). Farmers growing pulses in low-input systems are concerned about their poor ability to compete against weeds (Liebman and Dyck, 1993). Pea (*Pisum sativum* L.), particularly, is severely affected by weed competition because of its slow development at early growth stages. One weed management strategy consists in increasing the competitiveness of the cultivated system (Puricelli et al., 2003). Intercropping can improve competitiveness thanks of the better use of resources (Fernandez et al., 2002) by reducing their availability for weeds (Norris et al., 2001). Camelina (*Camelina Sativa L.* Crantz) is a promising oilseed crop with low input requirements that has been successfully grown when mixed with peas (Leclère et al., 2019; Paulsen et al., 2006). Its early vigorous growth could compensate for the low vegetative growth of peas, thus reducing weed emergence. A preliminary study has been carried to assess the effect of camelina intercropped with pea on soil coverage and weed incidence in organic farming compared with pea sole-cropping.

Materials and Methods

The study was carried out at the experimental organic farm of the University of Bologna at Ozzano dell'Emilia (44°25'N, 11°28'E). The experiment included three treatments: T_1 pea sole-cropping, T_2 camelina sole-cropping, T_3 pea + camelina. The experimental design was a randomized complete block design with four replicates. The seed rates were: 200 kg ha^{-1} for sole pea, 100 kg ha^{-1} for intercropped pea, 7.5 kg ha^{-1} for sole camelina and 4.4 kg ha^{-1} for intercropped camelina. Seeds were planted with a row drill, except for the intercropping where camelina was broadcasted after pea row seeding. No fertilizer was applied and the preceding crop was winter wheat. The experiment was sown on 26/10/2022 with a mechanical cereal seeder (Damax 17). Soil coverage was surveyed by using Canopeo app and taking three photos at 60 cm from the soil for each plot. The percent of soil coverage was recorded three times at 55, 98 and 128 days after sowing (DAS). The weed density was determined at 98 DAS counting the number of plants within an area of 0.04 m^2 for three times for each plot. According to Kashyap et al. (2021) the weed control efficacy (WCE) based on the weed density was calculated as follows:

$$\text{WCE}\ \% = (\text{wc} - \text{wt})/\text{wc} \times 100$$

where by *wt* is the weed density (weeds m^{-2}) in treated (Pea x Camelina) and *wc* is the weed density (weeds m^{-2}) in untreated control (sole Pea and sole Camelina).
All the data were subject to the analysis of variance (ANOVA) by using Statgraphics 19 – X64. Means of different treatments were compared using LSD-test ($P \leq 0.05$).

Results

Soil coverage increased over time reporting significative differences among treatments after 98 DAS. The highest values were surveyed in the intercropping as well as sole camelina plots at 98 and 128 DAS. However, there were no significant differences at 55 DAS (Figure 1A).

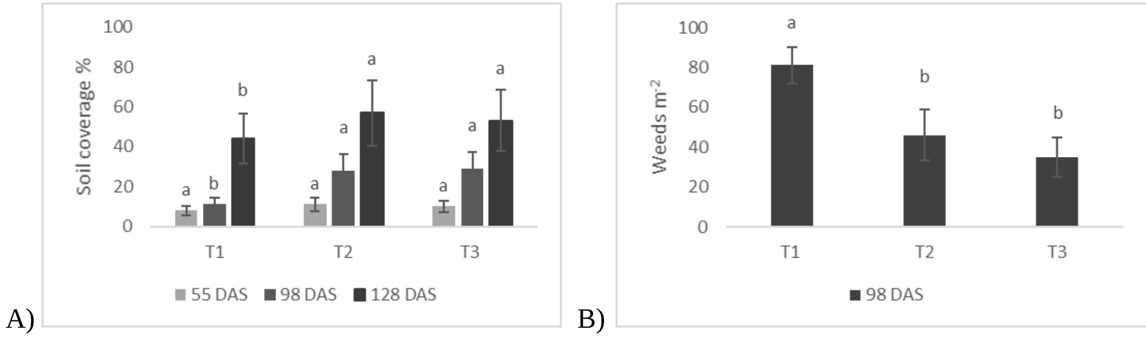

Figure 16. A) Soil coverage surveyed by the CANOPEO app, from 55 DAS to 128 DAS in the camelina-pea intercropping. B) Weed density (weed m^{-2}) at 98 DAS in the camelina-pea intercropping. T_1 pea sole-cropping, T_2 camelina sole-cropping, T_3 pea + camelina. Vertical bars: standard error. Different letters: statistically different means for $P \leq 0.05$ (LSD test).

The weed density and the weed control efficiency were assessed at 98 DAS and the lowest weed density m^{-2} was reported by the intercropping compared with the sole crops (Figure 1B). In terms of weed control efficiency, the intercrops reported an increment of 56% compared with the sole pea and of 23% compared with the sole camelina. This finding confirms the effectiveness of intercropping in weed-suppressing which has been shown in previous studies for pea-cereal intercropping (Begna et al., 2011; Gronle et al., 2014). A negative linear correlation ($R = -0.30$, $P = 0.07$) was found between soil coverage and weed density at DAS 98.

Conclusions

This preliminary study provided evidence of camelina-pea intercropping as an herbicide-free alternative crop management. Camelina-pea intercropping was able to accumulate a considerable amount of biomass increasing soil coverage and providing crop protection against weeds. The greater soil coverage is due to the presence of camelina in the space between the pea rows, that otherwise would have been taken up by the weeds. Further investigations are ongoing to determine intercropping productivity and its nutrients uptake efficiency.

Acknowledgements

The present research has been carried out in the framework of the SCOOP project, which is part of the CORE Organic Era-Net Programme supported by the European Union.

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Effect Of Cardoon Mulching On Weed Pressure And Productive Performance In An ‘Early’ Potato Crop

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Introduction

The ‘early’ potato (harvested from March to June) is an off-season crop widely cultivated in the Mediterranean Basin and playing a crucial role for its economy. In these areas, ‘early’ potato is commonly grown under high-input agricultural systems, in which weeds cause considerable economic and yield losses and are chemically controlled. The application of organic mulches is recognized as an effective and eco-friendly technique for improving soil quality and increasing crop yield (Sinkevičienė et al., 2009). However, to our knowledge, the effects of organic mulching was not studied in the ‘early’ potato cycle. Cardoon forms (*Cynara cardunculus* L.) are herbaceous perennial plants, which show strong phytotoxic effects on several target weeds due to the presence of allelochemicals belonging to sesquiterpene lactones (Scavo et al., 2019) and polyphenols (Scavo et al., 2020). Following these considerations, the aim of this study was to evaluate, for the fist time, the effects of cultivated cardoon mulching on weed control and yield of two ‘early’ potato cultivars.

Materials and Methods

A field experiment was conducted in the 2022 growing season at the experimental farm of the “I.I.S. Leonardo – sede A.M. Mazzei-” located on Giarre (CT), a typical area for ‘early’ potato cultivation in the southern Italy. The design was a split-plot with 3 blocks, considering the treatment (*i.e.* cardoon mulching *vs*. control with a weed control by hand at potato emergence) as main plots and potato cultivars (i.e. *Arizona* and *Levante*) as sub-plots (Figure 1). A cardoon mulching composed of the dry aboveground part of the plant was soil-surface applied at thickness of 3 cm. The effectiveness of weed control was determined by assessing the aboveground biomass of weeds at 90 and 120 days after planting from a 1.0 m^2 permanent quadrate per replicate. Weeds were clipped at soil surface and dried at 55 °C in a forced-air oven up to constant weight for dry biomass determination. Tubers were harvested manually at the end of the cycle (about 120 days after planting) when 70% of leaves were bleached and dry. Tubers which were greened, misshapen or displayed pathological damage were classed as unmarketable, as well as those with weight lower than 20 g. This allowed the calculation of the marketable yield (MY) and mean tuber fresh weight (MTFW). Data were statistically analysed for each cultivar by analysis of variance (ANOVA), setting the significance at the 0.05 probability level with the LSD test.

Figure 1. Experimental design

Results

The preliminary results here obtained were very similar for both 'early' potato cultivars in terms of weed control and crop productive traits (Figure 2). Data about weeds showed that cardoon mulching reduced the weed aboveground dry biomass by 72% in *Arizona* and by 50% in *Levante* at 90 days after planting. At the end of the crop cycle (120 days after planting), although a higher presence of weeds, their aboveground dry biomass was further reduced by 85% in *Arizona* and by 72% in *Levante*. Regardless of the treatment, a higher weed aboveground dry biomass was observed in *Arizona* than in *Levante* at both 90 (60 *vs*. 56 g DW m^{-2}) and 120 (276 *vs*. 184 g DW m^{-2}) days after planting.
Concerning the productive performance, cardoon mulching significantly increased the MY of *Arizona* and *Levante* by 9% and 16%, respectively (Figure 1). The increase of MY was mainly due to the MTFW, which was enhaced by 9% in both cultivars due to the application of cardoon mulching .

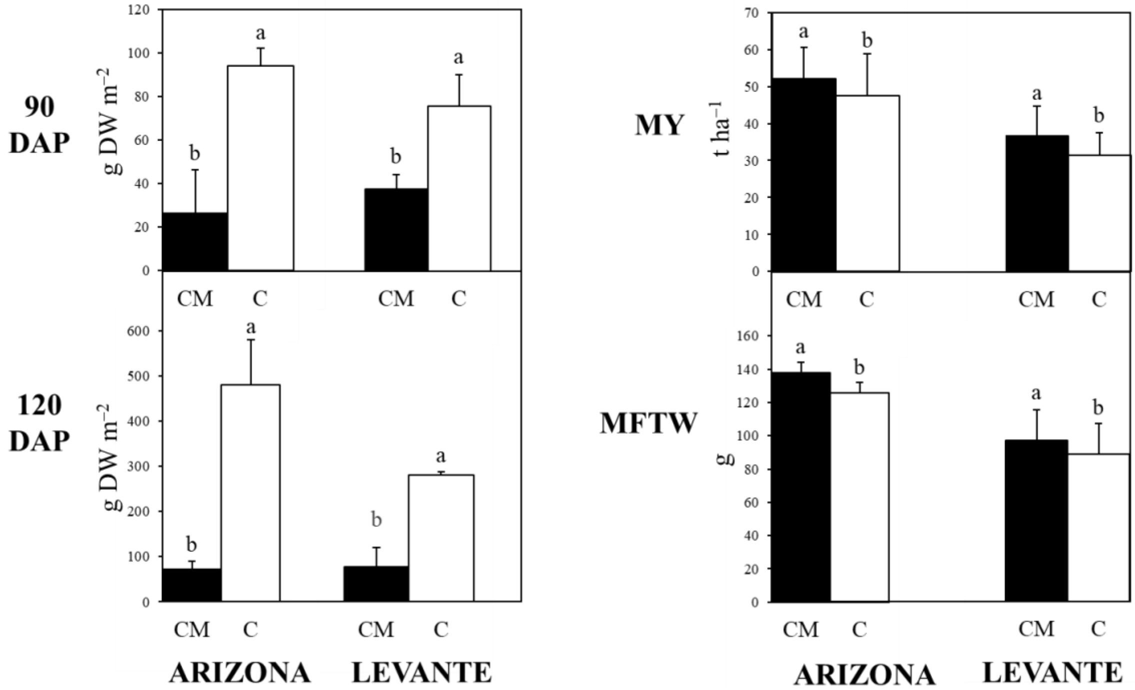

Figure 2. Weed aboveground dry biomass production (g DW m^{-2}) (on the left) and productive traits (on the right) in an 'early' potato crop. Different letters within each cultivar indicate statistically significant differences ($P \leq 0.05$, LSD test). Bars are standard deviation (n=3). DAP: days after planting; MY: marketable yield; MFTW: mean fresh tuber weight; CM: cardoon mulching; C: control.

Conclusions

The results highlighted that the soil-surface application of cardoon mulching could be a valid environmental-friendly technique to reduce weed pressure and increase the productive performances of two potato cultivars cultivated in the 'early' crop cycle. The highest benefits can be achieved in low-input agricultural systems and organic farming, where the use of agrochemical is reduced or avoided in favour of alternative eco-friendly practices. Other researches are, however, still necessary to better understand the effects of cardoon mulching on soil quality and crop bio-physiological traits.

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Screening Of Wheat Varieties For Shade Tolerance Within A Specialized Poplar Orchard For Future Implementation In Agroforestry Farming Systems

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Introduction

Silvoarable systems, which combine trees with arable crops on the same agricultural land, are receiving increasing interest for their high potential to reduce vulnerability to climate change (Lorenz and Lal, 2014), although they currently cover only ~0.1% of the agricultural area in Europe, i.e. 358,000 hectares (Nerlich et al., 2013). This scarce implementation is due to the farmers' concern for lower crop yield in the neighboring of trees, due to resources competition, and to the lack of knowledge on the most susitable crop varieties. Up to date, genetic variability has been poorly explored and mainly in pot experiments with artificial shading trials, and limited to aboveground interactions. For these reasons, there currently are no criteria for screening suitable varieties to implement within sustainable silvoarable systems according to tree characteristics and pedoclimatic conditions.
Within this framework, an open field experiment was conducted in Northern Italy to investigate the response of ten different common wheat varieties, including modern and old local varieties, cultivated in the narrow inter-row (6 m) of a specialized 4-year old poplar orchard (AF), i.e., without excluding belowground interactions with trees, in comparison with controls under full sun (C).

Materials and Methods

The trial was carried out during 2020-21 in a specialized poplar grove (AF) with 4-year old poplar trees (*Populus* × *euroamericana*) and 6×6 m planting design, located at the "Sasse Rami" pilot farm of Veneto Agricoltura, in Ceregnano (Rovigo, NE Italy). Trees were 14 m high, with 18 cm of trunk diameter at breast height at the beginning of the trail. Ten varieties of common wheat (*Triticum aestivum* L.) were cultivated in the AF treatment and in a neighboring field (100 m to the east) without trees serving as control area (C). Wheat included both old varieties preserved at the Nazareno Strampelli Institute in Lonigo (Vicenza, NE Italy), and modern commercial varieties, with contrasting synthetic index of quality, i.e. bread-making, biscuit-making and hard type varieties.
Wheat was sown on 25 October 2020 with a plot seeder with 240 kg ha^{-1} of seeds, 15 cm apart rows. Wheat plots were 1.2-m wide and 3-m long (3.6 m^2) arranged in a line in a tree alley with three replicates (n=3) completely randomized in both AF and C treatments (Figure 1).
Leaf area index (LAI; *LI-3100C Area Meter*, Li-Cor), leaf chlorophyll content (by SPAD-502), NDVI (by Greenseaker) and aboveground dry biomass were measured

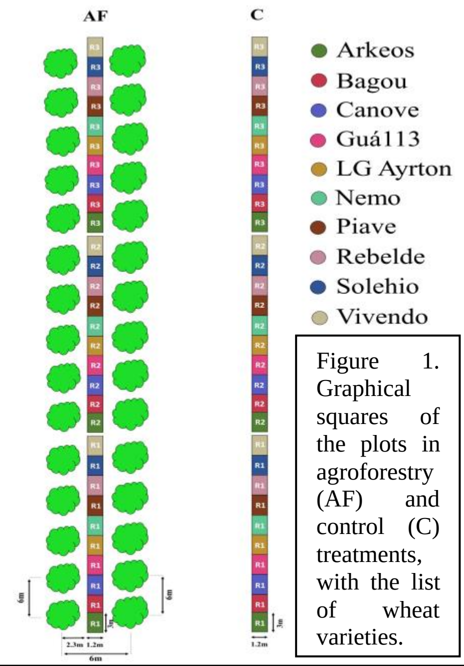

Figure 1. Graphical squares of the plots in agroforestry (AF) and control (C) treatments, with the list of wheat varieties.

at flowering. At harvest (29 June 2021), plants sampled on a 1-m^2 area for each replicate × variety × treatment were threshed to determine grain yield, TGW (Thousand Grain Weight), testing weight and grain protein content (by Kjeldahl method). Statistical significant differences were detected by R studio software v. 2.7 (Tukey's HSD test, $P \leq 0.05$).

Results

A significant genetic variability in response to agroforestry was revealed, as grain yield reductions in AF ranged between -31% and -75% depending on variety choice (-57% as average of all varieties). Under shading, the lowest yield reductions were observed in old varieties (-40% vs. C), a response that was associated to the most relevant delay of leaf senescence and improvement of leaf area index (from +20% up to +225% vs. C) and chlorophyll content (+12% up to +18% vs. C), while achieving the highest protein content in the grain (>17.3% DW). Modern varieties, despite the higher yield reductions under AF (-60% vs. C) and lower morpho-pohysiological plasticity as compared to old varieties, still achieved the highest absolute yield level under shading, particularly in the type bread making (469 g m^{-2}). Multigroup Discriminant Analysis (MDA) revealed a different behavior among variety types, i.e., according with their index of quality (Figure 2). Within modern varieties, the effects of shading on the type biscuit-making were mostly associated with variations in LAI/CAI and SPAD, while the effects on the type bread-making with yield, NDVI and HI. Differently, the impact of agroforestry on old varieties was mostly linked to protein content, leaf area and aboveground biomass.

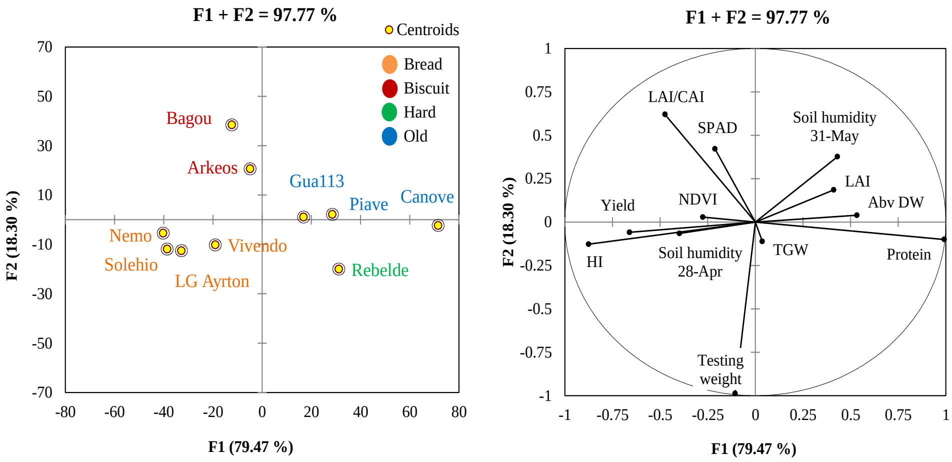

Figure 2. Principal component analysis (PCA, right) and discriminant analysis (DA; left) for the ten common wheat varieties in the agroforestry (AF) treatment.

Conclusions

The screening of wheat varieties cultivated in the narrow alleys of a poplar orchard is an innovative trial that was suitable for highlighting key traits of shade-tolerance, and possibly root competition, and contrasting responses among wheat varieties. Some interesting acclimation strategies associated to better light harvesting were highlighted, such as the increase of the leaf-to-culm area ratio in the modern type bread-making and old varieties, and longer maintenance of high leaf photosynthetic activity in the type biscuit-making, that could be used in future screening and breeding programs oriented toward agroforestry farming systems.

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Selenium Biofortification Of Winter Wheat (*Triticum aestivum* L.)

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Introduction

Selenium (Se) is one of the essential micronutrients that contributes to the optimal functioning of an organism, but many people's diet is deficient in this element (Broadley et al., 2010). Winter wheat is major dietary source of selenium in many parts of the world and furthermore wheat is the most efficient accumulator of Se within the common cereal crops (Gupta and Gupta, 2017). So, improving the selenium content in winter wheat kernel through biofortification represents a strategy to improve human nutrition. Therefore, the aim of this study is to evaluate the potential of winter wheat biofortification by means of foliar selenium application. Specifically, our aim was to assess the influence of selenium doses and application timing on selenium accumulation of wheat grain and straw, as well as assess the influence of genotype effect on selenium uptake.

Materials and Methods

The field experiment was conducted in 2020/21 at the experimental farm of Tuscany Region, called "La Tenuta di Cesa" (Marciano della Chiana, Arezzo, Italy). During the growing season (October 2020 to September 2021), the average temperature was 13.8°C, meanwhile the total annual precipitation was 741.4 mm. The soil textural class was sandy-clay-loam (sand 37%, Silt 27 %, and clay 34 %). Other soil properties are reported: total N 0.34 ‰; available P 0.97 mg kg^{-1}; exchangeable calcium, magnesium and potassium of 1550, 64.77 and 21.4 mg kg^{-1}, respectively; pH 8.13. The experimental design was set up as a split-plot design with three replicates, where two winter wheat (*Triticum aestivum* L.) varieties cultivars formed the main plot treatments, and subplot treatments consisted of application time at the two growth stages of wheat, i.e., at flowering (65 BBCH), indicated as T0, as well as the second application at watery ripe (71 BBCH), indicated as T1. Sub-subplot treatments corresponded to the five levels of Se including the control, applied via foliar spray at the following doses: 0, 2.57, 5.14, 10.27, 20.54 g ha^{-1}, as sodium selenite (Sodium selenite pentahydrate; $Na_2SeO_3 \cdot 5H_2O$), referred as S0, S1, S2, S3, and S4, respectively. Ammonium nitrate (NH_4^+) was applied in split application at a rate of 100 kg N ha^{-1}, 20 kg N ha^{-1} before sowing, 40 kg N ha^{-1} applied at tillering stage, while the remaining half 40 kg N ha^{-1} was applied at stem elongation. Two winter wheat varieties were used: a modern wheat cultivar (Bologna) and an "old" wheat cultivar (Sieve). Statistical analysis was performed using ANOVA, setting cultivar, time of application, selenium doses as variables; furthermore, multiple mean comparisons were carried out through post-hoc Tukey's test (p=0.05).

Results

As regards Se accumulation in grain and straw no significant differences were detected between the treatments, with the exception of the comparison between different times of Se application. In particular, application time had a highly significant effect on grain and straw Se concentration of both modern and ancient wheat cultivars; indeed, winter wheat was able to accumulate more Se in grain and straw when it is spread at the watery ripe stage than at the flowering stage. Bologna and Sieve varieties showed an increase of 2 and 1.5-fold in grain Se concentration, respectively, when the application of selenium was done at T1 compared to T0. Furthermore, Se dose had a stronger positive linear relationship with grain Se accumulation in T1 than in T0. Similar results were reported by Lara et al. (2019), as they detected a linear relationship between grain Se uptake and the increasing Se doses. However, the same could not be said for Se straw concentration, as no linear association was detected between the Se straw concentration and Se dose. Therefore, we speculate that the ratios of the added Se were not enough to exert significant differences in grain Se concentration. Our results are in agreement with Manojlović et al. (2019), as they detected no significant differences in Se grain concentration between various winter wheat varieties; on the other hand, they had found a significant increase in Se concentration in grain as the Se supply increased.

Table 1. Selenium accumulation in wheat grain and straw as response to increasing selenium doses (S0, S1, S2, S3, and S4, which correspond to 0, 2.57, 5.14, 10.27, 20.54 g ha^{-1} , respectively) and application time (T0 is referred to selenium application at flowering stage, while T1 at watery ripe stage). Mean values (n=3) ± Standard deviation are reported.

Application Time	Se level	Selenium concentration (mg kg^{-1} DM)			
		Grain		Straw	
		Bologna	Sieve	Bologna	Sieve
T0	S0	0.05 ± 0.01	0.08 ± 0.01	0.06 ± 0.01	0.07 ± 0.02
	S1	0.06 ± 0.02	0.08 ± 0.01	0.06 ± 0.01	0.09 ± 0.01
	S2	0.06 ± 0.02	0.07 ± 0.02	0.11 ± 0.01	0.12 ± 0.01
	S3	0.07 ± 0.01	0.08 ± 0.01	0.11 ± 0.03	0.09 ± 0.01
	S4	0.07 ± 0.01	0.07 ± 0.01	0.21 ± 0.04	0.10 ± 0.02
T1	S0	0.12 ± 0.01	0.09 ± 0.02	0.24 ± 0.04	0.13 ± 0.01
	S1	0.14 ± 0.01	0.15 ± 0.02	0.29 ± 0.02	0.26 ± 0.02
	S2	0.18 ± 0.01	0.17 ± 0.01	0.36 ± 0.01	0.36 ± 0.02
	S3	0.20 ± 0.02	0.26 ± 0.01	0.56 ± 0.01	0.56 ± 0.01
	S4	0.31 ± 0.01	0.26 ± 0.01	0.77 ± 0.01	0.77 ± 0.01
T0		0.06 ± 0.01 b	0.07 ± 0.01 b	0.11 ± 0.06 b	0.10 ± 0.02 b
T1		0.19 ± 0.07 a	0.18 ± 0.07 a	0.44 ± 0.20 a	0.32 ± 0.14 a
	S0	0.08 ± 0.03	0.08 ± 0.02	0.15 ± 0.09	0.10 ± 0.03
	S1	0.10 ± 0.04	0.12 ± 0.04	0.18 ± 0.12	0.17 ± 0.08
	S2	0.13 ± 0.06	0.12 ± 0.05	0.26 ± 0.13	0.18 ± 0.07
	S3	0.13 ± 0.07	0.17 ± 0.09	0.35 ± 0.23	0.29 ± 0.20
	S4	0.19 ± 0.12	0.16 ± 0.09	0.49 ± 0.28	0.30 ± 0.19

Conclusions

According to our results, Se biofortification is effective in enhancing the Se concentration of winter wheat, but it is noteworthy that grain and straw Se concentrations were more influenced by the time of application than by the different doses of Se. Therefore, the most important aspect of Se biofortification of winter wheat is the timing of selenium spread, rather than the amount of distributed element. However, further studies are required to assess the significant influence of the supplied Se on its concentration both in grain as well as straw.

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Processing Tomato Has Affected By Barrier And Curzate In Different Soil Fertilization

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Introduction

The current use of heavy agronomic inputs to increase crop yields is responsible for the weakening of the agroecosystem stability. The main damage is the loss of the structural integrity of the system, such as the reduced capacity to provide various ecosystem services, i.e. nutrient cycling and soil fertility. Sustainable practices are proposed as a possible solution to reduce environmental impact, while maintaining the production and quality levels of crops.

The aim of this study was to evaluate how the use of fertilizer sources and crop protection products can compete with the conventional ones. To achieve this goal, the use of different crop protection products and their interaction with different fertilization source was tested on processing tomato (*Solanum lycopersicum* L.) crop under field conditions.

Materials and Methods

Field trials were carried out at the experimental farm "Nello Lupori" of the University of Tuscia, located in Viterbo - Central Italy (45°25'N, 12°04'E, Alt. 310 m a.s.l.). The experimental site is characterized by a typical Mediterranean climate, with mild, humid winters and hot, dry summers. Annual rainfall averages 752 mm (last 30 years), spread mainly from September to May (569 mm). The farm is located in a volcanic area. The soil characteristics in the 0-30 cm layer are sandy-loamy (63%-22%) with a minimum amount of clay (15%). The total organic carbon is 1.07% and the total nitrogen is 0.12%, pH is neutral with a value of 7.1. The experimental trials were carried out using a randomized block design, with three replications. Two different fertilization treatments, mineral fertilization (M) and organic fertilization from compostable municipal organic waste (O) were applied. In addition, four different crop protection product treatments, control -untreated- (c), Curzate® (cur), Barrier®+Copper (b1), Barrier® (b2) were applied. The crop protection products used were: Barrier® Cosmocel, Calcium-based (Ca) 10% and Silicon (SiO_2) 24%; Curzate® 60% WG, antiperonosporic based on pure Cymoxanil 60 g. The plots size was 30 m^2 (6x5 m). The transplanting bed was prepared according to the common practices adopted for processing tomato transplanting by means of spading machine as main tillage and disk harrowing applied twice. Tomato transplanting was carried out manually in the first half of May, with 120 cm between rows and 33 along the rows. Organic fertilizer (O) was applied in a single application before harrowing (15 t ha^{-1}), while mineral fertilizer (M) was applied in two times, the first at the crop transplanting and second after three weeks, with a total dose of 100 kg ha^{-1} of nitrogen units.

During the whole crop cycle, tomato plants were irrigated with a drip irrigation system. Hand harvesting was carried out in the second half of August on a 1 m linear sample in the middle of each experimental plot.

The data obtained from the experimental trials were statistically analyzed by analysis of variance (ANOVA) using the statistical software package JMP version 4.0 (© SAS Institute Inc.). Fisher's protected least significant difference (LSD) test with probability level $P<0.05$ was used for mean comparisons. A linear regression model of marketable tomato fruits and tomato straw was performed separately for each crop protection product treatment.

Results

In Table 1, the tomato fruit yield and characteristics are reported. The number of marketable tomato fruits observed in both Barrier® treatments (b1 and b2) in combination with organic fertilization tended to show the highest values. In mineral fertilization Barrier® tended to be higher only to the Curzate® treatment (cur). In general, the yield of the marketable tomato fruits was the highest in organic fertilization with Barrier application (5.98 kg m^{-2} for b1 and 6.13 kg m^{-2} for b2 respectively) and in mineral fertilization with control (c) (6.06 kg m^{-2}). Organic fertilization (Table 1) higher affected straw weight compared with mineral fertilization.

Table 1. Tomato yield and straw. Values belonging to the same parameter with different letters are statistically

Fertilizer	Treatment	Number of marketable berries (n m^{-2})		Weight of marketable berries (kg m^{-2})		Weight of dry straw (kg m^{-2})		Sugars (°brix)	
O	b2	64,44	a	5,98	ab	0,328	ab	3,97	d
O	b1	66,78	a	6,13	a	0,385	a	4,06	bd
O	cur	50,42	bc	4,75	cd	0,344	ab	4,42	a
O	c	60,00	ab	5,51	ac	0,31	ab	4,03	cd
M	b2	53,39	bc	3,87	de	0,312	ab	4,33	ab
M	b1	53,33	bc	4,85	bd	0,293	ab	4,02	d
M	cur	47,22	c	3,39	e	0,297	ab	4,30	ac
M	c	64,89	a	6,06	ab	0,284	b	4,40	a

The tomato plants treated with the crop protection products and with mineral fertilization was not statistically significant for all treatments. Conversely under organic fertilization the results showed that straw weight was significantly related to marketable tomato fruits in cur and b2 treatments (Figure 1), confirming that tomato fruit yield is associated to the straw production. In the O and b2 treatments and in M and b1 treatments, the tomato fruits sugar content (Table 1) is significantly reduced compared to the others.

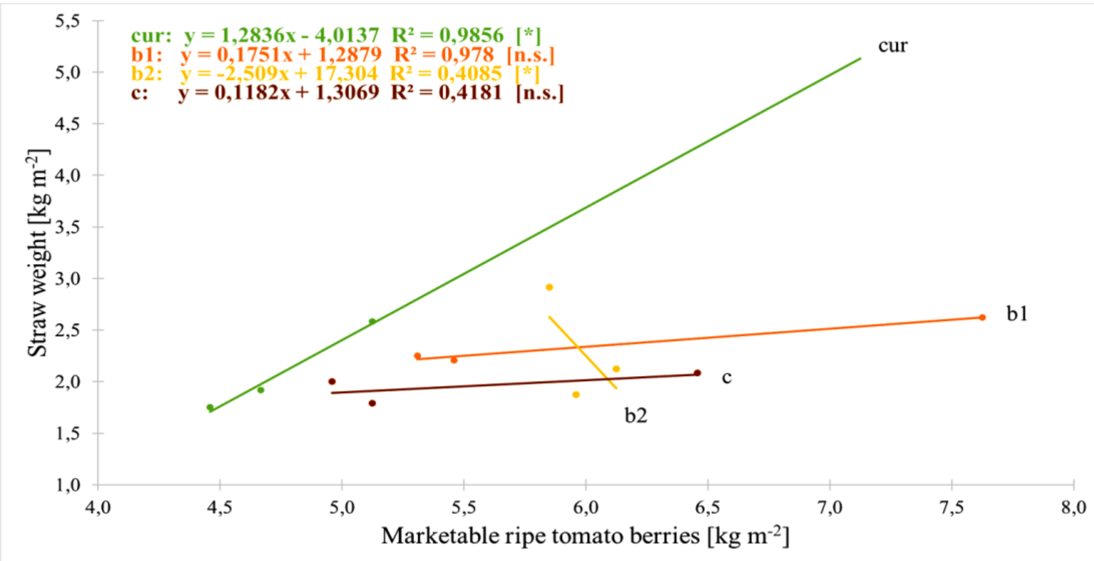

Figure 1. Fresh weight of marketable ripe tomato berries related to fresh weight of straw in different treatments under organic fertilization.

Conclusions

This study showed that different sources of fertilizers and crop protection products have significant effects in the marketable tomato fruits production. These could represent a kind of sustainable agronomic approach for processing tomato production. The use of crop protection products such as Barrier®, combined with the application of organic fertilizers, not only has less impact on the environment, but can also be extremely competitive in terms of production and therefore achieve environmental and economic sustainability.

Liquid Digestate Fraction Application Might Sustain Winter Wheat Production Improving The Nitrogen Use Efficiency

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Introduction

Worldwide there is a pushing need to move from the current economic model to a circular economy based on the recovery and revalorization of wastes through recycling and re-use (Gregson et al., 2015). In these circumstances, biogas plants are considered to be a promising carbon-free energy source for electricity production. Anaerobic digestate (AD) is the anaerobic digestion by-product that presents fertilizer characteristics and is produced at a rate of 180 Mt per year in the EU28. Therefore, there is a pressing need for AD sustainable usage. AD is usually separated into two fractions, *i.e.*, solid and liquid, before its land application. Solid AD fraction retains the greater part of organic matter and organic matter-derived N and is usually surface broadcast before its incorporation into the soil through tillage while liquid AD fraction is ammonia-N rich and can be directly injected into the soil (Crolla et al. 2013). Uniform fertilizer application represents the standard practice, being easier for farmers on a large scale field. Nevertheless, these practices lead to a mismatch between N inputs and crop N needs which may negatively impact the Nitrogen use efficiency (NUE) with consequent environmental and economic drawbacks. During the last decades, N site-specific management (e.g., variable-rate application "VRA") has been demonstrated to be a suitable tool for increasing NUE by maintaining, at the same time, satisfying crop production (Basso et al., 2013). This study aimed to evaluate silage winter wheat dry yield and NUE in response to different fertilizer types including both solid and liquid digestate fractions. Our starting hypothesis is that AD fractions might represent a reliable alternative to mineral fertilizers maintaining productions comparable to those of synthetic fertilizers and, at the same time, improving cropping agro-environmental sustainability.

Materials and Methods

The field experiment was carried out in the 2020-2021 wheat cropping season in Veneto Region (NE Italy) on a farm situated close to the Venice Lagoon and with silty clay/loam soil. The experiment included 18 rectangular fields (6 treatments × 3 blocks) covering ca. 27 ha where mineral fertilizer (MF), mineral fertilizer in VRA (VRA-MF), liquid digestate with a nitrification inhibitor (N-LockTM, Corteva Agriscience, Wilmington, DE, USA) (LD+), liquid digestate in VRA (VRA-LD), liquid digestate with a nitrification inhibitor in VRA (VRA-LD+) and solid digestate (SD) were applied to winter wheat (*Triticum aestivum* L.). Inside VRA treatments, management zones (MZs) were established according to the soil properties and apparent electrical conductivity maps. For each treatment and/or MZ, the optimal N fertilization rate was calculated by coupling Denitrification and Decomposition model "DNDC" simulations with an agro-environmental sustainability index (AESI) as reported in Grillo et al. (2021). The optimal N fertilization was on average in the 170-380 kg N ha^{-1} range, depending on fertilizer type (Table 1). At silage winter wheat maturity, yield and protein content were measured with a Cebis yield monitoring system and NIR spectrometer, respectively, mounted on a Claas Jaguar 990. The NUE was calculated as the N output-to-N input ratio according to EU Nitrogen Expert Panel (2015). The wheat growing season was characterized by 448 mm of rain and the air temperature was in the -6.5-25.2°C range, with monthly averages of 13.2, 8.5, 5.7, -1.1, 2.7, 2.1, 6.6 and 11.3 °C from October to May.

Table 1. N fertilization rate range applied for each fertilizer type (MF: mineral fertilizer, VRA-MF: mineral fertilizer in VRA, LD+: liquid digestate with a nitrification inhibitor, VRA-LD: liquid digestate in VRA, VRA-LD+: liquid digestate with a nitrification inhibitor in VRA, SD: solid digestate fraction).

	MF	VRA-MF	LD+	VRA-LD	VRA-LD+	SD
Mean	197 kg ha^{-1}	202 kg ha^{-1}	297 kg ha^{-1}	244 kg ha^{-1}	236 kg ha^{-1}	380 kg ha^{-1}

Results

Silage winter wheat dry biomass ranged between 14.9 to 18.8 t ha^{-1} with comparable results between treatments, 16.8 t ha^{-1} on average. Contrarily, cropping systems NUE was affected by agronomic management with the treatments ranked as follows: VRA-MF>MF>VRA-LD+>VRA-LD>SD>LD+. Higher NUE (i.e., > 90%) was recorded in VRA-MF while lower NUE (ca. 50%) was reached in SD and LD+ (Figure 1-left). An N surplus < 80 kg N ha^{-1} was successfully reached in more than 80% of MF and VRA-MF surfaces while it was seldom satisfied under LD+ and SD (Figure 1-right). The NUE sustainability zone (i.e., 50%<NUE<90% and N surplus<80 kg N ha^{-1}) was reached on a comparable surface under mineral fertilization (49% in MF and 30% in VRA-MF) and liquid digestate fraction in VRA (30% in VRA-LD and 41% in VRA-LD+). On the contrary, SD only marginally reached the sustainability zone (<2% of the surface).

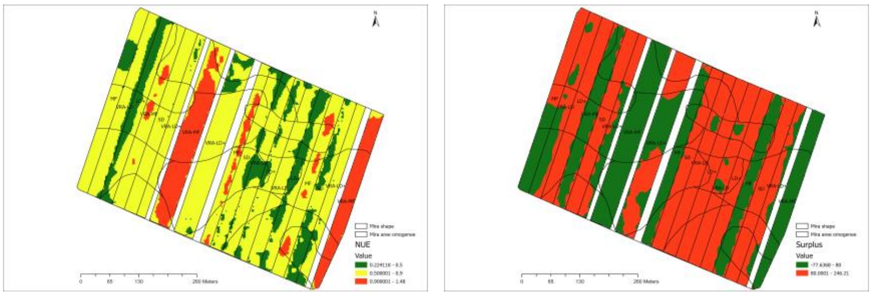

Figure 1. Map of silage winter wheat NUE (left) and N surplus (right).

Conclusions

The starting hypothesis is partially confirmed since liquid AD fraction might represent a reliable alternative to mineral fertilizers maintaining productions comparable to those of synthetic fertilizers and, at the same time, improving agro-environmental sustainability. On the contrary, solid AD fraction exhibited lower performances due to the high organic matter and organic matter associated-N. Therefore, longer-term studies to fully exploit solid AD fraction additional benefits (*e.g.*, improvement of the soil physical properties, the effect of residual N release) are namely requested.

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Evidence Of Declining Carbon Dynamics After 5 Decades Of Different Crop Residue Management

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Introduction

Nowadays the importance of increasing SOC in the soil gains increasing attention due to its double function of restoring soil fertility (Tiessen et al., 1994) and mitigating climate change (Chabbi et al., 2017). As also demonstrated by the attention drawn by the COP21 initiative of "4 per 1000" (URL: http://4p1000.org/understand) increasing the SOC in word soils is now more than ever a central issue (Rumpel et al., 2018; Poulton et al., 2018; Soussana et al., 2019). Consequently, understanding the factors affecting and/or limiting the C sequestration into a soil might play a key role in sustaining crop production, on the one side, and, protecting environmental health, on the other. This study aims to present the 0-60 cm SOC stock in a long-term experiment (LTE) started in 1966 involving different types of crop residue management and evaluated its SOC stock dynamics over time.

Materials and Methods

The LTE used for this study is located at the experimental farm of Padova University (Veneto Region, NE Italy 45° 21 N; 11° 58 E; 6 m a.s.l.) on a Fluvi-Calcaric Cambisol (FAO-UNESCO 2008) with a silt loam texture. The trial, which began in 1966, has been conducted on 60 35 m^2 plots. The experimental treatments were derived from the factorial combination of three crop residue managements (previous crop residue incorporation "RI", previous crop residue incorporation added with 1 t ha^{-1} of dried poultry manure "RI + PM", and residues removal "RR") with five levels of nitrogen fertilisation (0, 60, 120, 180, and 240 kg ha^{-1} y^{-1}) and four blocks. The PM was applied by burying it during shallow disk harrowing immediately after harvest providing about 60 kg N ha^{-1}. Before 1984, the trial was conducted with maize (*Zea mays* L.) in monoculture. Thereafter, a variable rotation scheme was used. Soil sampling was performed in 2020 at the end of the winter wheat growing season. 60 undisturbed soil cores were collected in the middle of each plot among the 0-60 cm soil profile through a hydraulic sampler, subsequently cut into two layers (0-30 cm and 30-60 cm) and measured for bulk density according to the core method. At the same positions, also 0-30 and 30-60 cm disturbed soil samples (120 in total) were collected, air-dried, and analysed for SOC through an elemental analyser. The 0-30 cm SOC stock obtained in 2020 was then compared with the pre-existent soil data series (1966, 1982, 1986, 1993, 2006) to evaluate its evolution.

Data belonging to the 2020 sampling campaign were analysed with a linear mixed-effect model based on a restricted maximum likelihood estimation method treating crop residue management, N level, and their interaction as fixed while the block as a random effect. Post-hoc pairwise comparisons of least-squares means were performed, using the Tukey method to adjust for multiple comparisons. Statistical analyses were performed with SAS software (SAS Institute Inc. Cary, NC, USA), 5.1 version.

Results

Preliminary results showed that higher 0-60 cm SOC stock was found after 54 years of the experiment when residues were incorporated into the soil compared to residue removal (75.0 vs 69.0 t ha^{-1}) while poultry manure had a negligible effect (Figure 1-a).

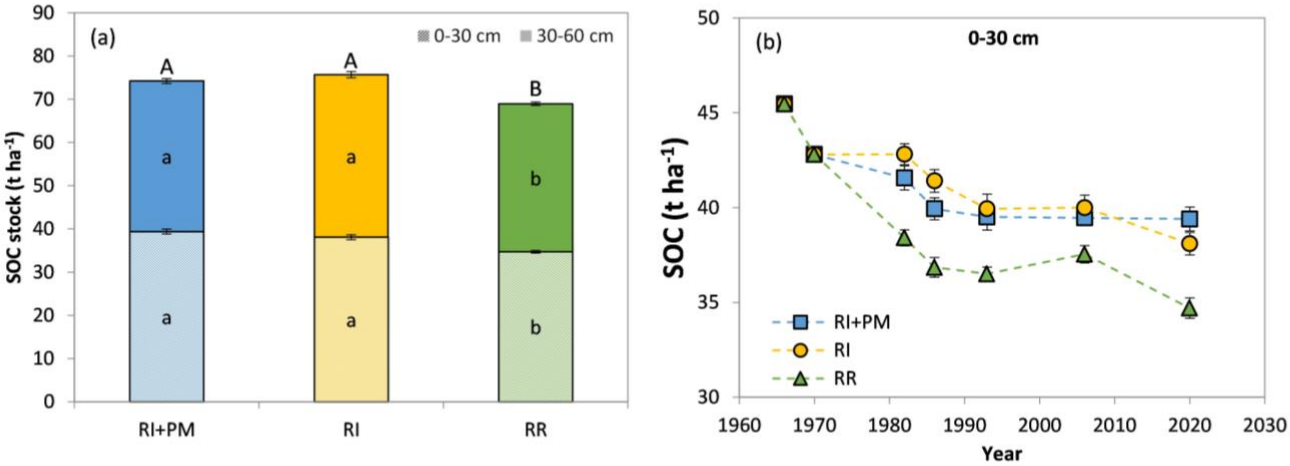

Figure 1. The 2020 soil organic carbon (SOC) (a) and 0-30 cm SOC stock dynamics in the 1966-2020 period (b). Different letters indicate differences according to the Tukey post hoc test at $p<0.05$ where lower case letters represent the single layer (0-30 and 30-60 cm) while upper case letters the entire studied soil profile (0-60 cm). RI + PM: previous crop residue incorporation added with 1 t ha^{-1} of dried poultry manure; RI: previous crop residue incorporation; RR: residues removal.

Comparing the 0-30 cm SOC stock with pre-existent data series, a general decreasing trend was observed from the start of the experiment in 1966 up to 1986, being greater in residual removal (-8.6 t ha^{-1}) than residual incorporation (-4.8 t ha^{-1}, irrespective of poultry manure addition) (Figure 1-b). In 2020, the difference between the above-mentioned systems was 4.1 t ha^{-1} corresponding to a 2.2 ‰, corresponding only to about half of what was suggested by the 4 per 1000 initiative. This SOC stock attributed to residue retention arose in response to 141 t C ha^{-1}, residue resulting in a 0.1% yearly conversion rate.

Conclusions

The present LTE study highlighted how the SOC stock in the Veneto region agroecosystem declined as a result of agricultural intensification and seemed to stabilise to equilibrium value only after 16 years. The adoption of crop residue incorporation allowed a lower magnitude of SOC decline compared to residue removal practice while the addition of poultry manure did not show any relevant effect. The residue rate of conversion (C from residue into SOC) was sensibly lower than other European LTE and was even not sufficient to reach the 4 per 1000 goal. Therefore an alternative use (e.g., bioenergy production) of, at least part, of crop residues is conceivable in a temperate environment for a more efficient C cycle. However, other beneficial effects of straw incorporation in soils, such as structural improvement, soil erosion reduction and nutrient recycling, have to be considered.

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The Impact Of Alley-Cropping On Growth Of Poplars And Yield Of Annual Intercrops Vs. Conventional Farming

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Introduction

Agroforestry (AF) practices fully embrace the strategies of the CAP policies towards the improvement of multi-functionality and sustainability of farming systems, while answering to the rising global demand for food and forest products. The re-introduction of trees in agricultural fields is known to provide environmental benefits and to increase C sequestration, enhancing at the same time the use efficiency of natural resources and the overall productivity per land unit (Santiago-Frejiandes et al., 2018). In the North of Italy there is an increasing interest towards AF systems with poplars; however, farmers are still reluctant to adopt agroforestry practices due to the risk of reduced crop yield in the neighboring of trees and uncertain tree growth (Eichhorn et al., 2006). Here, the productivity of a poplar alley-cropping system in NE of Italy is compared to the respective poplar and crop monoculture systems. The aim was to assess the impact of the alley-cropping design on growth of poplars and yield of annual intercrops, such as common wheat and soybean, until the midpoint (4 years) of the expected poplar lifespan.

Materials and Methods

The trial was carried out during the 2018-2022 period in a silvoarable alley-cropping system (AC) with poplar trees (*Populus* × *euroamericana*;) type HES (Higher Environmental Sustainability) located at the "Sasse Rami" pilot farm of Veneto Agricoltura, in Ceregnano (Rovigo, NE Italy, 45° 05'06" N, 11° 87' 66" W; 0.5-1m a.s.l.). The tree rows are placed along N-S oriented drainage ditches, 40 m apart, with 6 m between trees along the row (44 trees ha^{-1}), while a specialized poplar grove (6 × 6 m; ~290 trees ha^{-1}) was used as control (C). From 2019 to 2022, the diameter at breast height (DBH) and the height of the clone Moncalvo in both C and AC treatments were yearly recorded (n_C=14-15; n_{AC19}=3; $n_{AC20-22}$: 14-15). The radial growth of poplar trees was measured during the 4th vegetative season (2021) through dendrometers (Linear Motion Potentiometer, Bourns-3048). The grain yield of common wheat in 2019 and 2021 (var. Arkeos; CGS Sementi, Terni, Italy) and soybean in 2020 (var. P21T45; Pioneer-Corteva), cultivated in the alley have been revealed at 3 distances from tree row, named ½H (+6m), H (+12m) and C (+20m), where H=tree height and C=middle of the inter-row (considered as control), along transects orthogonal to tree rows both at east and west sides. Statistical analysis was carried out with R studio v. 1.4, using the Tukey's HSD test for means separation ($p \leq 0.05$) and t-test ($p \leq 0.05$).

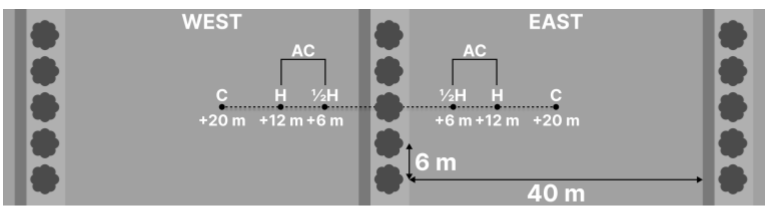

Figure 1. Scheme of sampling points along the transects.

Results

Growth of poplar trees

The DBH of the clone Moncalvo was significantly higher in AC vs. C ($p \leq 0.001$) during the whole measurement period, except for 2020. At the midpoint of expected lifespan (4th year), DBH was +19% higher in AC (24 cm vs. 20 cm in C). Contrarily, the height achieved by Moncalvo at the last year of measurement (2022) was significantly ($p \leq 0.01$) higher in C (15.4 m) than AC (14.3 m) (Figure 2). At the end of 2021 growing season, the annual radial growth of poplar trees was revealed to be slightly higher in AC as compared to C (20.5 and 18.9 mm in AC and C, respectively; $p < 0.1$).

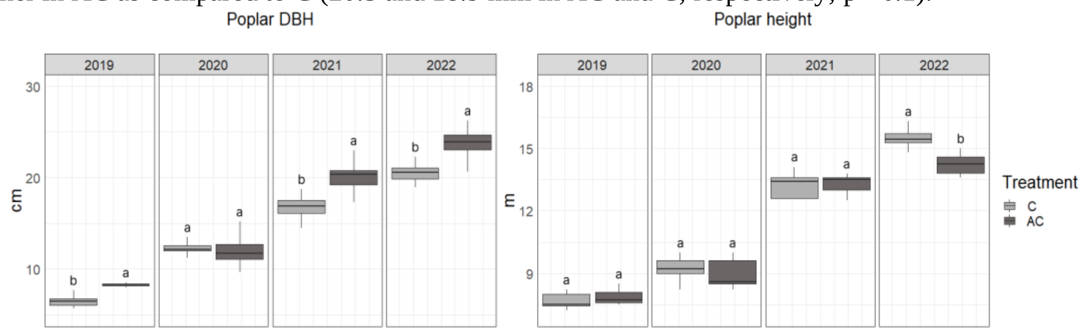

Figure 2. Diameter at breast height (DBH) and height of poplar trees in the poplar grove (C) and alley-cropping system (AC).

Yield of annual intercrops

The grain yield of common wheat was always increased at H distance from the trees as compared to C, particularly in 2021 at west side (+20% vs. C; $p<0.01$), while comparable yields were achieved at ½H position (max -4% vs. C; n.s.). Diversely, soybean was negatively affected the proximity of poplar rows, with a significant yield reduction at ½H (-24% and -43% at the east and west side of the poplar row, respectively; $p < 0.05$) vs. C. At H distance, instead, soybean yield variations vs. C were lower and not significant.

Table 6. Grain yield (g m^{-2}) of the annual intercrops at different distances from the tree row and % of variation (var.) vs. C.

Intercrops	West					East				
	½H	**%var./C**	**H**	**%var./C**	**C**	**½H**	**%var./C**	**H**	**%var./C**	**C**
Wheat (2019)	965.6 - **b**	=	1008.7 - **b**	+5%	965.6 - **b**	1007.0 - **a**	-1%	1038.6 - **a**	+2%	1015.0 - **a**
Soybean (2020)	265.1 - **b**	-43%	448.6 - **a**	-4%	467.8 - **a**	352.3 - **b**	-24%	540.4 - **a**	+16%	464.6 - **a**
Wheat (2021)	612.7 - **b**	+8%	736.2 - **a**	+29%	568.8 - **b**	746.6 - **b**	-8%	1035.4 - **a**	+28%	812.2 - **b**

Conclusions

The cultivation of poplar trees in a widely-spaced alley-cropping system allowed for slightly accelerating the growth of trees as compared to conventional high-population poplar groves, as highlighted by higher DBH and radial growth at the midpoint of tree life-span. Intercropping winter cereals like wheat with a deciduous trees species seems a successful strategy to implement high-productive alley-cropping systems. Instead soybean, as a summer crop, has large overlapping with the growing season of trees, and shading causes significant yield decreases, particularly at the est side.

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Investigating The Effects Of Soil Management In A Long-Term Experiment In Southern Italy: Preliminary Results For The Assessment Of The Soil Hydraulic Properties Using The Beerkan Estimation Of Soil Transfer Parameter (BEST) Methodology

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Introduction

In the last few years, more farmers are moving towards a conservative agriculture based on a set of practices such as zero tillage (or no-tillage), reduced tillage (such as minimum tillage), mulching and cover crops, aimed to prevent soil degradation, to improve water conservation and to enhance soil nitrogen through legumes in rural landascapes (Godfray et al., 2010). Soil hydraulic properties, i.e. the hydraulic conductivity function (HCF) and the water retention curve (WRC), are widely used to quantify the effect of soil management on soil physical and hydraulic properties and therefore, to evaluate the sustainability of the cultivation systems regarding these aspects. In particular, soil system behaviour should be monitored both during the transition period from conventional to conservative management and in the long-term period, thus considering multiyear experiments and repeated measures in space and time. However, soil hydraulic properties measurements are costly and time-consuming (Angulo-Jaramillo et al., 1997); consequently, simple, rapid, cheap and accurate methodologies should be applied, such as the Beerkan Estimation of Soil Transfer parameters (BEST) procedure (Lassabatère et al., 2006), that allows for the simultaneous determination of HCF and WRC. This paper presents the preliminary results of a study aimed at investigating the short- and long-term impacts of soil management and crops on soil physical and hydraulic properties. The dataset will be used also to investigate the spatial variability of key soil variables in a typical Mediterrean agro-environment.

Materials and Methods

The study was carried out in Foggia (41°27'N, 15°30'E), southern Italy, in a long-term experiment of the Council for Agricultural Research and Economics, Agriculture and Environment Research Center (CREA-AA). It started in 2002 and aimed at evaluating the effects of minimum tillage (MT) and no-tillage (NT) on continuous cropping system of durum wheat (*Triticum turgidum* subsp. *durum* Desf.); the treatments were allocated in a randomized complete block design (RCBD) with three replicates. Starting from the autumn 2020, each experimental unit was split into two parts by seeding wheat and, in the spring 2021, chickpea (*Cicer arietinum* L.). The experimental design was thus a split-plot with soil management as main plot factor and crop as the sub-plot factor.

The BEST-procedure for estimating the hydraulic properties of the soil was applied in summer (July) and winter (November) 2021, namely, at the end and at the beginning of two consecutive crop cycles of durum wheat (W) and chickpea (C). This allowed to estimate the hydraulic properties of the soil of MT and NT under W and C, i.e., the water retention curve and hydraulic conductivity function, and to measure ancillary variables, including soil bulk density, soil water content at the time of measurements, soil total organic carbon. A further soil sampling was carried out in summer 2022 to compare two consecutive cropping seasons (2021 and 2022) under comparable soil conditions.

Statistical analyses were performed using the R Studio software. For each sampling time, the effects of soil management and crops were tested by applying analysis of variance according to a split-plot design.

Results

The water retention curves showed relatively high differences, according with time of sampling (i.e., summer or winter), due to the different soil water content at the time of measurement (respectively, 0.16 or 0.35 $cm^3\ cm^{-3}$) and soil bulk density (equal to 1.3221 and 1.0073 $g\ cm^{-3}$ in summer and winter). However, regardless of antecedent soil water content or soil density, discrepancies in soil hydraulic properties between soil management (or crops) can also be attributed to differences in the field conditions at the sampling time, since the soil was recently tilled in winter and relatively undisturbed in summer. As a consequence, the water retention was comparatively higher in winter than in summer season (Figure 1). In accordance with these general soil conditions, BEST returned higher hydraulic conductivity values in summer than in winter. Table 1 shows the preliminary results of the comparison for the winter season.

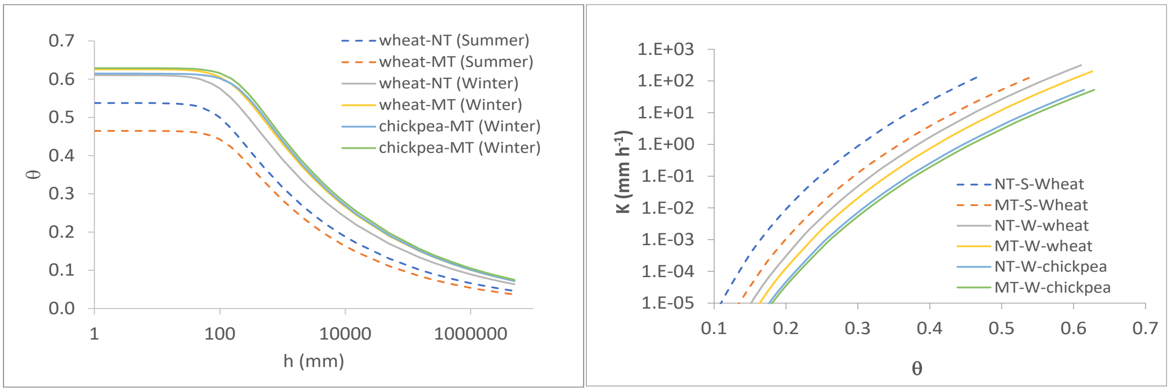

Figure 1. Soil water retention curves and hydraulic conductivity functions (respectively, on the left and right) obtained with BEST under minimum tillage (MT) and no-tillage (NT).

Table 1. Results of the analysis of variance on soil bulk density (*BD*), soil water content at the time of measurements (θ_i) and saturated hydraulic conductivity (K_S) obtained in winter season.

Sourse of variability	BD ($g\ cm^{-3}$)	θ_i ($cm^3\ cm^{-3}$)	Ks ($mm\ s^{-1}$)
Minimum tillage (MT) (mean)	0.9870	0.360	0.035
No-tillage (NT) (mean)	1.0275	0.334	0.051
Pr(>F)	0.10659	0.36827	0.64381
Wheat (W) (mean)	1.0125	0.356 a	0.0715 a
Chickpea (C) (mean)	1.0020	0.338 b	0.0145 b
Pr(>F)	0.30627	0.02131*	0.01772*
MT/NT x W/C Pr(>F)	0.97205	0.76950	0.35842

* indicates differences at $p \leq 0.05$. Within each column, means followed by different letters are significantly different. Pr(> F) indicates the probability value (*p-value*) to decide whether to reject the null hypothesis.

Conclusions

The BEST methodology was able to estimate the soil hydraulics functions through a simple and relatively quick procedure, thus allowing the collection of a large number of samples over space and time. Further information on the effects of the different soil management and cropping systems investigated will derive from the combined analysis of the data collected at the different sampling times and from the computation of capacitive indicators of soil physical quality derived from the water retention curve.

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The Role Of Compost In Mitigating Soil Greenhouse Gases Emissions From Cardoon Cropping Systems

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Introduction

Perennial crops can play a crucial role in climate change mitigation through their potential to increase Soil Organic Carbon (SOC) content and reduce Greenhouse Gases (GHG) emissions. Among these, cardoon (*Cynara cardunculs* L. var. Altilis) is considered a promising crop for its drought tolerance under Mediterranean conditions, its high biomass production and multiple uses of biomass components (D'Avino et al., 2020). The contribution of organic fertilizers to mitigating soil GHG emissions is debated within the context of the effects of agricultural systems on climate change mitigation (Sanz-Cobena et al., 2017). The use of compost as a source of N proved to reduce GHG emissions mitigation in annual crops (e.g. Forte et al., 2017), but there is little evidence of its impact on perennial cropping systems. The hypothesis of this study is that the soil amendment with municipal solid waste compost can mitigate the Global Warming Potential (GWP) of a cardoon cropping system under Mediterranean rainfed conditions. This study aims to assess the impacts of different N fertilization strategies (compost, mineral, mixed fertilization) on the GWP in the first two years of a cardoon cropping system for biomass and oilseed production.

Materials and Methods

The study was conducted in a private farm in Porto Torres, Sardinia, IT (40°48' N, 8°20' E). The climate is Mediterranean, with an annual rainfall of 552 mm, mostly falling from October to March. The soil in the 0-40 cm layer had a loam texture, with 25 g kg^{-1} of organic C content and a pH of 8.1. The field experiment was set as a completely randomized block design with four replications (300 m^2 per plot) per treatment. The following N fertilization treatments were compared: i) High Compost supply, with a target of N for the whole 4-years cropping cycle of 600 kg ha^{-1} of N, entirely supplied at the beginning of the experiment (HC); ii) Low Compost supply, with a target of N of 300 kg ha^{-1} of N, entirely supplied at the beginning of the experiment (LC); iii) Compost supply with a target N of 150 kg ha^{-1} of N at the beginning of the experiment and 45 kg ha^{-1} yr^{-1} of N from Mineral fertilizer supplied at the beginning of each year (CM); Mineral fertilization with 90 kg ha^{-1} yr^{-1} of N at the beginning of each year (MI); iv) unfertilized control (NF). The GWP was assessed by following the approach adopted by Pulina et al. (2018) as the sum between the emission of CO_2 equivalents resulting from soil C balance and N_2O (multiplying emissions by 300) and CH_4 (multiplying by 28) emissions. The soil GHG emissions (CH_4, N_2O, and heterotrophic CO_2 fluxes) were measured through a Closed Chamber technique coupled with GC analyses, with a sampling frequency from daily to bimonthly. The soil C balance input from crop residues was estimated according to D'Avino et al. (2020). The C input from fertilizers was assessed by measuring the C content of the supplied compost through an elemental analyzer. The effect of the interaction between year and fertilization on soil C balance and on the GWP was tested through the Analysis of Variance of fitted linear models. The estimated marginal means of the fitted models were computed to compare means. The significance of statistical computations was evaluated at $P<0.05$.

Results

The year x fertilization interaction significantly influenced ($P<0.001$) the total C input, the C balance, the GWP from N_2O ($P<0.01$), and the total GWP ($P<0.001$), while the simple effects of both year and fertilization significantly affected the C balance ($P<0.01$). The CH_4 emissions were negligible and were not included in GWP computation. The results are reported in detail in Table 1. The highest C input was observed under HC in the first year, mainly due to fertilization, and in LC in the second year, although any significant difference from the other fertilized treatments was observed. The higher C input is mainly associated with higher crop residues in the second year, thus leading to a potentially higher C sequestration. All the cropping systems were in C sink, except for MI and NF in the first year because of a very low C input from residues, which was not compensated by an increase of C stocks from organic fertilizers. The most impacting fertilization systems in terms of GWP were MI and NF during the first year and the NF in the second, while all the compost-based treatments proved to be able to mitigate soil GHG emissions to a greater extent than MI already from the first year, thanks to the increased soil C stocks from organic fertilization.

Table 7. Analysis of variance (*** P<0.001; ** P<0.01; * P<0.05; ns: not significant) and comparisons of mean values of soil C input, C output, C balance (Mg ha^{-1} of C), Global Warming Potential from N_2O, and total GWP (Mg ha^{-1} of CO_2eq) across years and fertilization treatment. Different letters indicate significant differences between interaction levels (P<0.05, Tukey's test)

	ANOVA	C input (Mg/ha of C)	C output (Mg/ha of C)	C balance (Mg/ha of C)	GWP N2O (Mg/ha CO_2eq)	Total GWP (Mg/ha CO_2eq)
	Year	***	**	***	***	***
	Fertilization	***	**	***	**	***
	YxF	***	ns	***	*	***
1	CM	0.93 (0.12) d	1.15 (0.28) ab	-0.22 (0.35) c	-0.13 (0.07) b	0.68 (1.25) a
	HC	6.68 (0.18) ab	1.17 (0.76) ab	5.51 (0.89) ab	-0.14 (0.03) b	-20.33 (3.24) bc
	LC	3.61 (0.11) bcd	1.46 (0.47) a	2.14 (0.4) bc	-0.12 (0.06) b	-7.98 (1.45) ab
	MI	0.48 (0.1) d	0.62 (0.27) b	-0.14 (0.24) c	-0.06 (0.04) ab	0.45 (0.87) a
	NF	0.46 (0.11) d	0.47 (0.29) b	-0.01 (0.27) c	-0.01 (0.01) a	0.03 (0.99) a
2	CM	6.38 (2.59) ab	0.82 (0.1) ab	5.56 (2.59) ab	-0.02 (0.02) a	-20.41 (9.47) bc
	HC	5.09 (2.25) abc	0.68 (0.14) ab	4.41 (2.32) ab	-0.01 (0.02) a	-16.18 (8.49) bc
	LC	7.57 (2.71) a	0.64 (0.24) ab	6.93 (2.6) a	-0.01 (0.01) a	-25.41 (9.52) c
	MI	5.26 (1.13) abc	0.46 (0.15) b	4.8 (1.11) ab	-0.01 (0.01) a	-17.59 (4.06) bc
	NC	2.94 (1.28) cd	0.46 (0.22) b	2.48 (1.43) bc	0.003 (0.003) a	-9.09 (5.22) ab

Conclusions

The studied cropping systems resulted in a C sink regardless of fertilization system, except for the higher emissions observed under FC and MI during the first year. The HC showed the highest potential for GHG mitigation as compost allowed to stock a high C in the soil since the first year. Furthermore, the increased stock of C compensated for the lack of soil C sequestration from residuals associated with the low biomass production observed in the first year. In these cropping systems, the soil C balance resulted as the main factor driving the mitigation of GHG emissions. Although higher N_2O emissions were observed in fertilized treatments than FC, the GWP from N_2O was not affected by fertilization. Moreover, the observed fluxes of N_2O from soil have never been higher than about 0.5 kg ha^{-1} of N_2O, then can be considered almost as negligible and, in any case, lower than the emission factor of 1% (ratio between N emission and N supplied with fertilization) indicated by the IPCC for this typology of organic fertilizers.

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Weed Community Evolution In Durum Wheat - Potato Rotation After 4-year Of Organic And Mineral Fertilization

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Introduction

Nowadays, it is necessary to adopt sustainable practices mainly based on the reduction of chemical inputs in the agro-ecosystems aimed to improve agro-biodiversity and natural biological processes. Mineral fertilization, typical of conventional agriculture, despite having an excellent effect on crop production, negatively affects the stability of agro-ecosystems, promoting specific pests, reducing soil fertility, and compromising the health of the environment. Conversely, the use of organic fertilizers provides benefits on soil fertility through increasing organic matter, improving soil structure and its stability. To reduce the use of mineral fertilizers, the European Commission promotes the application of organic waste in agricultural land. However, to achieving benefits on agro-ecosystems, fertilization management should be evaluated also in terms of weed community composition and evolution. Under sustainable agriculture, the optimal weed specie composition should avoid dominant weed species combined with low overall density. Therefore, it is essential to evaluate sustainable farming practices to meet agro-ecological goals. The main objective of this study was to evaluate how fertilization source (mineral and organic) affects weed specie composition and diversity after four years of durum wheat-potato rotation.

Materials and Methods

The field trials were carried out in Viterbo (45°25'N, 12°04'E, Alt. 310 m a.s.l.) in a soil with the following characteristics (0 - 30 cm soil layer): 63% sand, 22% silt and 15% clay, total organic carbon and nitrogen are 1.07% and 0.12%, respectively, while the pH is 7.1. The experimental site is characterized by a Mediterranean climate. The experimental treatments was two fertilization types [mineral fertilizers (M); organic fertilizer (O) (composted urban organic waste)]. The experiment was conducted using a complete randomized block design with three replications. The plot size was 50 m^2 (10 x 5 m). Organic fertilization was performed in both durum wheat and potato crops by applying 15 t ha^{-1} of organic fertilizer uniformly distributed before the soil preparation. Mineral fertilizers were applied according to the common practices adopted in the study area for both crops. In both fertilization management the same amount of nutrients was applied. In both crops, weeds were manually collected from a 1 m^2 quadrant randomly placed in the middle of each plot at the end of tillering stage and at flowering in durum wheat and potato, respectively. Weed species were classified in functional groups based on the classification proposed by Meiss et al. (2010) (Table 1). Data obtained from the experimental trials were statistically analyzed by analysis of variance (ANOVA). Fisher's protected least significant differences (LSD) test at the 0.05 probability level ($P < 0.05$) to compare the effects was used.

Table 1. Functional groups of weeds based on the classification proposed by Meiss et al. (2010).

Functional group (FG)	Weed characteristic
FG1	Annual broadleaf species, upright
FG2	Annual broadleaf species, climbing
FG3	Annual broadleaf species, rosette
FG4	Annual broadleaf species, other
FG5	Intermediate broadleaf species
FG6	Perennial broadleaf species
FG7	Annual grass species
FG8	Perennial grass species

Results

Figure 1 reported the canonical discriminant analysis (CDA) on functional groups of weed species observed in durum wheat and potato. The CDA analysis showed a tendency towards differentiation among weed communities according to fertilization management. In both crops, organic fertilization source was associated to different type of annual broadleaf species (FG1, FG4), while only in potato crop there was association also with annual broadleaf species (FG2) and in durum wheat, FG5 has the same ordination with organic fertilization treatment. Conversely, mineral fertilization in both durum wheat and potato crops was associated with in the annual grass species (FG7, Fig. 1). The association of grass weeds with mineral fertilization could be due to the high nitrogen availability in the soil after fertilizer application that allow the development of nitrophilous species, while the higher FGs associations observed in O fertilization than mineral fertilization in both crops indicate that there is more variability of the weed specie composition in organic treatment.

Density of annual, monocot and dicot weed species measured in durum wheat and potato crops under organic and mineral fertilization are reported in Figure 2. In according with the CDA analysis, the results reported in the box plot showed that mineral fertilization (M) increase monocot weeds and decrease dicot weeds density compared with organic fertilization treatment. Similar trend was observed in both crops, even if the greater differences was observed in durum wheat probably due to the higher nitrogen uptake of grass weed species than dicot species during the winter season. Under organic fertilization, the reduced soil nitrogen availability allow the establishment of a greater number of dicots species in both crops. Instead, annual weeds increase in organic fertilization in potato crop, while no differences were observed between fertilization source in durum wheat.

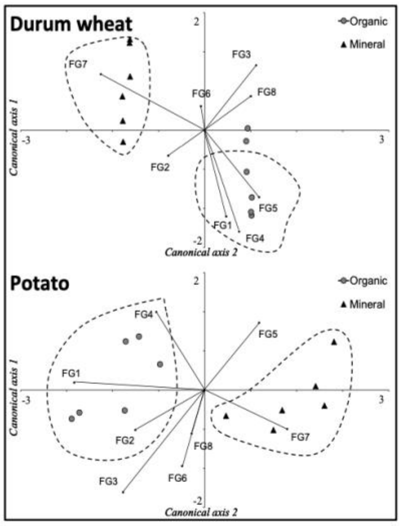

Figure 1. Canonical discriminant analysis (CDA) of the functional groups (FGs) of weed species observed in durum wheat and potato. Data were combined across the growing seasons.

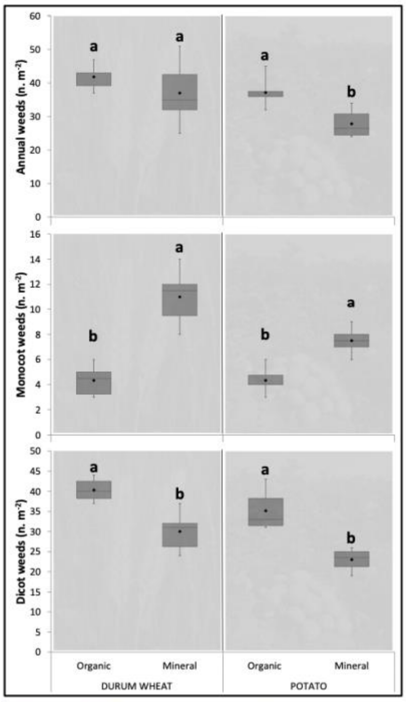

Figure 2. Density of annual, monocot and dicot weed species measured in durum wheat and potato crops subjected to organic and mineral fertilization. Groups with different letter are significantly different.

Conclusions

This study demonstrated that different fertilization sources affect weeds community composition after 4-year of durum wheat – potato rotation. From an agro-ecological point of view, the results showed as organic fertilization (O) could be considered as an alternative to mineral fertilization because it determines a reduction grass species that are notably known as competitive weeds. Further studies should be performed to assess how each management practice can affect the weed community composition, to address farmer's choice to sustainable agricultural practices.

Literature

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Are Compost And Digestate Able To Increase The Soil Organic Carbon In A Short Time?

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Introduction

The conservation and increment of soil organic carbon (SOC) content are critical aspects for the maintenance of agricultural soil health, crop productivity, and agroecosystem stability. Intensive agricultural activity (e.g. intensive tillage and mineral fertilization) so far has determined a decreased SOC content leading to significant losses of agricultural soil fertility (Purwanto et al., 2020). In this context, scientific studies on agricultural practices able to enhance greater SOC storage are of utmost importance. SOC indeed is a major regulator of various processes underlying the supply of nutrients and the creation of a favorable environment for plant growth, besides governing the creation of several soil-based environmental services (increase water use efficiency, nutrient buffering, erosion control, and flood prevention, climate and greenhouse gas regulation, etc..). Management practices that both maintain and/or increase SOC can thereby enhance agricultural soil resilience to ongoing climate changes. Fertilization with organic matrices is considered a valid tool to boost SOC stocks. However, the underlying processes for the SOC increase largely depend on different types of organic matrices and still need to be studied as remain partially unknown (Ye et al., 2019). For this reason, the present study aimed to assess the possibility to increase the SOC in a short time with two organic fertilization matrices (compost and digestate) in a herbaceous crop succession under two irrigation managements (irrigated vs. rainfed).

Materials and Methods

The experimental site is located at the experimentalfarm “Podere Fiorentina” in San Donà di Piave (45°38’13.10’’ N, 12° 35’ 55.00’’E, 1 m a.s.l.), in the north-eastern Italy. It is characterized by a sandy loamy texture with an average TKN and SOC content of 877.8 mg kg^{-1} and 8.5 g kg^{-1}, respectively. The experimental design included 10 plots (from 0.3 ha to 0.9 ha) for a total surface of 6.3 ha where two variables were tested: (i) fertilization: compost (from pruning wastes) vs. digestate (manure); and (ii) irrigation management: drip irrigation vs. rainfed. The present paper presents the first two years of a long-term experiment and considered the cultivation of maize in the first year (2019) and soybean in the second one (2020). The fertilization scheme for each year is summarized in Table 1.

Table 1. Cumulative organic carbon (Corg), N, P_2O_5, and K_2O supplied in the two years of experimentation through organic matrices. * 120 kg ha^{-1} supplied as mineral N

Years	Organic matrices	Corg (Mg ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
1st	Compost	3.3	260	290	350
	Digestate	2.9	250*	220	240
2nd	Compost	4.2	310	140	370
	Digestate	4.8	260	210	380

The experiment included the analysis of SOC, TKN, and NO_3^- content in the soil at the beginning of the experiment and at the end (harvest time) of each crop season. Besides the soil samples, at harvest time the crop grain yield was measured. The data were analyzed using a multifactorial ANOVA and the significance ($p<0.05$) was established with a Tukey HSD post-hoc test.

Results and discussion

Both matrices, after two years of application, showed a significant SOC increase in the first 0-40 cm soil layer. The digestate showed a higher SOC increase (+ 12.3%) from the experiment beginning (48.4 Mg ha^{-1}) compared to compost (+9.6% from the initial value of 49.0 Mg ha^{-1}). The type of organic matrices did not show a significant interaction with the irrigation treatments. However, these latter differently affected the SOC content (0-40 cm layer). The drip irrigation, after two years, showed a significantly higher SOC content (53.4 Mg ha^{-1}) compared to both previous years (43.0 Mg ha^{-1}on average). Under rainfed conditions, no differences in SOC content over time were observed. No significant difference was found for the soil TKN content after the two years, whereas the NO_3^- content significantly increased over time from 1.5 kg ha^{-1} at the beginning to19.8 kg ha^{-1} and the end of the experimental period, with no differences between the two biomasses. The fertilization matrices, in terms of crop yield, significantly affected maize (Figure 1) but not soybean (4.65 Mg ha^{-1}).

The obtained results showed that organic fertilization matrices can differently affect SOC accumulation in relation to their different composition and organic matter (OM) stability. In our study, the digestate had a significantly higher C:N ratio (20.1) than compost (13.2). The greater OM stability of digestate might have determined the higher SOC increment compared to compost. This digestate property indeed, mostly related to the anaerobic digestion processes, is usually reported as a key parameter that fosters its use in agriculture (Maynaud et al., 2017). The compost instead, when originating from pruning wastes, as in our case, usually contains a high amount of mineralizable C (Liu et al., 2019) which might affect the accumulation rate of SOC in agricultural soils. As for the N nutrition, both matrices left a residual amount of NO_3—N in the soil after harvest, determining a potential risk of leaching. This result suggests that the introduction of cover crops might be highly recommended in agrosystems managed with organic fertilization to minimize the risk of winter NO_3^- leaching.

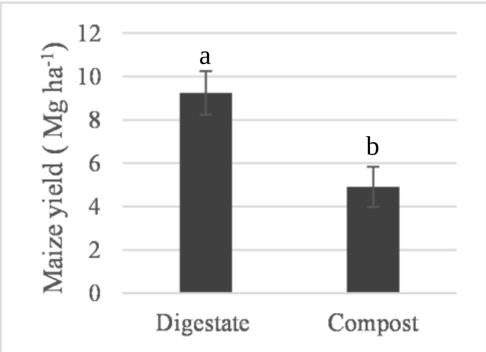

Figure 1. Maize grain yield at the end of the first year of experimentation

Conclusions

Organic fertilization, even with matrices of different origins, is a valid method to increase SOC stocks in agricultural soils but should be used with caution to minimize the potential risk of NO_3^- leaching. In view of this, the present study, which is still ongoing, included the introduction of winter cover crops to both control the potential NO_3^- leaching and to further raise the SOC stock.

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A Preliminary Study Of Industrial Hemp Response To Nitrogen Fertilization Using Hyperspectral Analysis

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Introduction

Industrial hemp (*Cannabis sativa* L.) is an annual herbaceous plant of the Cannabis genus belonging to the Cannabaceae family. It has been an important source of fiber, food and medicine for thousands of years in the Old World.

Many studies have shown that nitrogen fertilization has positive effects on the quantity and quality of hemp biomass production.

The aim of this study was to determine the response of seven industrial hemp varieties to application of nitrogen when is compared with the unfertilized control.

The response was measured by hyperspectral analysis in the range between 350-2500 nm. This analysis is able to record plant physiological changes induced by agronomic management in a fast, sustainable and inespensive way.

Materials and Methods

Cultivation

The study was conducted at the experimental farm "M. E. Venezian Scarascia", belonging to Council for Agricultural Research and Economics - Research Center for Agriculture and Environment (CREA-AA) in Rutigliano (BA), in Southern Italy, between spring and summer 2021. Seven hemp varieties (Carmagnola, Carmagnola Selezionata, Eletta Campana, Fibranova, Fibrante, Codimono, Carmaleonte) were sown at the end of April 2021. Two different nitrogen doses were used: control (0 Kg N ha^{-1}) and fertilized (120 Kg N ha^{-1}). Granular ammonium nitrate (21%) was applied in the trial one month after sowing. During the experiment the plants were maintained in well watered condition.

Hyperspectral analysis

Leaf spectral measurements were performed in the field with Field Spec IV spectroradiometer (Analytical Spectral Devices Inc., Boulder, Colorado, USA) using artificial light able to detect a spectral signature in a range of 350–2500 nm. The instrument was equipped with three spectrometers: one for the 350–1000 nm region characterized by a sampling interval of 1.4 nm, the second for 1000–1800 nm region and the third for 1800–2500 nm, these last two with a sampling interval of 2 nm. Field Spec IV provided spectra with 2151 bands having a resolution of 1 nm. A specifically developed leaf clip covering a spot of 10 mm diameter was related to the fiber-optic of spectroradiometer to a halogen lamp 6.5-watt, as a light source. In this way, the influence of the atmosphere with the measurements was avoided. The values of radiance were transformed into spectral reflectance as the ratio between the radiance reflected by the plant and the one from a standard white reference 10 × 10 mm^2 disk (Spectralon panel, Lab-sphere, Inc., North Sutton, NH, USA).

Determinations

In full bloom, three representative plants (stems) were selected for each variety and treatment. For each plant three leaves were selected in three different plant positions: apical, medial and basal. Then, 9 leaves were collected for each variety and treatment. One measurement on a spot of 10-mm diameter was replicated three times on the leaf selected for a total of 378 spectra collected. The calibration was repeated for each plant, thus, increasing the comparability of measurements.

Results

The mean reflectance of 7 varieties of hemp (*Cannabis sativa* L.) at two nitrogen doses (0-N and 120-N) is represented in Figure 1. Preliminary statistical elaborations were performed to determine the response of varieties to nitrogen treatments at two doses 0 and 120. The paired t-test of mean reflectances showed significance at a level of 5% throughout the range between 350 and 2500 nm (data not shown). Repeated paired t-test in the range 350-750 nm, where the greatest difference between mean reflectances was evident, confirmed the 5% significance found for the entire spectrum (data not shown). Carmagnola shows the highest reflectance in this range (data not shown). This result made the 350-750 nm range suitable for providing information on the response of hemp to nitrogen fertilization. The physiological functions of the plant, fundamental for its survival, are regulated by the carotenoid and chlorophyll pigments, detectable in this wavelength range. Carotenoid content is an indicator of plant stress (Armstrong and Hearst 1996; Demmig-Adams and Adams 2007) and closely related with a particular type of chlorophyll, Chla, in a ratio (Car/Chla) used as an indicator of the ecophysiological state of leaves and plants (Penuelas et al. 1995).

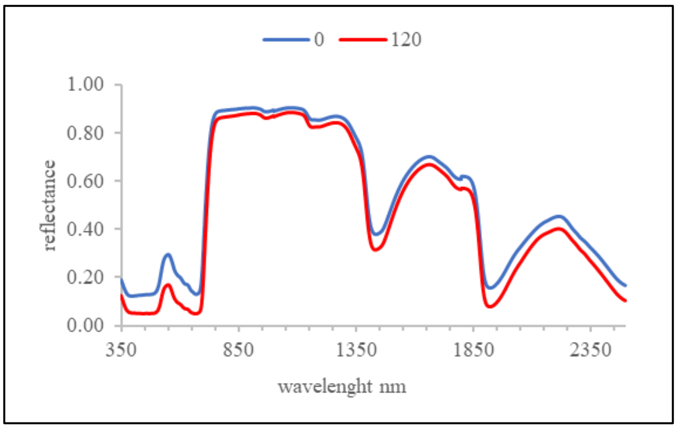

Figure 1. Representation of the mean reflectance of 7 Cannabis varieties at two nitrogen doses: control (0 Kg N ha^{-1}) (blue line) and fertilized (120 Kg N ha^{-1}) (red line).

Conclusions

This preliminary study confirmed the utility that hyperspectral analysis can have in detecting physiological changes in the hemp plants following the application of different doses of nitrogen fertilization. In fact, the detection of a significant response of the hemp varieties to such agronomic management, encourages to monitor in the future the physiological changes in the plant that result from this.

Acknowledgements

This work was supported by UNIHEMP research project “Use of iNdustrIal Hemp biomass for Energy and new biocheMicals Production” (ARS01_00668) funded by Fondo Europeo di Sviluppo Regionale (FESR) (within the PON R&I 2017-2020—Axis 2—Action II—OS 1.b). Grant decree UNIHEMP prot. n. 2016 of 27/07/2018; CUP B76C18000520005.

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An Example Of Proximal Plant Sensing With Hyperspectral Analysis For Precision Irrigation Of Apricot

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Introduction

Apricot (*Prunus armeniaca* L.) is an important fruit crop worldwide, belonging to a large family, the Rosaceae. In global terms, Italy is the third producer.The Emilia-Romagna is the Italian region with the largest surface followed by Campania, Basilicata and Apulia. In Apulia region, the apricot cultivation is prevalently (30.8%) located in Bari province. Apricot, like all crops in the Mediterranean area can suffer from low water availability so it is important a correct irrigation management. In this regard, hyperspectral analysis on apricot leaves was determined. This instrument was considered useful to detect the physiological response of apricot trees subjected to irrigation, because of its characteristics of speed, environmental and economic sustainability.

Materials and Methods

The experimental field was carried out in Putignano (BA), on apricot leaves of 2 varieties (Farlis and Farbaly) for 2 consecutive years (2019 and 2020). Leaves taken from 9 trees of each varieties were analyzed. Each tree was divided in 2 hemispheres, shaded and illuminated. On shaded hemishere, 2 theses were chosen: east, north. On illuminated hemishere, 2 theses were chosen: south, west. Along central lenght of tree 1 thesis was chosen called central. Three scans were carried out with Field Spec 4 on one leaf representing each thesis. Finally, each variety was represented by 162 spectra.
Leaf spectral measurements were performed in the field with Field Spec IV spectroradiometer (Analytical Spectral Devices Inc., Boulder, Colorado, USA) using artificial light able to detect a spectral signature in a range of 350–2500 nm. The instrument was equipped with three spectrometers: one for the 350–1000 nm region characterized by a sampling interval of 1.4 nm, the second for 1000–1800 nm region and the third for 1800–2500 nm, these last two with a sampling interval of 2 nm. Field Spec IV provided spectra with 2151 bands having a resolution of 1 nm. In order to reduce the random noise of the measurements Savitzky–Golay (SG) first-order polynomial algorithm was applied (Riefolo et al. 2020). Spectral data pre-processing was performed with ParLeS software (Rossell et al. 2008). The values of radiance were transformed into spectral reflectance as the ratio between the radiance reflected by the plant and the one from a standard white reference 10×10 cm^2 disk (Spectralon panel, Lab-sphere, Inc., North Sutton, NH, USA). The calibration was repeated for each plant, thus, increasing the comparability of measurements.

Results

In order to assess the water content in apricot leaves, we used the content indices WI and WI/NDVI (Penuelas et al. 1997). There are no significant difference between two years of collection. Comparing the reflectance within varieties among thesis, they are higher in Farlis than in Farbaly, except central thesis. The absorbance peak of water stays in Farlis at around 900 nm, while in Farbaly is slightly shifted at 920 nm, except central thesis (Fig. 1). The water content indeces computed are lower in Farlis than in Farbaly, except central thesis. These three parameters, reflectance, water content indeces and absorbance peak of water should show a lower water content in Farlis than in Farbaly, except central thesis. Also, there are no significant differences by ANOVA among the different theses in Farlis, while in Farbaly there are (data not shown). In fact a visual difference is evident among central thesis and the others, confirmed by a significance of t-test of Student (data not shown). For further confirmation, adding the reflectance of central thesis of Farbaly to all thesis of Farlis, there are no significant difference by ANOVA, resulting in a reflectance overlapping.

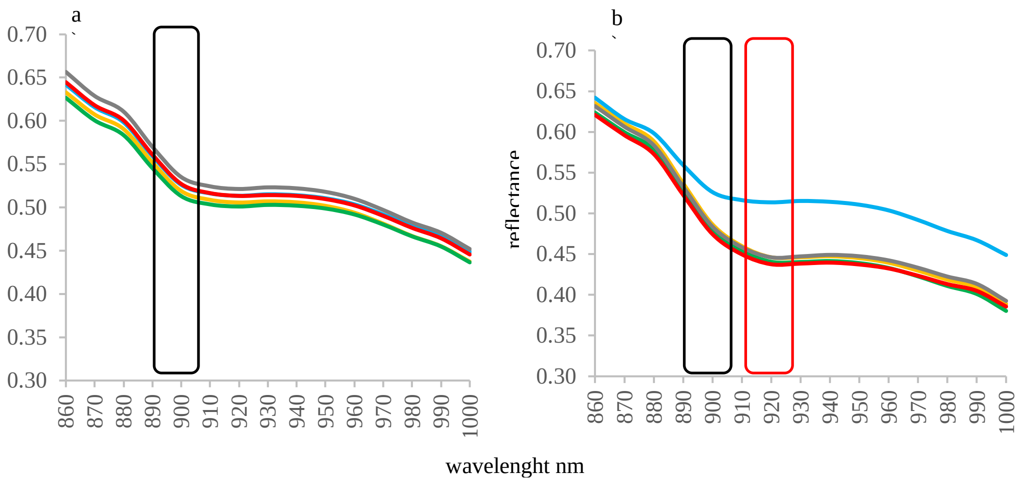
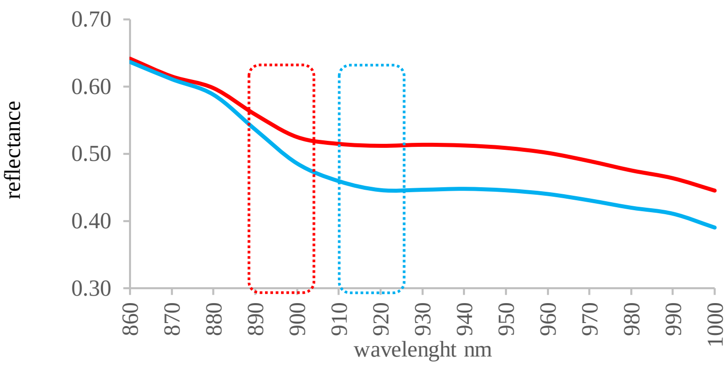


Figure 1. A comparison of the reflectance within varieties Farlis (a) and Farbaly (b) among thesis: east (yellow line), central (blue line), north (green line), west (red line), south (gray line). The absorbance peaks are indicated within the black rectangle (900 nm) and red rectangle (920 nm).

Figure 2. A comparison of water content between Farlis (red line) and Farbaly (blue line). The absorbance peaks at 900 nm (red dashed line) and at 920 nm (blue dashed line).



Comparing reflectance between varieties within theses (Figure 2) the absorbance peaks show a lower water content in Farlis than in Farbaly. These results are confirmed by the water content indeces and by a significant difference between two varieties (data not shown).

Conclusions

In Farbaly a significant difference was found between central thesis and the others. Central thesis of Farbaly overlapped to theses in Farlis. Farlis seems characterized by a lower water content than Farbaly, according to the results of reflectance spectra. This study has provided an example of how to help irrigation management according to the characteristics of precision agriculture.

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Processing Tomatoes Irrigated With Treated Wastewater:The RIUSIAMO Project

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Introduction

The growing need for crop irrigation water and the shortage of fresh water due to increasing uses and climate changes are crucial issues leading to treating wastewater for crop irrigation (Hristov et al., 2021). The capability to use treated wastewater in a Southern Italy irrigation district has been assessed. The Consortium "Bonifica della Capitanata" of Foggia managed a large district with pressure and an on-demand irrigation scheme on 163 kha. In Capitanata plain, some plants of tertiary treatment (managed by Acquedotto Pugliese, AQP) of municipal wastewater allows obtaining an average of 6 Million m^3/year that can be used for agricultural purposes.
The experiment aims to assess the effect of using tertiary treated wastewater for irrigation on processing tomato yield and quality compared to “conventional” water.

Materials and Methods

In the 2021 season, on a private farm in Trinitapoli (Capitanata plain, Southern Italy), an experiment with processing tomato (*Lycopersicon esculentum* Mill.) was set up. A strip plot design with elementary plots size of 9m x 30m, three replications, and two compared treatments, one with the irrigation with “conventional” water (CONV) and one with “treated wastewater” (TWW). TWW effluent was produced from a membrane ultra-filtration public plant near the experimental site. According to Italian law, the obtained water has characteristics for irrigation uses (DM 185/03 and L.R. 8/12). Therefore, a drip irrigation method has been adopted. Each field consisted of five double tomato rows with an inter distance of 180 cm and two driplines with a pitch of 35 cm and 2L/h flow rate.
Wheater stations and sensors were installed for monitoring agro-meteorological variables. Irrigation water, soil, and crop samples were taken to monitor the chemical-physical parameters, possible contaminants (heavy metals), and microbiological indicators (*Escherichia coli* and *Salmonella* spp.). Tomato hybrid "Taylor" was transplanted on 11 June 2021 and was harvested on 5 October 2021. Daily soil water balance and irrigation scheduling were calculated by a “cloud-based” Decision Support System (Bluleaf ™, developed by Sysman ICT company).
From 21 July to 5 October 2021, with a biweekly frequency, plant height, percentage of land cover, Leaf Area Index (LAI), and plant biomass yield were collected. LAI was measured with the LAI-2200 Plant Canopy Analyzer 2200. For the biomass, four plants for each plot were sampled, removing one for each coupled row, on which the fresh weight and the dry weight, separately for plant and fruits, were measured after oven drying at 72°C until constant weight.

Results

Seasonal water irrigation volume was about 7,210 $m^3\ ha^{-1}$ (in 44 watering events), representing a high volume compared to the typical water requirements of processing tomato. This high volume is probably related to the climatic conditions observed during the crop cycle. In particular, the maximum air temperature detected (40-42 °C) both in June (transplanting) and in August (fruit formation stage) significantly increased the crop irrigation water demand.

The crop development showed a LAI similar in the two treatments during the first phase of the growing cycle, while it resulted higher in TWW during the fruit maturity stage (Fig. 1). Total plant biomass at harvest (Table 1) was found to be greater in TWW than in CONV (125.92 *vs*. 92.45 t ha^{-1}), as well as the commercial fruit yield (105.34 *vs.* 75.42 t ha^{-1}). No difference of percentage of marketable fruit dry matter at harvest was observed for the two treatments (Table 1), with a slight superiority in the conventional water (5.6% *vs*. 5.0%, respectively, for CONV and TWW).

Table 1. Tomato biomass and marketable fruit yield at harvest, in t ha^{-1} of fresh and dry weight. Thedifferent letter represents averages statistically different at $P<0.05$ (Student t-test).

Irrigation water	**Total Plant Biomass** (t ha^{-1})		**Marketable Fruit Yield** (t ha^{-1})		**Total Plant** (d.m., % fresh weight)	**Marketable Fruit** (d.m., % fresh weight)
	Dry	Fresh	Dry	Fresh		
CONV	7.90 b	92.45 b	4.19 b	75.42 b	8.63	5.64
TWW	9.82 a	125.92 a	5.37 a	105.34 a	7.72	5.06

These positive effects on plant development and marketable fruit yield observed for the TWW treatment, were likely due to the increased amounts of nitrogen, phosphorus and potassium that they supplied to the soil. Under our experimental conditions, the total inorganic nitrogen (N), phosphorus (P_2O_5) and potassium (K^+) applied to the crop through treated irrigation water were 128 kg ha^{-1}, 108 kg ha^{-1} and 223 kg ha^{-1} for the N, P_2O_5 and K^+, respectively (data not shown). Therefore, this additional N, P_2O_5 and K^+ content provided by the TWW treatment represents approximately 85%, 72% and 110% of the crop requirement, respectively. The microbial quality of the marketable yield, monitorated through microbiological indicators, was not affected by irrigation treatments (data not shown).

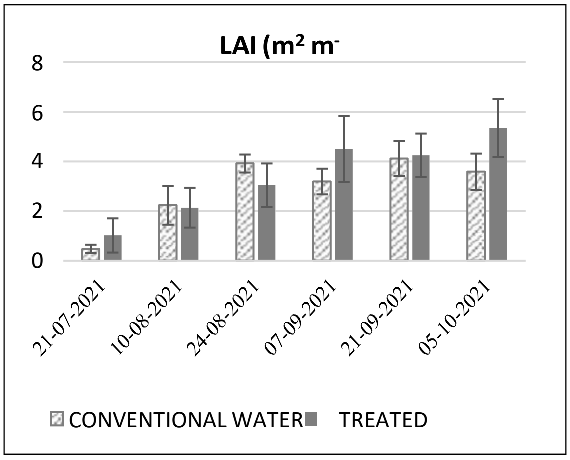

Figure 1. Leaf Area Index of tomato in the two irrigation treatments. Bars indicate the standard deviations.

Conclusions

Even if derived from only one year of experiment, some aspects can be highlighted:

i) positive effects on crop growth and marketable yield were likely due to the increased amounts of nutrients nutrients (i.e. N, P_2O_5, and K^+);

ii) the microbiological quality of the marketable yields was similar between the two compared irrigation treatments (CONV and TWW).

Acknowledgments

This research received financial funding from Puglia Region PSR Mis. 16.2 – “Distretti irrigui per il riuso sostenibile delle acque reflue depurate: modelli organizzativi e tecnologie Innovative – RIUSIAMO” project, CUP: B79J20000070009.

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Soil Tillage Ground Data For Validating Tillage Change Maps Identified By Remote Sensed Data

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Introduction

Conventional tillage involves approximately 66% of the arable land in Europe [https://ec.europa.eu/eurostat]. This practice influences negatively soil water moisture, nitrogen and phosphorus fluxes, and it also increases surface runoff and soil erosion (Foley et al., 2011). For these reasons, the Common Agricultural Policy (CAP) promotes the conservation agriculture (CA) that can prevent and mitigate soil degradation processes (Rinaldi et al., 2022). It is, however, also important to set up appropriate methods to periodically assess the level of adoption of CA at global scale. The availability of Copernicus Sentinel data (S-1 and S-2), systematically acquired over large areas at high spatial and temporal resolution, can enable cost effective tools to monitor tillage/no-tillage practices, which can occur sparsely in space and in time. An assessment of the accuracy of the methodology employed to identify tillage changes is therefore necessary to get reliable products. The objective of this study is to present the last data set collected in an Italian cal/val test site and some examples of tillage change maps at high resolution (e.g. ~100m).

Data set

The Apulian Tavoliere agricultural test site represents an opportunity for large scale calibration and validation of earth observation derived products. A large historical data base about land use, plant and soil parameters is available. National and international collaboration allowed new research outcomes, about land use and LAI. The detection of tilled fields, the accuracy improvement of the spatial and temporal resolution of Surface Soil Moisture (and irrigated fields) represent innovative and useful services in semi-arid environments (Mattia et al., 2022). For this purpose, over the past years, weather, land use, soil moisture, plant biomass and tillage data have been collected at Apulian Tavoliere (Italy, Rinaldi et al., 2020). The collected information were geo-referenced and compiled into a database. The remote sensed images employed for this study are Sentinel-1 (radar IW- GRD products) and Sentinel-2 (optical MSI-L2A products) time series, acquired every 6 and 5 days, respectively. In particular for the tillage change identification, the last ground data set of ground observations have been collected in the framework of the ASI-SARAGRI project. The main periods when tillage operations were observed with on the-road surveys have been from July to October. The following roughness classes, referred to ridges height or clump size, were used: 1 = less than 3 cm; 2 = from 3 to 10 cm; 3 = greater than 10 cm.

The fields percentage for the main tillage kinds observed during the surveys have been:

- Disk harrowing – Roughness classes 1-2 = 37%
- Plowing - Roughness classes 2-3 = 31%
- Chisel – Roughness class 2 = 15%
- Field cultivator – Roughness classes 1-2 = 10%
- Others = 7%.

Tillage change maps

The tillage change maps have been obtained by a double-scale change detection method applied over bare fields to time series of S-1 VH backscatter and S-2 NDVI, this last computed from the NIR (B8) and Red (B4) bands. The VH polarization of S-1 SAR data is particularly sensitive to surface roughness changes due to, for instance, ploughing, harrowing, etc. (Mattia et al., 2011); while S-2 NDVI are suitable to identify bare or scarcely vegetated soils, which are exposed to tillage operations. The two spatial scales are used to separate the contrast between the changes occurring at field scale (due to e.g. tillage changes) and those obtained at medium scale (due to e.g. precipitation) (Satalino et al., 2018).

As an example in Fig. 1 a map of tillage changes taking place between 28 June - 4 July, 2021 is shown. The map identifies a number of areas (red spots) of various dimensions, which are predicted as ploughed fields, after durum wheat harvest. These maps have been assessed comparing with ground truth data derived from local surveys. Preliminary results on historical data show that an overall accuracy of 82% over the Apulian Tavoliere site has been achieved. Anyway, additional accuracy assessment by using new data is in progress.

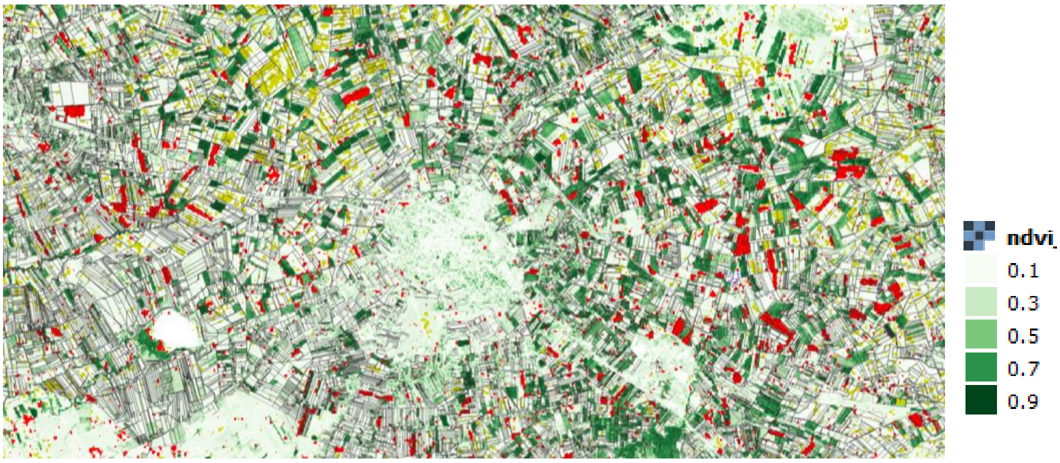

Figure 1. Map (Apulian Tavoliere, Italy) of temporal changes (between 28 June - 4 July, 2021) of VH polarization S-1 data superimposed on a NDVI S-2 image. Rolled fields are in yellow, plowed fields are in red.

Conclusions

The study demonstrated the ability of SAR and optical sensors to monitor tillage at the farm scale, 100m resolution; future research is directed toward validating the NDVI threshold and backscatter variations to be used to monitor changes in soil roughness. This application, from the perspective of the CAP, which requires the adoption of practices related to conservation agriculture, may be useful in identifying tilled fields.

Acknowledgements

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Intercropping Of Wheat And Subterranean Clover To Enhance Soil Quality And Reduce Weed Pressure

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Introduction

Wheat is the most important herbaceous crop cultivated across the Mediterranean Basin, where weed pressure and soil nitrogen availability are the main limiting factors affecting wheat production. To overcome such limitations, an irrational use of synthetic herbicides and mineral fertilizers was adopted by the the middle of the 20th century onward. Nowadays, the exploration of alternative and sustainable agronomic practices for wheat cultivation has become mandatory. Intercropping, is an ancient widely practised technique in smallholder cropping systems thanks to its numerous ecosystem services (Khanal et al., 2021). In recent studies, incorporating subterranean clover (*Trifolium subterraneum* L.) dead mulches into the soil has been found to reduce weed infestation and enhance soil fertility in a Mediterranean apricot orchard (Scavo et al., 2020, 2021). Keeping in mind these considerations, the goals of the present study were to evaluate subterranean clover-wheat intercropping as a tool to i) reduce the weed soil seedbank, ii) weed aboveground biomass and iii) increase the soil mineral N content.

Materials and methods

The trial was carried out in organic farming during the 2020/2021 growing season at the Fontanazza farm, located in central Sicily (Caltanissetta, Italy), in a randomized block design with 4 replications. Treatments under study were: 1) durum wheat (**DW**), 2) durum wheat-subterranean clover intercropping (**DW + INT**), 3) bread wheat (**BW**), 4) bread wheat-subterranean clover intercropping (**BW + INT**). Both wheat cultivars and subterranean clover were seeded on December 2020 at a rate of 230 and 192 kg ha^{-1}, respectively. No fertilizers were provided. In DW and BW, weed control was performed by two shallow choppings in post-emergence. Soil samples were taken twice at 0–15 cm depth by using a 4 cm-diameter steel probe: April (T_1) and September (T_2) for the weed seedbank, March (T_1) and June (T_2) for molecular analyses. For the weed seebank, each soil sample was a composite of five soil cores per plot (each of 0.75 dm^3), collected along the diagonals of the central part of each sampling area. Seed extraction was done by putting soil samples into a metal tube with a removable cap fitted with steel mesh of 250 μm, and the extracted fraction was placed inside Petri dishes, air-dried for 24 h, hand-separated from inert particles and counted as the number of seeds m^{-2} of surface area for each plot. For molecular analyses, once soil DNA was extracted, the quantitative RT-PCR was applied to quantify the genes *amoA* and *nifH*, used as primers for the bacteria *Nitrosomonas europaea* and *Rhizobium leguminosarum*. Threshold cycle (Ct) values, which are inversely proportional to the amount of target nucleic acid in the sample, were determined in triplicate and converted to ng of DNA using the equation derived from the standard curves. To determine the extractable N, 10 g of soil samples were transferred into 250 mL bottles with 50 mL of 0.5 M K_2SO_4. The suspensions were then shaken for 1 h, end-over-end, filtered through glass fibre Whatman GF/A and 0.45 μm Millipore filters, and finally centrifuged for 15 min at 3,000 rpm. The concentrations of NH_4^+ and NO_3^- in the extracts were colorimetrically measured by diffusion. In addition, the aboveground biomass of weeds was determined from a 1.0 m^2 permanent quadrate per replicate. The data were subjected to two-ways analysis of variance (ANOVA) considering the 'treatment' and the 'sampling time' as fixed factors. Means were separated with the LSD test at $\alpha = 0.05$.

Results

Wheat-subterranean clover intercropping significantly reduced weed pressure both in April and June. In particular, averaged over sampling times, DW + INT reduced the soil seedbank size and the aboveground biomass by 72 and 76%, respectively, as compared to DW (Figure 1A, 1B). Similarly, a reduction of 78 and 70% was found in BW + INT with respect to BW. Moreover, keeping in mind that Ct values are inversely proportional to the amount of target nucleic acid in the sample, DW + INT increased by 35% *N. europea* and by 31% *R. leguminosarum* as compared to DW (Figura 1C); at the same time, BW + INT enhanced the amount of *N. europea* and *R. leguminosarum* by 20 and 29%, respectively, as compared to BW. The results obtained by RT-PCR were corroborated by the levels of soil mineral N (Figure 1 D). Indeed, DW + INT increased the levels of NH_4^+ by

131%, of NO_3^- by 63% and of total N by 105%, respect to DW. The same trend was observed for BW + INT, which enhanced the amount of NH_4^+, NO_3^- and total N by 141-159 and 149%, respectively, with respect to BW.

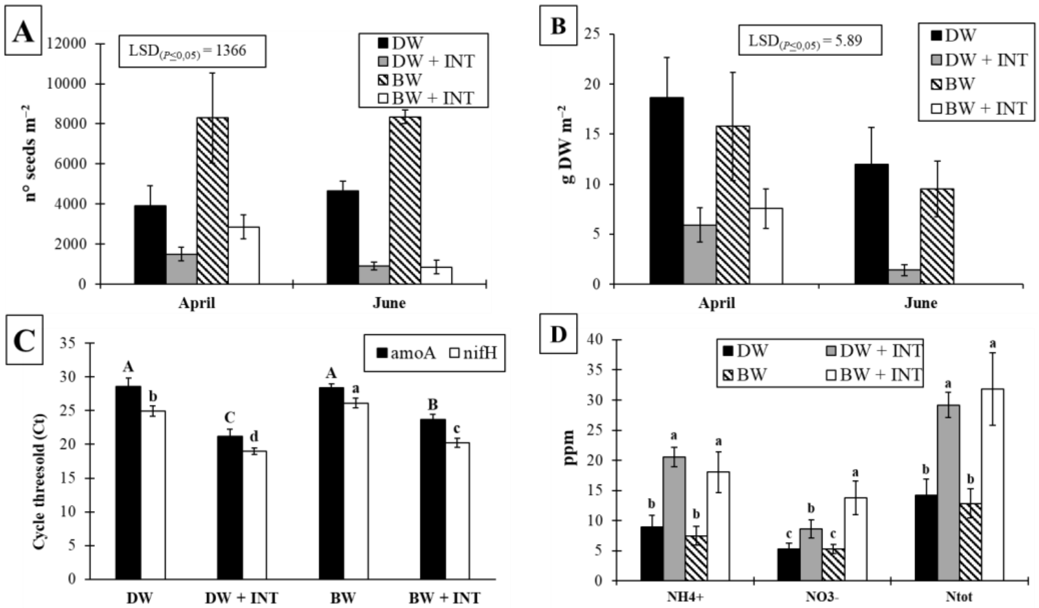

Figure 1. (**A**) Weed soil seedbank (n° seeds m^{-2}), (**B**) weed aboveground dry biomass production (g DW m^{-2}), (**C**) quantitative RT-PCR analysis of *Nitrosomonas europaea* (amoA) and *Rhizobium leguminosarum* (nifH) and (**D**) soil mineral N forms in wheat-subterranean clover intercropping systems. Bars are standard deviation (n=3). The LSD value was calculated with the Fisher's protected LSD test at $P \leq 0.05$. DW: durum wheat; DW + INT: durum wheat-subterranean clover intercropping; BW: bread wheat; BW + INT: bread wheat-subterranean clover intercropping.

Conclusions

The results here obtained demonstrated the efficacy of intercropping wheat with subterranean clover to highly decrease the impact of both potential and real weed flora, while at the same time increasing the amount of *N. europea* and *R. leguminosarum* and, as a consequence, the levels of ammoniacal and nitric soil N. Such sustainable agronomic practice will allow a reduced dependence of Mediterranean wheat cropping systems on external inputs. However, further efforts are needed to evaluate its effects in the medium-long term period.

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Close Contact Between Vermicompost And Mineral Fertilizers In Soil Improves An Early Uptake Of Mineral Phosphorus By Ryegrass

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Introduction

Organo-mineral fertilizers (OMF) are made by combining an organic fraction (OF) with one or more mineral fertilizers to get a product that unites characteristics of inorganic and organic fertilizers (Smith et al., 2020). This type of fertilizer has shown a higher nutrient use efficiency compared to mineral fertilizers alone, even if the OMFs have a low organic C content (Florio et al., 2016); however, it is not clear the interactions between fertilizer grain and soil that causes it. The use of combined ^{15}N and ^{33}P direct labelling methods has ben used successfully to study the fertilizer nutrient uptake by ryegrass (Traoré et al., 2020). The objective of this study was to test if the close contact in a mixture of vermicompost and mineral fertilizer solution that emulates grains of OMFs, affects the Italian ryegrass (*Lolium multiflorum*) nitrogen (N) and phosphorus (P) uptake.

Materials and Methods

A greenhouse pot experiment was performed using a calcareous soil. The treatments were mixtures with two C-N-P ratios, 7.5C-20N-10P and 7.5C-20N-10P. Controls were non-fertilized soil (0C-0N-0P), only N fertilizer (0C-20N-0P), only P fertilizer (0C-0N-10P), N and P fertilizers (0C-20N-10P), plus two treatments with only compost (7.5C-0N-0P and 15C-0N-0P). Each pot contained 1 kg of soil. Vermicompost was added to two holes per pot, and above it potassium phosphate solution (^{33}P = 0.6 mCi), and 4 hours later ammonium sulfate solution (atom% ^{15}N = 5%), were added at a dose corresponding to 300 kg N ha^{-1} and 65.5 kg P ha^{-1}. Ryegrass was harvested after 4 and 8 weeks.

Results

In both cuts, treatments fertilized with both N and P had higher biomass and NP uptake. In the first harvest, 7.5C-20N-10P had higher biomass than 15C-20N-10P and 0C-20N-10P (2.0 g vs 1.6 g and 1.6 g); a similar trend was seen in P uptake from fertilizer (3.1 mg P kg^{-1} soil vs. 2.6 and 2.5 mg P kg^{-1} soil, respectively. Fig 1.). No significant differences between these three treatments were found for N uptake, nor biomass and P uptake in the second cut, although the trend was that by increasing the C content in soil, the NP uptake decreased.

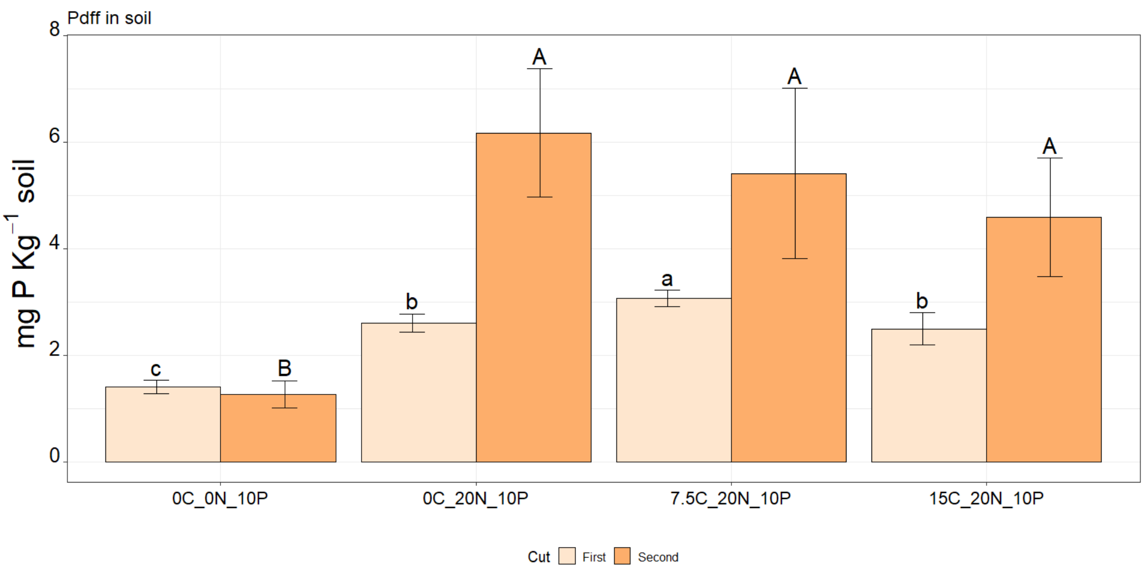

Figure 17. Fertilizer P uptaked by shoots in % of shoot P. Lower case letters indicate differences for first cut values, upper case letters indicate differences for second cut values.

Conclusions

These results show that small amounts of vermicompost are capable of increasing P availability in an early ryegrass stage, probably by reducing the contact of phosphate to soil particles that could fix it. However, increasing quantities of organic C did not result in an increased protection effect on P although there is a trend that shows that with higher values of C, it could be a lower uptake in the short term, probably caused by a microbial immobilization of nutrients.

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Legume Based Rotation In Low Input Agricultural Systems: Sustainability Aspects, Agronomic Traits And Nutritional Features

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Introduction

Current global consumers interest in alternative protein sources to meat has increased worldwide, and it is driven by the preservation of good health, environmental sustainability, and animal welfare. Legumes are one of the largest source of plant-based meat alternatives (PBMAs), and among them, peas (*Pisum sativum* L.) may be identified as nutritious and sustainable protein substitute. Besides being an important source of high-quality proteins, peas contain high levels of dietary fibers, resistant starch, vitamins and minerals, as well as health promoting antioxidants (Udahogora, 2012). In this work the agronomic performance of grain legumes (pea grain) will be evaluated in Italian environment, and the nutritional and health characteristics of peas will be investigated for human nutrition.

Materials and Methods

Trails included the cultivation under organic conditions of one ‘afila’ cultivar of pea and a mixture of three different cultivars of peas. The experimental fields were located in Loiano (44°17'55.3"N 11°21'13.2"E, 800 m a.s.l) and in Ozzano dell’Emilia (44°24'49.7"N 11°28'24.5"E, 200 m a.s.l). Analyses about soil characteristics are in progress. The seeds were purchased from Arcoiris S.R.L (Modena, Italy) and sown at 200 kg/ha of seed. Winter and Spring sowing were chosen for Loiano and Ozzano, respectively. Organic manure (at 100 kg N/ha) was applied as pre-treatment. Trials were all rain fed and weed management was carried out manually. During the cultivation cycle, phenological variables were periodically recorded on a statistically significant number of pea plants until the harvest. The harvest was performed at two phenological stages: green ripening (BBCH-79) and dry ripening (BBCH-89). Grain yield was estimated by randomized sampling and it was reported as Mg/ha. The green ripening peas were evaluated for: free (FP), bound (BP) and total polyphenol (TP) and flavonoid (FF, BF, TF) compounds as previously described by Di Silvestro et al. (2012); anti-oxidant activities according to the DPPH and FRAP assays (Benzie & Strain, 1996; Floegel et al. 2011).The quantification of carbohydrates (Fructose-FRU, Sucrose-SUC, Glucose-GLU, Raffinose-RAF and Galactose-GAL) was identificated by using Megazyme array kits, cat. no. K-SUFRG and Megazyme, cat. no. K-RAFGA.

One-way analysis of variance (ANOVA) in conjunction with Tukey’s honest significant difference was performed for comparing the two growing locations. Significance between means was determined by least significant difference values for $p < 0.05$. Discriminant analysis was applied to the standardized data matrix of FP, BP, TP, FF, BF, TF, DPPH, FRAP, and GLU, SUC, FRU, RAF, GAL recorded in the two growing locations and carried out by using Statistica 6.0 software (2001, StatSoft, Tulsa, OK, USA).

Results

The growth parameters of pea crop (Table 1) displayed a significant higher level in the field of Loiano, due to a longer period of accumulating biomass by the winter pea crops, and a more effective utilization of post-winter water (Prusiński et al., 2016). Green ripening biomass yield was 3363 Mg/ha and 3353 Mg/ha for Loiano and Ozzano, respectively, indicating no significant difference. However, the harvested dry ripening grain showed a significant higher biomass yield in Ozzano (16945 Mg/ha) compared to Loiano (860 Mg/ha). This unexpected result is related to an excessive presence of weeds and high incidence of wild animals in the field of Loiano during the vegetative development of the plant.

		heigh (cm)	branches (n°)	flowers (n°)	pods (n°)
Location	Loiano	60.27 a	15.50 a	2.69 a	3.70 a
	Ozzano dell’Emilia	33.25 b	12.56 b	1.40 b	2.27 b
Variety	monovarietal	51.91 a	13.85 b	2.21 a	3.34 a
	mixture	48.97 a	15.01 a	2.24 a	3.02 a
	LxV	ns	***	ns	ns

Table 1. Different letters within each column: significant different values ($p \leq 0.05$, Tukey’s least significant difference test). The number of stars represent significant differences at 0.05 (*), 0.01 (**) and 0.001 (***) probability level. Ns = non significant. LxV = location x variety

Among nutritional analysis, Loiano samples showed the highest level of polyphenols and antioxidant activity, displaying 143.5 mg of gallic acid equivalents (GAE) per 100g of dry weight (DW), 1.15 mmol/100g of FRAP and 3.27 μmol TE/g of DPPH activity. This trend may reflect plant response to specific abiotic stresses of the growing environment (Klepacka et al., 2011), as occurred in Loiano field. The highest values of GLU and FRU were observed in Ozzano peas (0.31 and 0.41 g/100g DW, respectively), whereas no significant difference of SUC was observed between the two sites. Nonetheless, the content of RAF was significantly higher in Loiano grain (0.93 g/100g), due to its role in the cold acclimatisation of plants, explaining its high content in peas cultivated in a mountainous location and in winter season (Jones et al, 1999).

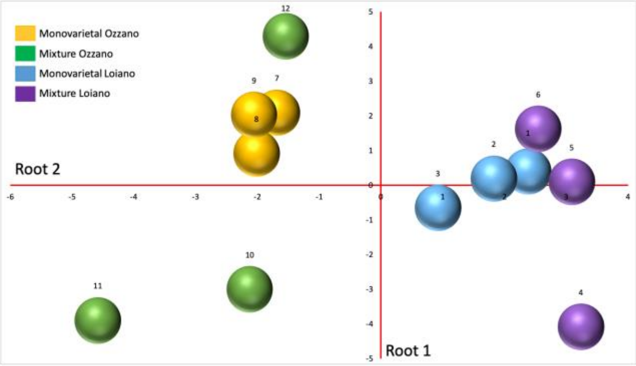

Figure 1. Scatter plot of pea plants cultivated in two different locations according to the health-promoting compound composition defined by the first two canonical functions.

Figure 1 shows a scatter plot of pea samples grown at two different locations defined by the first two canonical functions. The distribution of cases (peas variety and locations) along Root 1 was strongly influenced by sugars (GLU, SUC, FRU, RAF, GAL) and flavonoids (FF, TF); while along Root 2 it was mainly determined by polyphenol content and antioxidant activity (FP, BP, TP, BF, DPPH and FRAP). The multivariate technique showed high discrimination power as indicated by the Wilks' lambda value of each variable (< 0.000001), significant at $p < 0.005$.

Conclusions

The present data showed that location may affect the agronomic and nutritional characteristics of pea crops. Nevertheless, these results are representative of only one year of crop cycle (2021). Hence, future studies are required to further investigate this correlation.

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Sustainable Intensification In Organic Agriculture Through The Use Of Intercropping, Cover Crops And Biostimulants: The GO.BIO Project

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Introduction

The GO.BIO (Gruppo Operativo Bio-agricoltura Innovazione Organizzazione) is an innovation project aimed at supporting the innovation of the organic agri-food supply chains through quality certification and introduction of innovative techniques in Umbria region, specifically addressed to enhance product traceability in the organic farming sector to have a significant impact in terms of added value and employment, environmental quality and biodiversity. The project consists of three innovation transfer tasks: Task 1, the technical innovations at field and farm-scale (agroecological innovation); Task 2, management and supply chain relations; Task 3, smart traceability. This paper includes some of the activities of Task 1, specifically, the inclusion of intercropping and cover cropping, and the use of biostimulants in small grain cereal and in vegetable crops. The application of intercropping and cover crops in organic farm systems could i) improve weed control; ii) increase biodiversity; iii) reduce the risks of nitrate leaching; iv) increase the farm self-sufficiency; v) improve crop yield and quality of products (Gebru, 2015; Kaye and Quemada, 2017). Furthermore, the use of biostimulants could improve i) crop settlement; ii) nutrients availability iii) nutrient and water use effciency; v) crop resistance to biotic or environmental stresses (Parađiković et al., 2019). Preliminary results of the first year of GO.BIO project is hereby reported.

Materials and Methods

Four field experiments (exp#1, #2, #3 and #4) were conducted in organic farms representative of different pedoclimatic areas of inner Central Italy (Perugia province, Umbria) . In exp#1, a temporary intercropping (TIC) of Turanicum wheat *(T. turgidum* subsp. *turanicum* (Jakubz.) Á. Löve) + field bean (*Vicia faba* var. *minor* L.) was sown in a typical hilly area (Torre Colombaia farm) and compared to pure stand Turanicum wheat (Control). At early wheat shooting stage, field bean was incorporated into the topsoil by rotary hoeing (April 2021). At harvest (July 2021), wheat plants were sampled to determine yield components. Exp#2 was carried out in a mountain area near Norcia (1000 m asl; Agricola Dolci farm). A volunteer cover crop (CC) in october was grown until mid April when it was terminated by hoeing. A spring emmer crop (T. *turgidum* L. *spp.dicoccum* (Schrank ex Schübler) Thel.) was sown just after CC termination as well in soil left bare during winter (Control). At harvest (August 2021) the yield components were recorded.

In exp#3, the effect of a protein hydrolysate biostimulant (Bst, Sinergon Bio, CIFO) was tested in durum wheat (*T. durum* Desf.) in a typical farm located in the plain (Le due Torri farm) and in soft wheat (*T. aestivum* L.) in a typical farm in a hilly area (Torre Colombaia farm). Both cereals were sown in November 2020 and they were sprayed 3 times during their growth cycle: namely at tillering, at shooting and at heading. Bst treated wheats were compared to standard fertilization practices applied in each farm (Std) (i.e., 20 t ha^{-1} manure every three years + annual probiotic activator in durum wheat or excipient for soil, EM·1® in soft wheat) and to unfertilised control fields. At harvest (July 2021), the yield and the aboveground biomass partitioning were recorded. Finally in exp#4, the effect of biostimulant (Bst) based on seaweed extract (Macys BC 28, CIFO) was tested in lettuce (*Lactuca sativa* L.), in two greenhouse crop cycles (April to June and September to November 2021). Lettuce plants have been treated two (Bst2) or three (Bst3) times within each crop cycle and compared to untreated plants as a control. At harvest the lettuce yield was recorded. All data were subjected to ANOVA and analysed using R core Team (2014).

Results

TIC doubled the grain yield of turanicum wheat (Exp#1, Table 1), however a proper data analysis was not performed due to the lack of repeated measures in Control. In exp#2, a positive effect of the cover crop was observed in emmer (+22% as compared to Control, Table 2), although such an increase was not statistically significant maybe due to the high variability of the observations (Table 2).

Table 1. Exp#1. Straw and grain yield (t ha^{-1} DW) in TIC and Control durum wheat.

Treatments	Straw	Grain
Control	3.3	1.0
TIC	5.9 (20.9)	2.6 (22.1)

Variability Coefficient (%) for TIC is reported in brackets

Table 2. Exp#2 Straw and hulled grain yield (t ha^{-1} DW) in emmer after cover crop (CC) and in the Control.

Treatments	Straw	Grain
Control	1.0	0.70
CC	2.0	0.80
SED	*0.531*	*0.232*

The application of Bst in small grain cereal (exp#3), slightly increased grain yield (Table 3) as compared to Std (+17% in durum wheat and +33% in soft wheat) and to controls (+11% in durum wheat and +40% in soft wheat). In lettuce, biostimulant was effective in both cycles, and mainly with 3 applications (Bst3), in increasing total biomass (+70% in spring and +60% in autumn) and plant size (+93% in spring and +64% in autumn).

Table 3. Exp#3. Straw and seed yield (t ha^{-1} DW) in BST treated *durum* and *soft wheats* as compared to standard fertilisation protocol.

	Durum wheat		*Soft wheat*	
Treatments	Straw	Grain	Straw	Grain
Control	7.2	5.5	4.1	2.0
Std	7.4	5.2	3.6	2.1
Bst	7.7	6.1	5.4	2.8
SED	0.25n.s.	0.24*	0.19**	0.13**

***, *, n.s. F value significant at P<0.01, 0.05, and not significant, respectively*

Table 4. Exp#4. Lettuce Yield (Y, kg m^{-2}) and single head wheigt (HW, g heads^{-1}) in Bst2 and Bst3 treatments as compared to untreated control in spring and in autumm production cycles.

	Spring cycle		Autumn cycle	
Treatments	Y	HW	Y	HW
Control	5.5	214	1.5	259
Bst2	8.8	386	2.4	422
Bst3	9.3	413	2.4	424
SED	*0.73***	*37.8***	*0.32**	*56.7**

***, *, F value significant at P<0.01 and <0.05, respectively*

Conclusions

In organic farming systems, the adoption of intercropping and cover cropping in small grain cereal production, as well as the use of biostimulants in vegetables like lettuce, might represent a valid tool to improve the yield coupled to some beneficial agronomic and ecosystem services, such as an easier weed control and a lower use of external inputs.

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Can Shading Affect Nitrogen Fixation Of Forage Legume Swards? An Assessment Of B-Value Through The ^{15}N Natural Abundance Method

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Introduction

Tree-based intercropping systems are gaining pace as a land-use strategy to cope with climate change and provide environmental, economic, and social benefits (Kay et al., 2019). The integration of nitrogen-fixing crops between trees can be a solution to increase the land productivity and reduce the reliance on external inputs by increasing nitrogen (N) availability and then both tree and crop growth (Querné et al., 2017). Intercropping perennial legumes with trees can also reduce nitrogen losses, due to the higher amount of N accumulated in stable forms in the soil due to biological N_2-fixation and N root compartimentation (Hernandez-Esteban et al., 2019). On the other hand tree competition for light (Mantino et al., 2021), water (Nasielski et al., 2015) and nutrients (Isaac et al., 2014) eventually could limit legume growth and N_2-fixation (Querné et al., 2017). The isotopic method based on ^{15}N natural abundance is one of the most used methods to assess Biological Nitrogen Fixation (BNF) (Unkovich et al, 2008). The B-value, that is defined as the $\delta^{15}N$ value of a legume when completely dependent on N_2-fixation for satisfying its N demand, is of primary importance for BNF estimations (Nebiyu et al., 2014). The B-value may vary with species, plant age at harvest and growing conditions, e.g. light availability (Unkovich and Pate, 2000). Therefore, the B-value found in literature could not be representative for all legumes and environments, in particular for legumes grown intercropped with trees and thus subject to shading conditions. In this pot experiment we assessed the B-value of several forage legumes, as affected by different levels of simulated shading and grown in N-free medium.

Materials and Methods

A greenhouse pot experiment was established in March 2021 at the Department of Agriculture, Food and Environment (DAFE) of the University of Pisa to determine the B-value for ^{15}N calculations about two forage legume species grown in a field trial located at the Center of Agri-Envirnomental Research "Enrico Avanzi" of the University ofPisa, San Piero a Grado (Pisa) (43°41'6.97"N 10°20'29.22"E), using the same shade treatments.The experimental layout complies with a two-factor randomized complete block (RCB) with three replicates (24 x 22 x 20 cm sizing each pot). The first factor (FORAGE SPECIES) includes three different swards: i) sulla (*Hedysarum coronarium* L.) cv. Silvan, (ii) alfalfa (*Medicago sativa* L.) cv. Messe (iii) ryegrass (*Lolium multiflorum* L.). cv. Teanna, as a non-legume control for natural levels of ^{15}N in the medium. The second factor (SHADE) had three increasing shading levels: s0) the control, representing full light availability, s25) and s50), corresponding to a reduction of potential light availability of 25 and 50% respectively. Pots were filled with river sand, with the aim to avoid interactions between the substrate and N_2-fixation, and before the sowing, sulla and alfalfa seeds were inoculated with their own rhizobacteria. According to Varella et al. (2011), shading was simulated by woody slats, with the same frame of the field trial (0.10 m wide, with a distance between each slat of 0.10 m for s50 and 0.20 m for s25). Slats were placed at 80 cm above bench level after cropsowing. To simulate field conditions, the PAR (Photosynthetic Active Radiation) was supplied using a proper LED-lamps system (https://www.c-led.it) during the day. Sulla and ryegrass failed because they were sown too late, thus their sowing was replicated in November 2021. To assess the level of N_2-fixation of legume crops under the different levels of shade, aboveground biomass was manually mowed four times (from July to October) during the growing season 2021 for alfalfa, and three times (from February to May) during the growing season 2022 for sulla and ryegrass. At the end of the season also the digged roots were collected. The biomass was oven-dried at 60°C, milled and inserted in tin capsules will be analyzed with an elemental CHN analyzer and mass-spectrometer to estimate ^{15}N natural abundance ($\delta^{15}N$) (Peoples et al., 2015).

Results

The preliminary results of alfalfa $\delta^{15}N$ showed not significant shading effect at each mowing time to shoots (tab. 1) and roots, respectively . Only at the second mowing, s25 resulted in significantly higher $\delta^{15}N$ than s50 and s0 respectively (- 0.585 vs -1.161 and -1.182 $\delta^{15}N$), possibly meaning reduced N_2-fixation but it wasn't possible to explain this difference with the shading treatment. Overall, for alfalfa grown in controlled environment, nitrogen fixation wasn't affected by shading.

Table 1. Mean value ± standard error (SE) of alfalfa shoot δ ^{15}N at each mowing time during the season 2020/21.

	mowing			
treatment	**1**	**2**	**3**	**4**
s0	-0.52 ± 0.06 a	-1.18 ± 0.17 b	-1.09 ± 0.14 a	-0.71 ± 0.03 a
s25	-0.71 ± 0.14 a	-0.59 ± 0.11 a	-1.02 ± 0.09 a	-0.82 ± 0.06 a
s50	-0.54 ± 0.10 a	-1.16 ± 0.35 b	-1.28 ± 0.15 a	-0.97 ± 0.07 a

Different lowercase letters indicate significantly different δ ^{15}N shoot values for the Tukey HSD test ($P<0.05$).

Conclusions

The greenhouse pot trial in controlled conditions allowed to get on-station data to use with BNF calculations. Using of the same shading treatment applied in the field it was needed to obtain thorough B-values according to the parallel field experiment conditions. For alfalfa, grown in N-free medium and under controlled conditions, shading did not affect δ 15N, thus, B-value data collected on this pot trial, could be useful to assess BNF for legume swards cropped in Tuscany costal plain, also under tree-based intercropping systems.

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In Field Continuous Measurements Of N_2O And CO_2 Soil Fluxes: Preliminary Results From The LIFE AGRESTIC Project

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Introduction

Measuring soil fluxes of carbon dioxide (CO_2), and nitrous oxide (N_2O) in agricultural soils at high frequency requires appropriate technology. Within the LIFE project AGRESTIC - Reduction of Agricultural GReenhouse gases EmiSsions Through Innovative Cropping systems (LIFE17 CCM/IT/000062), coordinated by Horta srl, CO_2 and N_2O emissions are measured in two pilot farms located in northern and southern Italy (Ravenna and Foggia). In each farm, two cropping systems, conventional (CCS) and efficient (ECS), are compared to assess whether the introduction of legumes in the rotation and the use of a Decision Support System (DSS) is effective in increasing the mitigation potential of the ECS.

Materials and Methods

The AGRESTIC prototype is composed by (i) two GHG monitoring stations one installed in Ravenna (RAV) and the other one in Foggia (FOG); and (ii) an IT infrastructure for collection, management, and elaboration of data from the two GHG stations. The chamber technique is used to estimate emissions of CO_2 and N_2O. Each station hosts two GHG detectors in a shelter. A Local Processing Unit is installed in the shelter to manage the measurement cycle, to store the raw data in a SD card and to transmit data via GPRS. Eight flow-through non-steady-state automatic chambers are connected to the shelter through a double pipe (inlet and outlet) 15 m long. The measurement cycle is set to allow 9 measurements per chamber and per day. The IT infrastructure developed within the project allow to (i) monitor in real time the functioning of the GHG stations, (ii) import the raw data in the database (DB), (iii) calculate fluxes of CO_2 and N_2O and flag the data quality, with scripts running automatically. Additional technical information on the prototype is reported in Volpi et al., 2020. In each demonstrative site the GHG station was placed between two fields, one cultivated with ECS and the other one with CSS, installing 4 chambers per field. Data elaboration to calculate cumulative emissions of CO_2 and N_2O is carried out periodically (about each two months) using a script developed using R (R Core Team, 2022), and aggregating the data considering the soil management (e.g., crop type or bare soil). The steps of data elaboration can be synthetized in the following: (i) extraction of the CO_2 and N_2O fluxes and the dates of the agricultural operations from the DB, (ii) filtering the chamber to calculate the daily mean of the fluxes based on a minimum set of measures available in each day (5), (iii) join of the daily fluxes data with the information on soil management, (iv) calculation of the cumulative emissions for each GHG using a linear interpolation. This work reports the results of the cumulative CO_2 and N_2O emissions estimated in Ravenna and Foggia in the two cropping systems, from the installation of the GHG stations to the harvest of durum wheat in June 2021. Details of the crop sequence are reported in Table 1.

Results

Cumulative CO_2 emissions were 2725 g CO_2 m^{-2} in RAV CCS, while they were 1708 g CO_2 m^{-2} in RAV ECS. In FOG cumulative CO_2 emissions were 1394 g CO_2 m^{-2} in CCS and 1512 g CO_2 m^{-2} in ECS (Figure 1). N_2O cumulative emissions were 470 mg N_2O m^{-2} in RAV CCS, while they were 207 mg N_2O m^{-2} in RAV ECS. In FOG N_2O cumulative emissions were 107 mg N_2O m^{-2} in CCS and 94 mg N_2O m^{-2} in ECS.

Conclusions

Monitoring of soil GHG with the AGRESTIC prototype will allow at the end of the project the evaluation on the potential mitigation of GHG emissions from soil of the ECS. The AGRESTIC database will be used to calibrate and test a model to estimate the N_2O emissions from agricultural soils.

Table 1. Crop sequence, nitrogen applied and crop yield in ECS and CCS in the two demonstrative sites.

Site	System	Soil use	Date start	Date end	Tot N applied (kg/ha)	Crop yield (t/ha)
FOG	CCS	Bare soil	28 Nov 2019	29 Apr 2020	n.a.	n.a.
		Sunflower	30 Apr 2020	17 Sep 2020	56.0	0.4
		Bare soil	18 Sep 2020	30 Nov 2020	n.a.	n.a.
		Durum wheat	1 Dec 2020	25 Jun 2021	222.0	2.9
FOG	ECS	Bare soil	28 Nov 2019	17 Feb 2020	n.a.	n.a.
		Lentil	18 Feb 2020	29 Jun 2020	0	0.2
		Residues	30 Jun 2020	21 Sep 2020	n.a.	n.a.
		Bare soil	22 Sep 2020	30 Nov 2020	n.a.	n.a.
		Durum wheat	1 Dec 2020	25 Jun 2021	98	4.3
RAV	CCS	Bare soil	9 Dec 2019	1 Apr 2020	n.a.	n.a.
		Maize	2 Apr 2020	10 Sep 2020	196.6	8.8
		Bare soil	11 Sep 2020	19 Oct 2020	n.a.	n.a.
		Durum wheat	20 Oct 2020	24 Jun 2021	180.4	6.8
RAV	ECS	Pea	9 Dec 2019	19 Jun 2020	0	4.0
		Bare soil	20 Jun 2020	10 Oct 2020	n.a.	n.a.
		Durum wheat	20 Oct 2020	24 Jun 2021	130.0	7.4

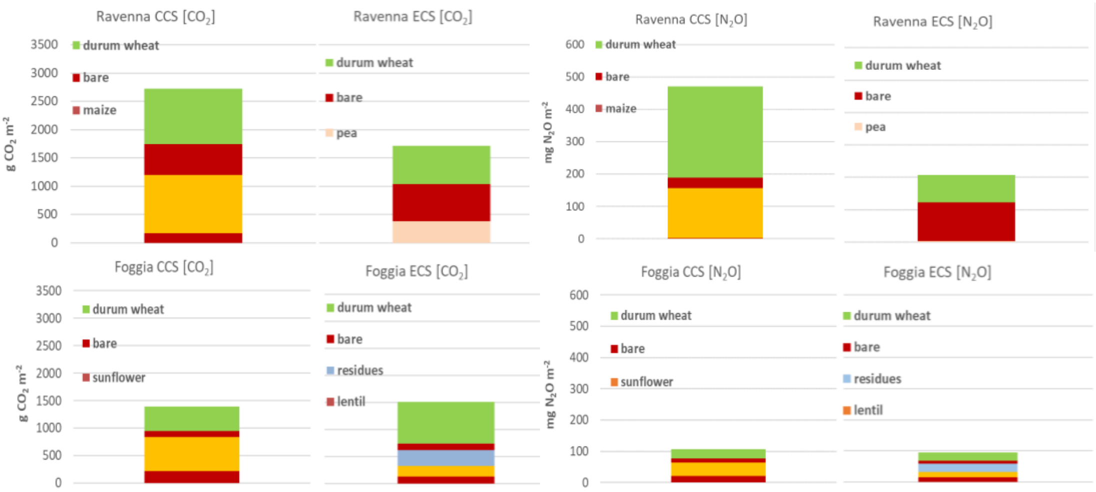

Figure 1. Cumulative CO_2 and N_2O emissions in the two sites and cropping systems.

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Session 4

2050 perspective: where to produce?

ORAL PRESENTATIONS

Low-Input Crop Management For Small Scale Family Farming Of Maize In Semi-Arid Sub-Saharan Africa

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Introduction

Maize is the main staple crop for small scale farmers in southern Africa and Mozambique. Its farming in Mozambique is mostly under rainfed low input, and subject to considerable risk of low yields or crop failure due to sub-optimal water and/or nutrient availability. Substantial decline in soil fertility is another challenge in small-scale farming as it relies mostly on traditional shifting agriculture. In this context, many rural households face food insecurity and therefore, the need to search for sustainable alternatives in crop management arises.

We selected a few management options that are compatible with low input family farming: drip irrigation, rotation with nitrogen fixing crops, adoption of selected local open-pollinated maize varieties and hand tillage for weed suppression.

This study aims to assess the productivity of two maize varieties under optimal and sub-optimal soil water availability, two different soil tillages, adopting monosuccession and rotation with cowpea (*Vigna unguiculata*) in the tropical semi-arid area of southern Mozambique.

Materials and Methods

The field trial was carried out during three growing seasons from 2018 to 2021 (in 2020 the trial has been discontinued due to Covid-19 pandemic) at the "Centro de Desenvolvimento Agrário de Sábiè" (CEDAS) (80 m a.s.l., 25.319 S, 32.265 E).

The experimental design was fully randomized with three replications. The experimental factors were crop variety, with two levels (PAN12 a commercial hybrid, and Matuba a local open-pollinated variety); soil water restitution, with two levels (30% and 100% of potential crop evapotranspiration, ETp); soil tillage with two levels (disk harrowing and hand hoeing); and crop rotation, with two levels (maize after maize and cowpea (*Vigna unguiculata*) - maize).

The sowing took place at the beginning of the dry season (between May and July).

All the plots were fertilizer with 200 kg/ha NPK 12-24-12 before sowing, followed by two top dressing fertilization with 100 kg/ha of urea (46%N) at 30 and 50 days after sowing.

Irrigation was scheduled when the sum of daily ETm corresponded to the volume, subtracting rainfall events from the calculation. The daily ETm was calculated according to:

$ETm = ET0 \times Kc \times Kp$

where ETm is the maximum daily evapotranspiration (mm); E0 is the evaporation of class-A pan (mm); Kp is the pan coefficient, equal to 0.80 in semi-arid environment. Crop coefficient (Kc) was reported for grain maize by FAO guidelines (Allen et al., 1998).

The irrigation volume was calculated according to the following equation:

$V = 0.66 \times (FC - WP) \times \phi \times D \times 10^3$

where V = water amount (mm); 0.66 = readily available water not limiting for evapotranspiration; FC = soil water content at field capacity (27% of dry soil weight); WP = soil water content at wilting point (11% of dry soil weight); ϕ = bulk density (1.1 g cm^{-3}); and D = rooting depth (0.6 m).

When maize grain reached maturity and a moisture content below 15%, harvest was performed. All the plants within a sub-plot of 6.4 m^2 were collected and weighted as fresh aboveground biomass. The grain was separated from the cob and weighted. A sub-sample of the aboveground biomass and of the grain was dryed for the estimation of the dry matter content. The grain yield is reported for the standardized moisture content of 13%. Factorial Anova has been performed using the R software (R Core Team, 2013).

Results

During 2018 growing season, water input was 210 mm and 594 mm for I30 and I100 respectively, of which 51 mm provided by rainfall; while in 2019 growing season, water input was 269 mm and 706 mm for I30 and I100 respectively, of which 64 mm provided by rainfall.

Irrigation was the factor responsible for most of the variability of grain yield in both years, resulting in a highly significant difference between I30 and I100. The highest yields have been achieved under optimal irrigation in 2019, with an average of 8.3 t ha^{-1}, while in 2018 the yields were lower, showing an average under optimal irrigation of 4.32 t ha^{-1}. Grain yields under sub-optimal irrigation were extremely low, with an average of 0.34 t ha^{-1} in 2018.
Variety had a statistically significant effect on grain yield on both years. The commercial hybrid PAN12 was the most productive both in 2018 and 2019, with an average of 2.77 and 4.96 t ha^{-1} respectively. The open-pollinated variety Matuba showed lower yields.
The tillage factor showed a non-significant effect both in 2018 and 2019. However, the disk arrowing before sowing allowed to achieve slightly higher grain yield than hand hoeing.
In 2019, crop rotation showed a non-significant effect on grain yield.

Table 1 – Grain yield (t ha^{-1}) for the different levels of the experimental factors during 2018 and 2019 crop season. The p-value has been calculated for factorial Anova.

Factor	Level	Grain yield 2018 t ha^{-1}	p-value 2018	Grain yield 2019 t ha^{-1}	p-value 2019
Tillage	Hand hoeing	2.06	0.103845	3.92	0.09567
	Disk harrowing	2.60		4.92	
Variety	Matuba	1.89	0.009224	3.33	0.01319
	PAN12	2.77		4.96	
Irrigation	I100	4.32	1.28E-10	8.30	1.89E-09
	I30	0.34		0.54	
Rotation	Monosuccession			4.02	0.14012
	Rotation			5.22	

Conclusions

Irrigation is a key factor in achieving high maize grain yield in the tropical semi-arid sub-Saharan Africa during the dry season; however the adoption of improved genotypes allows to reach the full potential of this crop. Extending the study to further crop seasons will be necessary to assess the validity of tillage management and crop rotation in the studied area.

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A Machine Learning Modelling Framework For Durum Wheat Yield Forecasting In Central-Southern Italy

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Introduction

Durum wheat (*Triticum turgidum* subsp. durum Desf.) is the most economically important cereal crop to produce dried pasta. Forecast of crop yield is one of the most critical research areas in crop science, which allows the development of the decision support systems, optimising nitrogen (N) fertilization and food safety Filippi et al., 2019; Shahhosseini et al., 2020; van der Velde et al., 2019). Several authors have focused on the use of on-farm or remote-sensing data sources. Other studies have focused on publicly available datasets but were conducted on one field site or neglected the potential benefit when N fertilizer is commonly applied. Moreover there are two ways to forecast yield which are deterministic based methods (Basso et al., 2011; Valkama et al., 2020) (DSSAT, SALUS, ARMOSA) and on the other hand, stochastic methods based on field and remote sensing offer a new avenue to find a relationship between the biotic and environmental predictors and can be deployed in vast areas. In this work, four independent field experiments on durum wheat in Central-Southern Italy were used to build scalable machine learning (ML) models to predict the durum wheat yield using fertilization N management, pedo-climatic and remote sensing data.

Materials and Methods

The Four Italian experimental sites have been considered, two located in the Marche region and two in the Basilicata region. All sites have a different experimental design where durum wheat was grown for several years. To follow the whole crop development, three phenological phases have been defined to perform the UAV multispectral image acquisition. Multispectral images were acquired at crop tillering , stem elongation, and anthesis to compute the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge index (NDRE). At crop maturityfor each experimental site, test areas were randomly selected and georeferenced by using the Leica Zeno 20 (Fiorentini et al., 2019). The grain yield (t dry matter ha^{-1}) has been measured in each test area harvesting 1 m long-row. Moreover before the sowing operation it was measured several soil chemical data such as soil texture, soil organic carbon, potassium, N, and the carbon/nitrogen ratio (C/N), were measured for each field under analysis. The data provided to the different machine learning (ML) algorithms are comprehensive in fertilization management, meteorological data such as temperature and precipitation, physical and chemical properties of the soil and vegetation indexes (VIs). Five different algorithms were compared, (1) Linear Model (LM) as the benchmark algorithm, (2) Support Vector Machine, (3) K Nearest Neighbors, (4) Random Forest and (5) Stochastic Gradient Boosting as (ML) methods.

Model transferability was tested by using a dataset that the models were not used during the training procedure (Chollet, 2021). Moreover, the varImp function of caret R package (Kuhn, 2008) was used to visualize the variable importance to describe which covariate contributed most to the construction of the models. Variable importance refers to how much a given model "uses" that variable to make better predictions.

Results

The results show that the grain yield obtained from the four sites are different. GBM and RF obtained significantly lower values of RMSE and MAE and considerably higher values of R^2 compared to LM, SVM and KNN models during the calibration process. The results demonstrate that the GBM and RF models performed better than the other models evaluated in this work, with an RMSE of 0.48 t ha^{-1} and 0.47 t ha^{-1}, respectively, while the LM, SVM and KNN obtained an RMSE respectively of 0.68, 0.69 and 0.65 t ha^{-1}. We have evaluated the models with two different datasets, referred one to the Marche region (Marche 1) and the other one to the Basilicata region (Basilicata 2).The results demonstrate that the GBM model performed better than the other models by obtaining significantly lower values of RMSE and MAE and considerably higher values of R^2 compared to other models during the evaluation phase. While regarding the variable importance analysis, it was observed that the N covariate was the most important feature in all the models except for the linear model. Evaluating the feature importance of the ML models, the three most important variables in descending order are

N, precipitation, and temperature. While considering the feature importance of the best model, such as the GBM model, the five most important features are N Management, Precipitation, Temperature, N soil content and NDVI ZS22.

Conclusions

In this work, we explore the possibility of combining several different source data, such as N management, pedo-climatic and remote sensing data of four Italian experimental sites to train and test five machine-learning algorithms to predict the durum wheat yield.
The GBM was the best ML algorithm, with a 0.58 RMSE of the test set and a lower error metrics variation between calibration and transferability.
It was observed that N, precipitation, and temperature were the features that helped the most to improve the model's accuracy. So they must be considered in future grain yield ML modelling approaches.
The generated model can be scaled for the Marche and Basilicata region, having the soil samples acquired in field and the multispectral satellite images from the Copernicus program and the meteorological data from NASA.

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Camelina ativa An Interesting Oilseed Crop For Marginal Lands

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Introduction

Marginal lands can be used to grow industrial crops in order to feed growing bio-based feedstock demand (such as for vegetative oils) reducing competition for land with food production. Marginal lands are soils uncultivated, or at risk of abandonment, generally affected by adverse biophysical constraints thus economically unsuitable for conventional agriculture. Camelina [*Camelina sativa* (L.) Crantz] has been identified as a particularly interesting multipurpose crop, thanks to its remarkable agronomic versatility and for the wide range of obtainable products, first the unique oil of its seeds (Zanetti at al., 2021). Indeed, camelina is an annual oilseed crop, belonging to the *Brassicaceae* family, native of Europe. Camelina is highly suitable to different European pedo-climates and the availability of both winter and spring types further expand its cultivation area to whole Europe. Additionally, the low agricultural input requirement, the very short growing cycle, and the tolerance toward many biotic and abiotic stresses have made camelina a good candidate for areas considered marginal (Putnam et al., 1993). This study aims to contribute new insights on the possibility of cultivating camelina in fields characterized by steep slope, one of the most widespread and critical marginal constraint in the Mediterranean area (Von Cossel et al., 2019), and it represents one of the first documented trials of growing camelina in marginal conditions.

Materials and Methods

Two trials were carried out at the experimental organic farm of University of Bologna in Ozzano dell'Emilia (44°26' N 11°28' E) characterized by 15% and 25% slope. The experiment has been replicated for three years (Tab 1).

Table 1 Main dates and meteorological parameters characterizing the trials of UNIBO

Crop	Slope (%)	Growing season	Sowing date	Harvest date	Mean T (°C)*	Cumulative precipitation (mm)*
Camelina	25	1	16/11/2018	14/06/2019	5.1	229
	25	2	10/11/2019	05/06/2020	3.6	227
	15		07/01/2020	05/06/2020	5.8	200
	25	3	23/10/2020	25/05/2021	7.1	259
	15		20/01/2021	03/06/2021	10.1	176

'Cypress' Camelina variety provided by Smart Earth Camelina (Canada) was sown at two seeding rates: i) low (LD, 600 seeds m^{-1}) and ii) high (HD, 800 seeds m^{-1}). The seed was drill with double-disk openers in rows 0.17 m apart for LD, conversely the seed was broadcasted and simultaneously covered with soil through teeth harrowing for HD. Sowing depth was the same in the two systems and corresponded to about 10 mm. The crop was never irrigated and cultivated according to organic farming practices.

All the data were subject to the analysis of variance (ANOVA) by using Statgraphics 19 – X64. Means of different treatments were compared using LSD-test ($P \leq 0.05$).

Results

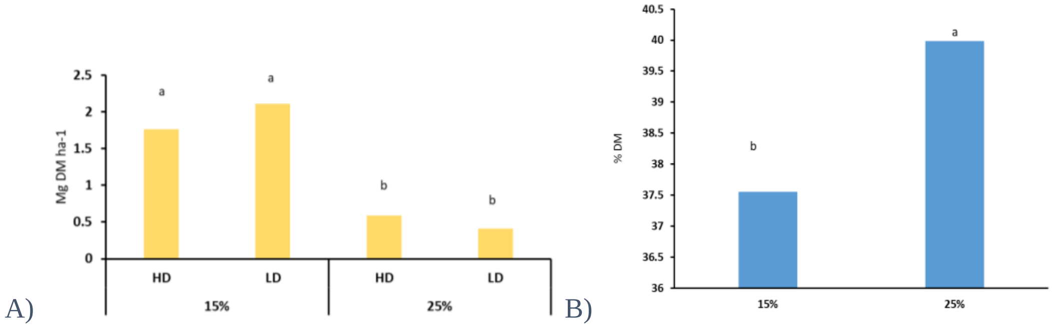

Figure 18. A) Seed yield (Mg DM t ha^{-1}) in relation to slope (15% and 25%) and sowing density (LD= 600 seeds m^{-1} drilled and HD= 800 seeds m^{-1} broadcasted). B) Oil content (% DM) in relation to slope (15% and 25%). Different letters: statistically different means for $P \leq 0.05$ (LSD test).

The seed yield in the steep slope (25%) was 0.42 Mg t ha^{-1} and was significantly reduced compared to the mild slope (15%) that was 1.93 Mg t ha^{-1}. Nevertheless, Camelina was able to maximize seed yields as confirming its ability to adapt to marginal soils with characteristics that are not suitable for agriculture. However, the broadcasted reported the same seed yield of drilled seeding in the both slope.
Concerning of the oil content, the higher value (40%) was highlighted by the steep slope, whereas the mild slope obtained the lower (37.5%). This result was likely due to a balancing effect (less seeds with higher oil content). As evidence of this, a study reported that seed yield decreasing in camelina was balanced by an oil yield increasing (Reinhardt et al. 2021).

Conclusions
Camelina sativa showed interesting potentials to be grown in marginal sloping land without agronomical input. The steep slope reduced the total oil yield of 75% compared with non-marginal conditions field.

Aknowledgments
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POSTERS

Enhancing Pastures Management For Biodiversity Conservation: The LIFE ShepForBio Project

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Introduction

In the last decades, a strong reduction of agro-pastoral practices in grasslands located in many marginal environments, especially in mountain areas, produced deep changes in their vegetation status, altering the important ecosystem services provided by these resources, represented not only by forage production, but also by ecological conservation, landscape heterogeneity, soil and biodiversity protection and space for wildlife (Bengtsson et al., 2019). Reduction of animal grazing or even abandonment of pastures leads to encroachment by woody species which in turn determine reduction of herbaceous open areas (Urbina et al., 2020). Hence, conservative management of these threatened habitats is the core challenge of several European directives and European Agricultural policies (Napoleone et al., 2022). Recovering and/or maintaining these ecosystems by mechanical operations is highly money and time consuming and in some conditions not easily applicable due to geo-physical limitations, thus the application of rational grazing systems represents an effective and sustainable way for conservation (Papanastasis, 2009).

To address these issues, the LIFE project "Shepherds for Biodiversity in Mountain Marginal Areas" (ShepForBio, LIFE 20NAT/IT/001076, 2021-2027), co-funded by the EU LIFE ENV programme and involving different parties (*i.e.* Universities, a National Park, private companies, local authorities) aims at enhancing open grassland habitats (listed in Natura 2000 Directive) located in the Northern Apennines, identifying and applying feasible and sustainable strategies for their recovery and conservation.

Materials and Methods

The study area interests Emilia-Romagna and Toscana regions, almost entirely located inside the National Park "Foreste Casentinesi, Monte Falterona e Campigna" and covering a total surface of about 500 ha. The habitats interested by the project are the following:

- 6210: Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*);
- 6230: species-rich *Nardus* grasslands, on siliceous substrates in mountain areas;
- 5130: *Juniperus communis* formations on heaths or calcareous grasslands.

In these areas, a monitoring protocol has been implemented so as to evaluate *ex ante* and *ex post* benefits from management interventions concerning the conservation status of vegetation and of other associated ecosystem services (e.g. landscape, biodiversity, birds, insects, etc.).

An example of one of the sectors identified is reported in figure 1. After recovery, these areas will be used for grazing under specific management plans which will be developed along the project, so as to ensure the long term maintenance of these habitats.

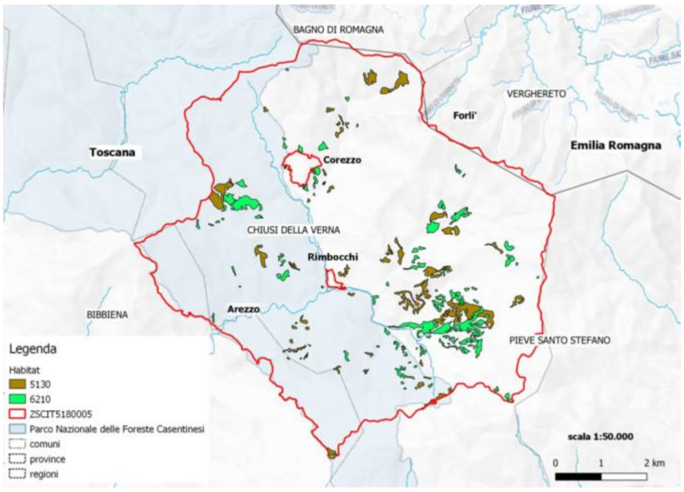

Figure 1. One of the sector ("Valle Santa") interested by the project, with the areas covered by occurring habitats (in brown 5130 and in green 6210) and boundaries of local administrative authorities.

Results

The expected results of the project concern the recovery of specific areas and the improvement of the ecological value of habitats 6210, 6230 and 5130 (in some cases of priority importance) through restoration interventions and long term management. For each site, specific pastoral plans will be developed so as to promote rational management methods based on calculating potential stocking rate, grazing techniques and intensity, eventual mowing in specific sectors, to be adopted by the administrators of the lands. Moreover, specific interventions will be applied to promote pastoral activities: building of infrastructures for pastoral activities (fences, systems to prevent predator damage, watering points) will be implemented to accelerate the return of pastoral and grazing activities.

In addition to these specific conservation actions, other activities to promote and replicate pasture management and its effectiveness for conservation purposes are envisaged within and outside the project area. In particular, several actions will be devoted to education, like the organization of a School for shepherds and breeders scheduled in several training cycles. Actions are also planned for the dissemination of results, both at Italian and international level, and for the promotion of pastoralism as a tool for the conservation of biodiversity in the European context. To make sure that the outcomes of the project will be maintained also beyond ShepForBio duration, a regional strategy for the conservation of the target habitats will be deployed so as to support mountain pastoralism under a set of good practices locally tested in the project and by the provision of agri-environment schemes and specific measures to be encouraged (*i.e.* inside RDP and other programs).

Conclusions

The LIFE project ShepForBio represents a good opportunity to promote the importance of recovering endangered grassland for biodiversity conservation by means of abandoned areas recovering, infrastructure creation for their management, optimal grazing systems identification and application for their long-term sustainability. Concurrently, the project will increase capacity building and awareness on the importance of these ecosystems and their recovery for biodiversity conservation.

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Effects Of Fish Protein Hydrolysate On Lettuce Growth/Developpment Under Controlled Conditions

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Introduction

One of the main components of Mediterranean diet is the consumption of fish. In fact, it is recommended to eat more fish (at least twice a week) than meat due to its high-quality protein content, low fat content, and importance as a source of vitamins and minerals (Prato and Biandolino, 2015). In Liguria region, as other coastal areas, the quantity of fish by-product is high. For a sustainable use of this resource and to increase the sustainability of crops cultivation, the objective of this study was to assess the effect of some foliar plant biostimulants with a fish by-product protein hydrolysate, on the growth and development of lettuce (*Lactuca sativa* L. 'Summerbel') in green-house conditions.

Materials and Methods

Lettuce (*Lactuca sativa* L., cv. 'Summerbel') seeds were sown in Petri dishes. After two days, seedlings were transferred to pots and grown in green-house at 25°C and R.H. 50%. All applied treatments (Table 1) were obtained within the FISH (PSR Regione Liguria) project.

Table 1. Description of treatments applied to lettuce plants.

Treatment	**Acronym**	**Dilution**	**Description**
Control (-)	Ctrl	-	Only tap water
Control (+)=commercial product	CP	1/750	FISH-MIX®, Biobizz
Control (+)=fermented hydrolysed nutrient	Ctrl-FH	1/500	FH FISH 15
Control(+)=basified fermented hydrolysed nutrient	Ctrl-BFH	1/500	BFH FISH 15
Hydrolyzed product	H	1/500	FISH 15ID
Basified-hydrolyzed product	BH	1/500	FISH 15IDB
Fermented-hydrolyzed product	FH	1/500	FISH 15IDF
Basified-fermented-hydrolyzed product	BFH	1/500	FISH 15IDFB

Foliar application of treatments was carried out at a rate of 4 $mLplant^{-1}$ at 24, 31 and 38 days after sowing. Each treatment was applied on 11 plants. Morphological (plant height and number of leaves) as well as physiological (leaf chlorophyll, flavonoids, anthocyanins content and the nitrogen balance index - NBI) parameters were monitored during crop development (31, 38 and 44 days after sowing). In addition, at the 44 day after sowing, the fresh and dry aerial biomass of plants were evaluated.

Results

The BFH treatment increased significantly the number of leaves/plant by 10% and 21% at 38 and 44 days after sowing, respectively, compared to control plants (Fig. 1 and Fig. 2). Moreover, plants treated with BFH were significantly higher than control plants by 18% and 20%, respectively at 38 and 44 days after sowing, respectively. The chlorophyll content of leaves, NBI and fresh dry weight of plants treated with BFH were significantly higher than control plants, at the 44th day after sowing (end of the experiment), by 46, 84 and 38% respectively. However, the flavonoids content of plant leaves treated with BFH product was significantly lower than control plants by 23% at the last measurement (44 days after sowing; data not shown).

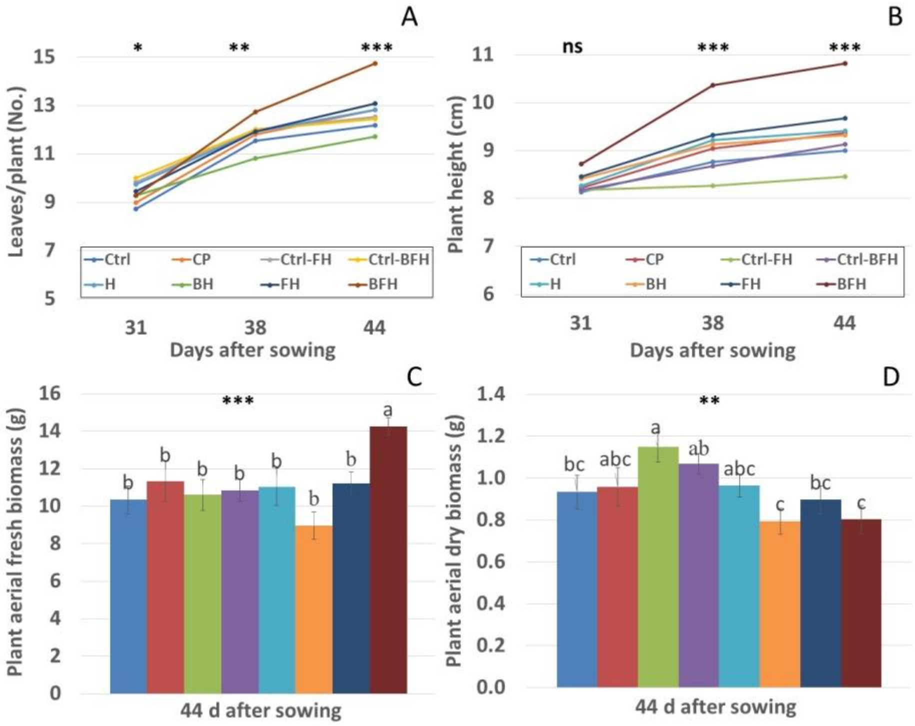

Figure 1. Effect of treatments on lettuce in green-house conditions on number of leaves/plant (A) andplant height (B) 31, 38 and 44 days after sowing, and on aerial fresh biomass (C) and aerial dry biomass (D) 44 days after sowing. Significance levels of post-hoc Tukey's HSD tests are indicated as ns: $p>0.05$; *: $p\leq0.05$; **: $p\leq0.01$; ***: $p\leq0.001$".

Figure 2. Plants of lettuce at the end of the experiment. From left to right: Control plant (ctrl), plant treated with fermented hydrolysed product (FH) and plant treated with basified fermented hydrolysed product (BFH).

Conclusions

In general, plants treated with BFH product have demonstrated a significant higher growth of morpho- physiological parameters, compared to plants treated with other products and in particular water-treated(control) plants.,

Literature

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Influence Of Biostimulants On Legume Crops In Mediterranean Environments

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Introduction

Legume crops have an important role to the agriculture goals such as manage food and nutritional security for the growing population, as a source of plant proteins and with an increasingly importance in improving humans health, mitigate climate change and its adverse effects on the agro-ecosystems fixing atmospheric nitrogen in symbiosis with the soil bacteria rhizobia, increasing soil carbon content, and stimulating the productivity of the crops that follow (Lal, 2015).

In addition, legumes contribute to reduce the emission of greenhouse gases, as they release 5–7 times less GHG per unit area compared with other crops and to increase crop diversity and reduce use of external inputs (Jensen, 2012). The European decline of legume production does not reflect the other regions of the world situation such as Canada or Australia, where legume cultivation has been increasing in these few decades. This decline is also due to low and unstable yields and susceptibility to biotic and abiotic stress conditions. In these areas, monoculture of cereals, has been replaced by extended and diversified crop rotations together with the use of conservation tillage (Stagnari, 2017).

In this context, biostimulants can play a key role in reducing the need of fertilizers and improve condition of crop and their productivity.

Biostimulants includes compounds, substances and microorganisms that enhancing nutrient efficiency, abiotic stress tolerance, plant quality traits, crop vigor, yield and support to uptake of nutrients.

Within these the application of the microbial biostimulants are relatively new on legume crops especially in the Mediterranean environments.

Several studies show how the inoculation with arbuscular mycorrhiza fungi can enhance the potential benefit for legumes production, protein content and improve resistance to several stress (Campanelli, 2013; Meena, 2015; Begum Naheeda, 2019).

Materials and Methods

Field experiment was carried out in Gravina in Apulia, southern Italy (40°53'N, 16°17'E, 456 m asl), during the cropping season 2020-2021. The site is typical of a semi-arid Mediterranean climate, with an average annual rainfall of 450 mm concentrated mainly during October-May, and with an average annual temperature of 13.5°C.

Soil is typical of area, silty loam, with good fertility. Previous crops was durum wheat. Different legumes, sowed in different time, according to the better sowing time of the crop, were compared:

- Faba bean (cv Protabhat 69 and Scuro di Torre Lama) (sowing19/12/2021)
- Peas (cv Aviron and Bluetooth) (sowing 19/12/2021)
- Lentil (cv Crimson and Dupuy) (sowing 06/02/2021)
- Chickpea (cv Rita and Pascià) (sowing 06/02/2021)

A comparison between microbial biostimulants for each legume crop was carried out:

- *Trichoderma harzianum* T-22 (Tric);
- Commercial mix of microorganisms (*Glomus* spp., *Azobacter* spp., *Bacillus* spp., *Trichoderma* spp, *Streptomyces* spp) (Mix);
- Control (no treatment).

The comparison was realised according a strip plot design with each treatment in the main plots and the legume varieties in the sub- plot. At the harvest time were collected productive data.

Results

The effect of microbial biostimulants was positive, even if with variations within species and varieties were recorded (Figure 1).

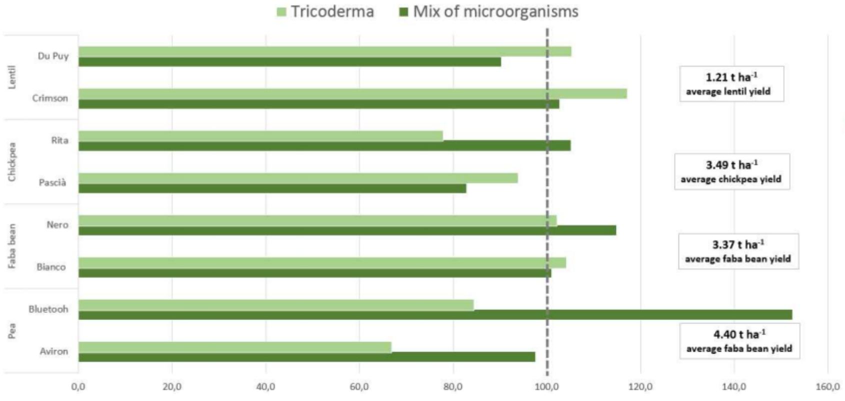

Figure 1. Influence of biostimulants on legume crops

The four species compared confirm the different productive performances in the southern environments. In general, the highest yield was obtained with peas (4.40 t ha^{-1}), chickpea and field beans reached 3.40 t ha^{-1}, while lentils remained at lower yield level (1.21 t ha^{-1}). Considering 100 the value of the production obtained by the single species in the control, it is possible to note the increases and decreases in production obtained from the crops inoculated with Tric or Mix.

The greatest production increase, over 50%, was recorded in the pea crop, and in particular with the Bluethoot variety inoculated with Mix. A highest decrease was recorded with Tric treatment with the Aviron variety (-33%), on the contrary with the same variety the Mix inoculation showed a very slight decrease (-2.5%).

All the microbial biostimulants treatments in faba bean crop showed a yield improvement, even if of modest entity. The greatest increase was obtained with the Scuro di Torre Lama variety inoculated with Mix (15%).

In the case of chickpea, the Rita variety was found to be sensitive to treatment with Mix, recording an increase in production of 5%. In all other cases, a decrease in production was noted.

Increases between 5 and 17% were recorded in the two varieties of lentils treated with Tric, while, with Mix, only the Crimson variety showed a modest increase in production (2.7%).

Conclusions

The use of microbial biosimulants represents a sustainable tools to increase resilience of cultivations in agriculture. These methods appear to be effective for a sustainable field management and to improve the yield performance.

The field experiments demonstrate that the inoculation of selected microorganisms, alone or in combination, can improve the yield response of cultivation in differente species of legumes, especially in the Mediterranean environments considering their positive effect on the control of the water stress.

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Durum Wheat Tolerance Mechanisms To Salinity In The Mediterranean Climate Change Hotspot

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Introduction

Salinity is a problem related to both soil and water quality particularly in arid and semi-arid areas, such as the Mediterranean basin, where the scarce total annual rainfall and high interannual variability impose a state of semipermanent water stress and constantly increase the water demand for irrigated agriculture (Ferchichi et al., 2018; Maggio et al., 2011). Tuel and Eltahir (2020) have classified the Mediterranean area as a climate change hotspot projected to undergo an anomalous reduction in winter rainfall (up to 40%) in the next decades further exacerbating salinity problems. Early exposure to salinity disturbs plant-water relations since it impairs the plant capacity to take up water from soil, thus decreasing stomatal aperture and transpiration, and limiting cell expansion and division. Long-term exposure to salinity determines accumulation of toxic salts (e.g., Na^+ and Cl^-) and reduces beneficial nutrients, thus causing nutritional imbalance oxidative stress, with severe consequences for plant growth, development and survival (Annunziata et al., 2017 and refereces therein). The extent of the damage to crops depends on the concurrent salt toxicity levels and phenological stage sensitivity to salt stress. Seedling stage, for example, is the more vulnerable phase of durum wheat growth under salinity. This species, mainly cropped in Mediterranean type climate, is more sensitive to salinity than bread wheat and yields poorly on saline soil partly due to the scarce ability of durum wheat to exclude Na^+. This latter has, in fact, a damaging effect on cytosol and organelles because it tends to replace potassium in key enzymatic reactions and alter plant metabolism. For this reason, the K^+ to Na^+ ratio is more critical than the absolute amount of Na^+ for the cell performance under salinity (Annunziata et al., 2017). Plant respond to salinity by enacting specific strategies for cell osmotic adjustment and control of ion and water homeostasis to minimize stress-damage and to reestablish growth. A ubiquitous mechanism that plants have evolved to adapt to salinity involves toxic ions sequestration in the vacuole, as cheap osmotica, and synthesis and accumulation of compatible compounds for osmotic adjustment and oxidative stress protection in the cytosol (Carillo et al., 2008). Since it is unquestionable that the elucidation of these physiological responses to salinity is instrumental to improve salt tolerance, the aim of this study was to clarify the crucial mechanisms directly involved in salt stress tolerance in durum wheat seedlings.

Materials and Methods

Durum wheat seedlings (*Triticum durum* Desf. cv Ofanto) were grown in hydroponics. On day six of hydroponic culture 10 mM nitrate was added and starting from day 10 of culture, the hydroponic medium was supplemented with 50 mM NaCl, increased to 100 mM NaCl on the day 11. Data presented in the results were determined in shoot tissues harvested at the end of the experiment (20 d of culture). Growth and analyses were performed as described in Woodrow et al. (2017), and Gabriel et al. (2021)

Results

In durum wheat plants under salt stress and low light, the salt dependent stomata closure decreased the CO_2 exchange and the enzymatic CO_2-fixation activity, determining over-excitation of the photosynthetic apparatus and production of ROS. In these conditions, proline was rapidly synthetized at the onset of stress in older tissues, while glycine betaine (GB) started accumulating after prolonged stress, especially in young tissues even at low nitrogen nutrition. GB, together with proline, contributed to scavenge ROS, osmoregulate the cytosolic compartments, stabilize membranes and buffer redox potential. However, simultaneous salinity and high light inhibited GB synthesis, while fine-tuned relatively few selected metabolites of primary metabolism, in particular GABA, amides, minor amino acids and hexoses, in addition to proline, which were probably the main responsible for the osmotic adjustment, the biochemical pH-stat, the assimilation of the excess of ammonium and the scavenging of ROS. Moreover, the same plants accumulated also oligosaccharides of the raffinose family known to serve as desiccation protectant in seeds, as transport sugar in phloem sap and as storage sugars. The results are summarized by the principal component analysis (PCA) in figure 1.

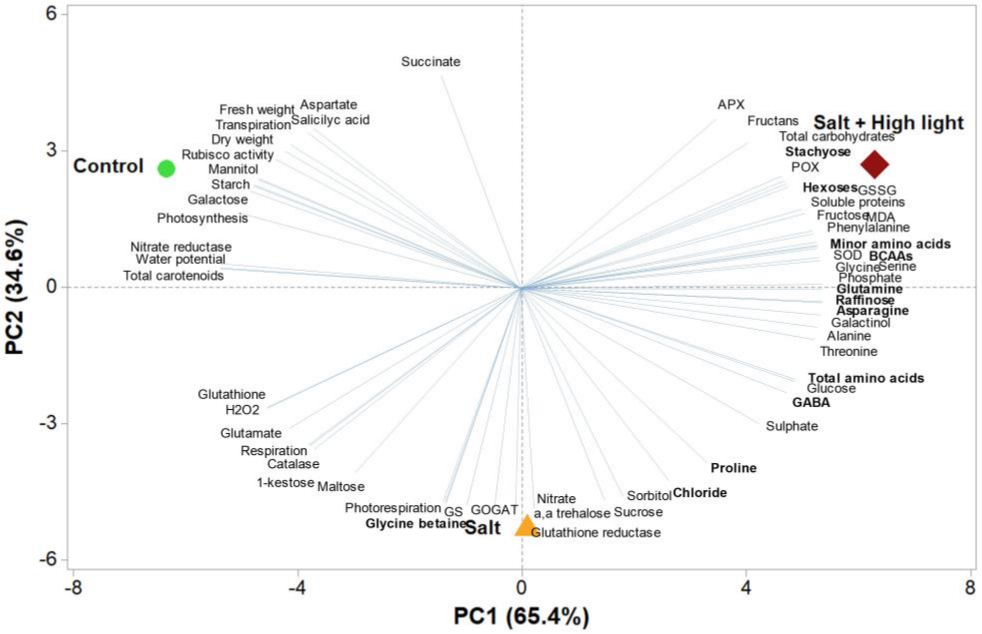

Figure 1. Principal component analysis (PCA) of the biometric traits, physiological and biochemical parameters analysed in durum wheat seedlings in control, salt stress (100 mM NaCl) and/or high light (900 µmol $m^{-2} s^{-1}$ PAR).

Conclusions

Durum wheat plants can enact ubiquitous mechanisms involving the synthesis and/or accumulation of small molecules (< 500 Da) which directly or indirectly trigger cell osmoregulation, homeostasis and protection against oxidative stress. Finding strategies to amplify the salt stress response also using exogenous small natural or synthetic bioactive molecules, derived from human or animal research, could be a promising strategy to ameliorate toxicity symptoms induced by salinity or further eliciting plant tolerance to salt stress.

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Effect Of Preceding Crops On Organic Processing Tomato Grown In Mediterranean Environment

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Introduction

The global market for organic processing tomatoes has been overgrowing in Italy. However, the yield gap between organic and conventional systems represents the most significant limitation to the further expansion of organic farming. Crop rotation is considered the keystone of organic farming management, as it contributes crucially to maintaining soil fertility (Karavidas et al., 2020) and sustaining crop production. Furthermore, as reported by IPCC, the ongoing climate changes negatively impact agricultural activity, especially in Mediterranean environments and particularly for the spring-summer crops (Lange, 2020). As part of the ongoing project *Soft (Smart Organic Farming Techniques* financed under the PSR Puglia 2014-2020 funds, Measure 16 - Cooperation, Submeasure 16.2), the present study focused on the effect of different preceding crops on the yield, quality, and water use efficiency (WUE) of processing tomato grown in two different environments.

Materials and Methods

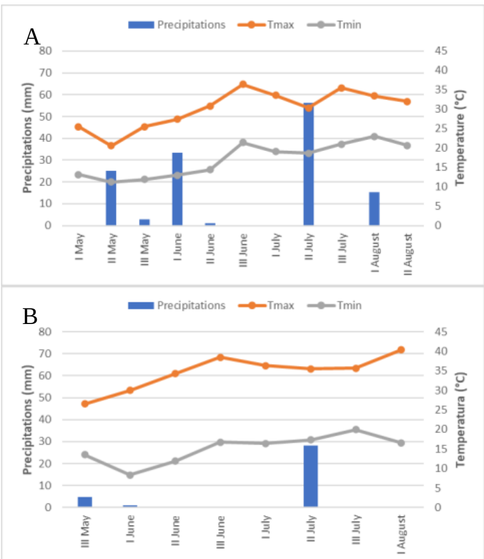

Figure 19. Weather condition at Daunian Subappennine (A) and at Tavoliere delle Puglie (B)

Field experiments were conducted in 2021 in the Apulia region, Southern Italy, on the hill area of Daunian Subappennine (altitude: 217 m a.s.l., latitude: 41°23′47″N, and longitude: 15°20′04″E), and the lowland area of Tavoliere delle Puglie (altitude: 69 m a.s.l., latitude: 41°18′59″N, and longitude: 15°57′51″E) on a clay loam soils (USDA, 1999), under organic cultivation system. The processing tomato (*Lycopersicon esculentum* Mill.), hybrid 'Taylor' (Nunhems Italia Srl), was cultivated after two preceding crops: durum wheat (*Triticum durum* Desf.) and faba bean (*Vicia faba* L. var. minor Beck.). Plants were transplanted on May 10 at Daunian Subappennine and on May 12 at Tavoliere delle Puglie in paired rows with a plant density of 2.7 plants m^{-2}. The amount of water to supply at each irrigation event was determined using the cloud-based decision support system Bluleaf™ (Sysman Progetti e Servizi Srl, Rome, Italy). This system is based on the data collected by wireless sensors (AgriSense™, Netsens, Florence, Italy) for real-time acquisition of weather and soil moisture data at 0.3 m and 0.6 m depth, which are used to compute daily ETc. Daily reference evapotranspiration (ETo) was calculated using the Penman-Monteith equation, and the crop coefficient (Kc) values were derived in an environment similar to our experimental site. ETc was estimated as ETo × Kc, following the FAO two-step procedure. A drip-irrigation system was used, with a single plastic pipe arranged in the middle of each paired row. The amount of water supplied in each irrigation event was measured by flow meters placed on the main irrigation lines of the experimental fields. During the crop season, standard organic agricultural practices were performed. The crop was hand-harvested in the two locations when the ripe fruit rate reached about 95% (August 22 and August 10, 2021, at Daunian

Subappennine and Tavoliere delle Puglie, respectively). The marketable fruit yield was measured on six plants per plot, and the total soluble solids content (°Brix) was assessed on ten fruits $plot^{-1}$. Finally, the ratio between marketable yield and the total water received by the crop (irrigation + rainfall) was used to define the water use efficiency (WUE; kg m^{-3}). The field experiments were arranged in a randomized block design with three replicates in the two locations. Daily meteorological conditions were recorded by two weather stations placed close to each experimental field (figure 1). Tukey's tests detected statistically significant differences among means at the 5% probability level after ANOVA.

Results

The total amounts of the irrigation water utilized during the tomato crop cycle differed between the two environments under study, corresponding to 5836.0 and 7879.6 m^3, at Daunian Subappennine and Tavoliere delle Puglie, respectively. This relevant difference could be attributed to the higher temperature recorded in the lowland environment ($Tmax_{average}$=33.5°C), which caused the higher evapotranspiration, together with the lower precipitations (43mm respect to 134 mm in Daunian Subappennine).

Table 8 Effect of environment and preceding crop on marketable yield and WUE

	Marketable yield t ha^{-1}		WUE kg m^{-3}	
	Durum wheat	Faba Bean	Durum wheat	Faba Bean
Daunian Subappennine	68.5±0.21^{B}	101.0±0.29^{A}	9.5±0.21^{B}	14.1±0.29^{A}
Tavoliere delle Puglie	54.8±0.25^{C}	68.0±0.20^{B}	6.6±0.25^{D}	8.2±0.20^{C}

The preliminary results obtained during this first experimental year showed that the application of crop rotation with legume as the preceding crop significantly increased the marketable yield of the tomato crop in the organic system. This effect was most noticeable in Daunian Subappennine (+ 47%, with respect to +24% in Tavoliere delle Puglie), where better termo-pluviometric conditions occurred. In the organic systems, the legume introduction into the crop rotation acts as an N source and seems to mitigate the effect of adverse climatic conditions on the yield, as occurred in Tavoliere delle Puglie. This was also confirmed by the higher WUE obtained when Faba bean was the preceding crop. Moreover, the higher WUE values were shown in the Daunian Subappennine environment, where the higher yield values were obtained, despite the lower water amount received by the plants (Table 1). Finally, in this environment, the crop's qualitative respons was better than in the Tavoliere delle Puglie, since the °Brix value was significantly higher.

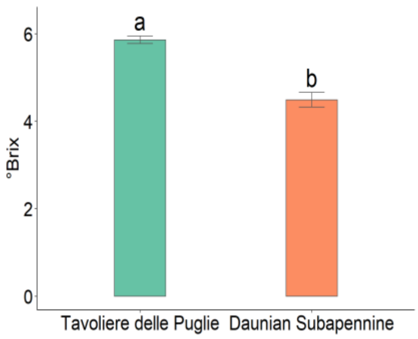

Figure 2 Effect of environment on °Brix

Conclusions

Our study confirmed the importance of crop rotation with legume in the organic systems, particularly in processing tomato, increasing yield, quality, and water use efficiency. Furthermore, in years particularly dry and hot, the hill marginal areas appear more productive than the lowland environments until now considered more suitable for the cultivation of processing tomato. This role acquires even more importance in the light of ongoing climate change, even if multi-year studies are necessary to go deep inside this aspect.

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Tolerance Of Safflower To Different Concentrations Of Heavy Metals Polluted Soil

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Introduction

Soil contamination with heavy metal caused by anthropogenic activity gives rise to a number of environmental problems such as desertification, contamination of water resources and/or contamination of food crops, which can lead to serious health problems for humans directly or indirectly and to disturbance of the ecosystems. To avoid these problems, soil decontamination becomes essential to guarantee land availability in the future. Several methods to decontaminate soil can be used. Among all the available techniques, phytoremediation is a sustainable and renewable technique that utilizes plants to remediate the contaminated site (Ciaramella et al. 2021).

To optimize phytoremediation application in heavy metal contaminated soils, the used crops need to fulfill several conditions: the tolerance to heavy metals, high production of biomass, deep and extensive root systems, well-known agronomic techniques, and low request for agronomic input. In this way, the cultivation of energy crops for phytoremediation is a valid alternative that promotes the production of a renewable and sustainable feedstock for energy while remediating the soil.

In this scenario, *Carthamus tinctorious* L. an oilseed specie capable of grown in stressful conditions, such as drought and salinity, appears suitable to promote soil remediation and at the same time is indicated as a possible crop dedicated to the production of biomass for energy (Ciaramella et al. 2022).

In this experiment, safflower was tested in contaminated soil with different heavy metals (zinc, cadmium, lead, and nickel) in different concentrations.

Materials and Methods

The present experiment was carried out during March-November 2020 at the University of Catania. Safflower was grown in pots of 12 kg each, previously contaminated with heavy metals. Comparing to an untreated control (C), two factors were studied: four heavy metals (Cd, Pb, Ni and Zn) and two soil concentration 4 (Cd4) and 8 mg kg^{-1}(Cd8) of Cadmium, 450 (Zn450) and 900 mg kg^{-1}(Zn900) of zinc, 110 (Ni110) and 220 mg kg^{-1} (Ni220) of nickel, 450 (Pb450) and 900 mg kg^{-1}(Pb900) of lead. The four heavy metals were added to the soil using nitrate of cadmium [$Cd(NO_3)_2$], nitrate of lead [$Pb(NO_3)_2$], nitrate of Zinc [$Zn(NO_3)_2$], and nitrate of nickel [$Ni(NO_3)_2$]. Pots were arranged in a completely randomized design with three replications.

Nitric metal salt per pot was calculated by multiplying the molecular weight of the salt by the grams of metal contained per pot and finally dividing by the molar weight of the metal. The irrigation was kept in optimal conditions for the whole crop cycle.

Plants were harvested at full seed ripening stage, they were collected, and the fresh weight was recorded. The subsamples were oven dried at 65 °C until constant weight. Regarding the heavy metal's concentration in plants, the samples was reduced in ash in a furnace at the temperature of 550 °C for 5 hours, late the digestion was performed using a solution of nitric acid and after the extraction the heavy metal present in the solution was measured by atomic absorption (AAnalyst 200 AA Spectrometer).

The tolerance index was calculated by the ratio between the total biomass grown in contaminated pots and the biomass grown in non-contaminated pots.

Results

The productivity of dry biomass yield was express in percentage, and the untreated soil (C) was used as a reference. The graphic showed that nickel, cadmium and zinc affected the yield, while the presence of lead in the soil did not affect the productivity of safflower. In particular for lead treatment in the concentration of 450 and 900 mg Kg^{-1}, the yield increased by 20.9% and 12.6%, respectively. In nickel contaminated treatment, there was a reduction of yield in both concentrations, with a biomass yield reduced by 21.1% for Ni110 and 38.7 for Ni220. Whereas in cadmium concentration treatment, the biomass yield was not affected in the low concentration (Cd4), but in the high concentration (Cd8) there was a reduction in the biomass yield by 10.1%.

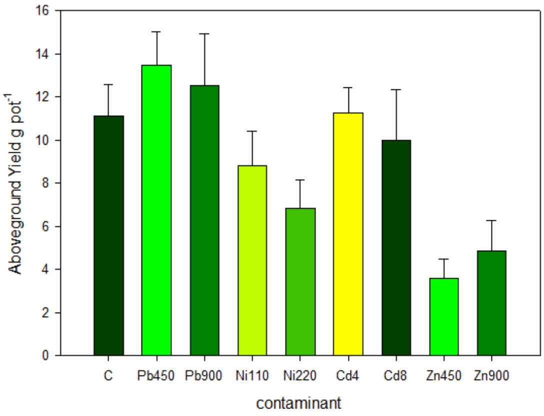

Figure 20. Aboveground biomass in g pot^{-1} in relation to the studied treatments

The zinc concentration treatments determined a high reduction of the yield compared to control with a loss of 67.8% and 56.4% for Zn450 and Zn900 respectively.

The tolerance index was calculated in order to evaluate the susceptibility of plants in the heavy metal soils. Safflower showed great tolerance in lead contamination, with tolerance index up than 1 and equal to 1.21 and 1.13 for Pb450 and Pb900.
In nickel contaminated treatment, the tolerance index was slightly decreasing at raising level of nickel in the soil, with value equal to 0.79 and 0.61 for Ni110 and Ni220, respectively. A similar trend was also observed in cadmium concentration with value equal to 1.01 and 0.90 for Cd4 and Cd8, respectively. While for zinc treatment the tolerance index was lower than 0.50 for both concentrations, showing more susceptibility to this heavy metal. The value was equal to 0.32 and 0.44 for Zn450 and Zn900, respectively.

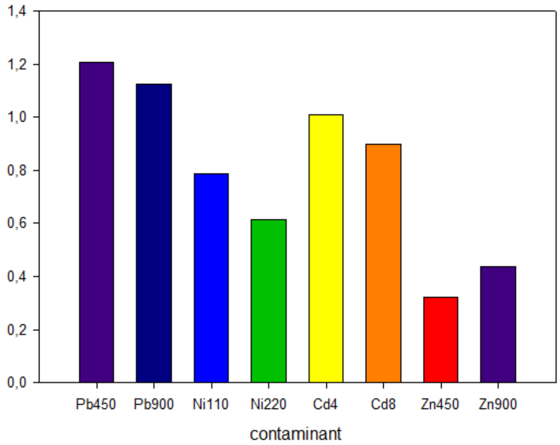

Figure 21. Tolerance Index of the studied treatments

Conclusions

The present study pointed out the ability of *Carthamus tinctorius* L. to grow in four different heavy metal contaminated soil. Among the different heavy metal evaluated in this study the presence of lead not affected the safflower biomass yield that showed a great tolerance to this heavy metal. Zinc affected more than the other heavy metals the biomass yield in this study and showed the highest susceptibility compared with the other heavy metals.

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Fucoidans Application Induces Positive Morpho-Physiological Traits For Increased Drought Tolerance In Tobacco

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Introduction

Biostimulants are natural products able to induce beneficial responses in plants in terms of growth, productivity, and abiotic stress tolerance (Di Stasio et al., 2020). Seaweed extracts (SWE) are among the most effective biostimulants able to increase plant tolerance to different abiotic stresses, such as drought and salinity. However, the mode of action of SWE are not fully understood. SWE contain several molecules that can account for the beneficial effects of their application. Among these molecules, fucoidans content is up to 12% in *Ascophyllum nodosum* (Venardou et al., 2022), which is one of the main brown algae used for biostimulant formulation. Fucoidans are polysaccharides made by high percentages of fucose and represent the main structural carbohydrates of brown algae. The general composition of fucoidans is fucose and sulphate, representing 44.1% and 26.3% of total dry weight, respectively. In plants, fucose is part of the cell wall and is needed for its extensibility. Plant fucosylation is therefore pivotal for plant development and functioning, as well as for tolerance to different stresses. Previous experiments showed that fucosylation is involved in plant freezing tolerance (Panter et al., 2019) and stomatal movements (Waszczak et al., 2020). Therefore, it is possible that fucosylation can play a role also in other stresses affecting plants, such as drought. The aim of this study was to verify whether exogenous fucoidans application can induce morpho-physiological adaptations that can trigger plant tolerance to drought stress, giving a useful insight for the functionalization of SWE biostimulants.

Materials and Methods

Tobacco seeds (*Nicotiana tabacum* cv. Samsun) were germinated in styrofoam trays. One month after germination, plants were transplanted in rhizotrons and grown under greenhouse conditions. Rhizotrons consist of boxes with a transparent window filled with soil, which allow for non-destructive observations of roots (Smit et al., 2000). At three days from the transplant, fucoidans were applied as foliar treatments at two concentrations (60 mg L^{-1} and 120 mg L^{-1}). The root area was assessed by image analysis performed with ImageJ (U.S. National Institutes of Health, Bethesda, MD, USA). To measure leaf stomatal traits, leaf impressions were performed with a drop of cyanoacrylate glue on a microscope slide. An optical microscope was used to take 20x images. The acquired images were then analysed with ImageJ to measure the stomatal density. During the growth cycle, gas exchange measurements were performed with a Licor-6400. The intrinsic water use efficiency (iWUE) was calculated as the ratio between the net assimilation rate and transpiration. Finally, plants belonging to control and 60 mg/L fucoidans were subjected to three days water withholding. The measure of leaf relative water content (RWC) was performed on the youngest fully expanded leaf.

Results

The application of fucoidans increased root growth by both 60 and 120 mg/L (+26% and +22%, respectively) (Figure 1A). The treatment with fucoidans induced a higher stomatal density (+21% and +12%, respectively) (Figure 1B). The intrinsic water use efficiency (iWUE) was significantly increased in plants treated with 60 mg/L and 120 mg/L (+40% and +49%, respectively) (Figure 1C).

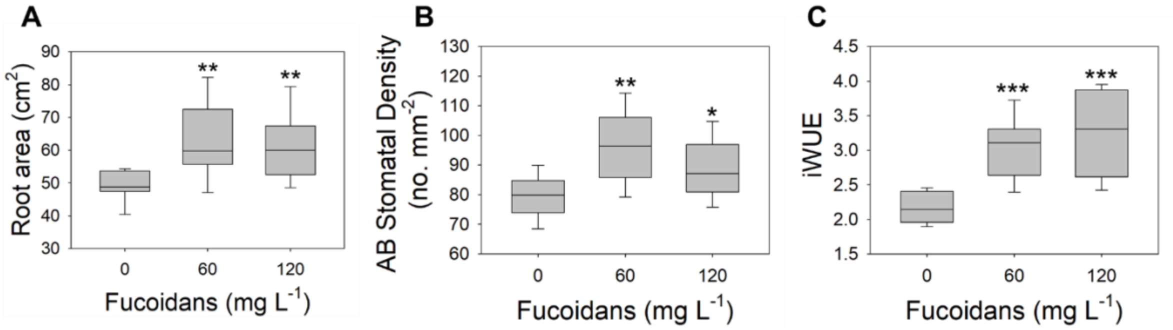

Figure 22 Root area (A), abaxial stomatal density (B) and intrinsic water use efficiency (C) in tobacco plants treated with 60 and 120 mg/L fucoidans. Asterisks indicate significant differences according to test-t (* = $p<0.05$; ** = $p<0.01$; *** = $p<0.01$).

Finally, after three days of water withholding (WS), control plants showed lower RWC (-4%) compared to well-watered plants (WW). On the contrary, plants treated with 60 mg/L fucoidans and subjected to WS showed not significant changes in RWC compared with WW plants (Figure 2).

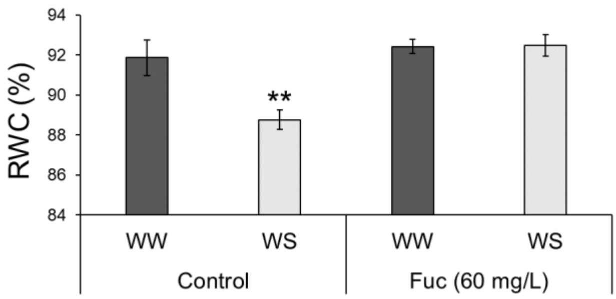

Figure 23 Relative water content (RWC) of tobacco plants grown under well-watered (WW) and water stress (WS) conditions and treated or not with fucoidans (60 mg/L). Asterisks indicate significant differences between WW and WS plants according to t-test (** = $p<0.01$).

Conclusions

Tobacco plants treated with fucoidans showed positive morpho-anatomical modifications in terms of root area and stomatal density (Figure 1A-B) that probably reduced plant water requirement, as indicated by the higher iWUE (Figure 1C). This led to a higher tolerance toward water stress since plants treated with fucoidans maintained higher RWC compared to untreated plants under water stress. Therefore, fucoidans represent important molecules contained in SWE-based biostimulants that can partially account for the beneficial effects of these biostimulants in increasing plant tolerance to abiotic stresses. These results shed light on the importance of fucosylation in plant responses to drought stress, paving the way to a novel mechanism of tolerance that deserves further investigation.

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Hyperspectral Vegetation Indices To Assess Water And Nitrogen Status Of Sweet Maize Crop

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Introduction

Water and nitrogen (N) have long been known as two primary restricting inputs for crop production. Matching N supply to water availability is essential to accomplish an optimal crop response and satisfactory use efficiency levels for those input resources. Proximal sensing methods enable rapid, non-destructive water and nutrient deficiency determination, and they are widely used in the precision agriculture (Pinter et al., 2003). Narrow-band vegetation indices use reflectance in red and near-infrared to collect the red-edge section of the spectrum, thus they have been favourably included in studies aiming to estimate crop nitrogen concentration (Chen et al., 2010), leaf chlorophyll content (Vincini et al., 2011), light-use efficiency (Garbulsky et al., 2010), as well as to detect water stress (Zarco-Tejada et al., 2013) and diseases (Calderón et al., 2013).

In this study, the sensitivity of narrow-band vegetation indices to describe the response of sweet maize under different water and nitrogen management approaches was investigated. To this aim selected structural, red-edge and water-band indices were chosen, and their performance was evaluated.

Materials and Methods

The study was carried-out in Valenzano (41°03'N, 16°53'E, 77 m above sea level), Southern Italy. Sweet maize (Zea mays var. saccharata L.) was grown from 19 May to 3 September 2020 under different water and nitrogen availability in a split-plot experimental design with three replicates. Irrigation treatments (I), as the main plot factor, included: i) full irrigation (I100), ii) deficit irrigation (I50) and iii) rainfed treatment (I0). Nitrogen (N) was the sub-plot factor, with the amounts of i) 50 kg ha^{-1} (low level, LN) and ii) 300 kg ha^{-1} (high level, HN).

During the growing season of sweet maize, different bio-physiological parameters such as leaf gas exchange, leaf chlorophyll content, relative water content, crop reflectance, canopy temperature, leaf area index and dry above-ground biomass were measured. Using the collected spectral reflectance data, the VIs were computed for each treatment. Description and abbreviation for each index is listed in the table below.

Statistical analyses were performed using the R programming language. The effects of treatments (I, N) and time of measurement (days after sowing, DAS) were tested applying repeated measures analysis of variance (ANOVA), using a general linear model. Correlations among VIs and both biometric and physiological parameters were investigated using Pearson correlation coefficients. Simple linear regression analysis was then applied to assess the relationship between selected crop bio-physiological data and vegetation indices.

Table 1. Indices derived from the hyperspectral visible and near-infrared bands.

Description	**Abbreviation**	**Description**	**Abbreviation**
Red-Edge Inflection Point	REIP	DATT index	DATT
Normalized Difference Red-Edge	NDRE	MERIS terrestrial chlorophyll index	MTCI
Narrow-band Normalized Difference Vegetation Index	NNDVI	Double Difference index	DD
Modified Chlorophyll Absorption Reflectance Index	MCARI	Structure Intensive Pigment Index	SIPI
Double Difference index	DD	Water Band Index	WBI
Structure Intensive Pigment Index	SIPI	Ratio WBI and Normalized Difference Vegetation Index	(WBI/NDVI)
Chlorophyll Indices	Cl, Cl_{green}, $Cl_{red\text{-}edge}$		

Results

The crop spectral reflectance increased more rapidly in the infrared region and the slope of the red-edge became steeper, especially in the treatments under full irrigation and high nitrogen level. All indices, except of MCARI and Cl_{green}, were significantly affected by irrigation and the effect varied over time (interaction irrigation x DAS). Nitrogen levels significantly affected red-edge based indices (REIP, NDRE, MCARI, $Cl_{red\text{-}edge}$, DD, DATT, MTCI, together with CI), whereas structural (NNDVI, Cl_{green}) and water band indices (WBI, WBI/NDVI) did not vary significantly. The highest discriminating capability was shown by NDRE, $CI_{red\text{-}edge}$, DATT and MTCI. Among all the indices tested, the NNDVI and WBI/NDVI indices had the best ability to differentiate the interaction of irrigation x nitrogen, showing a greater discriminating capability under low nitrogen. $Cl_{red\text{-}edge}$ was the only index affected by the interaction between irrigation, nitrogen and DAS.
Among all analyzed indices, MTCI, DATT, and DD showed the strongest positive correlation with chlorophyll content. Similarly, LAI, as well as gas-exchange parameters indicated the highest correlation with indices such as REIP, DD, NDRE, DATT, MTCI, while WBI and WBI/NDVI displayed a negative correlation with all analyzed parameters, except for canopy temperature.

Conclusion

Our results demonstrated the importance of red-edge based vegetation indices for assessing the sweet maize status. In particular, the red-edge indices had the high sensitivity to nitrogen levels, especially NDRE, $CI_{red\text{-}edge}$, DATT and MTCI that showed great discrimination capability. In addition, among the studied indices, NNDVI and WBI/NDVI were the only indices affected by the interaction of water and nitrogen, with the ability to separate low nitrogen regimes. Our study highlighted the crucial importance to choose appropriate narrow-band vegetation indices for monitoring plant eco-physiological response to water and nitrogen stresses.

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Water Availability And Yield Of Spearmint Cultivated In Inland Areas Of Southern Italy

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Introduction

Interest in medicinal plants and their derivatives is growing as consumers become more aware of natural products. In fact, according to the World Health Organisation, around 80% of the world's population uses medicinal plants and their derivatives in health, cooking, cosmetics and agriculture. Underlying the wide use of medicinal products are the many active compounds, some as yet unknown, contained in the leaves, seeds, flowers, fruits, barks and roots of thousands of plants which, when properly extracted and processed, exert their biological activity.

The Italian medicinal plant sector is today very diverse and still rather fragmented. In order to create a real system, it is necessary to further deepen the knowledge of the medicinal plant supply chain, from a sustainable point of view and starting from the cultivation aspects, which are fundamental for the production of medicinal products. Today, the cultivation of medicinal plants is growing due to the wide fields of use; there are more than 7,000 hectares of cultivated surfaces, and the organic portion is also increasing. In spite of this conspicuous increase in cultivated surfaces, it must be remembered that, despite the efforts of farms, Italy still imports a large part of its medicinal products from foreign (about 70%). It is necessary to increase domestic cultivation to meet domestic needs. This need must be confronted with some long-standing problems in the medicinal sector, which is also linked to the lack of adequate agronomic knowledge capable of producing product specifications that are useful for obtaining satisfactory yields in terms of both quantity and, above all, quality. The solution to these problems is agronomic experimentation, which is able to provide the answers that farmers are asking for.

Among medicinal plants is spearmint, the essential oil of which is widely used in the cosmetic, pharmaceutical, culinary and agricultural industries. The scarcity of this essential oil has increased the demand for spearmint cultivation in recent years. Among other cultivation techniques, irrigation practice and the consequent availability of water play a key role in production (Chrysargyris et al., 2021), especially at a time of climate change. (Lovelli ae al., 2012). In this context, mulching could assume a relevant role (Bechini et al., 2017; Benincasa et al., 2014). Therefore, the aim of this work is to highlight the effect of mulching on the yield of spearmint plants grown in inland areas of southern Italy.

Materials and Methods

The trial was carried out on a crop of spearmint (*Mentha spicata* L.) grown in the area of the municipality of Baranello (CB) on a clay soil. The plants under study were transplanted 12 months before the start of the trial on 1 June 2020. From this date, five bioagronomic samplings were carried out at time zero (first test day, 0 DAT) and after 20, 40, 60 and 80 days from the start of the trial. The studied plants were divided into four theses (repeated five times): one was regularly irrigated according to the specific water requirements quantified by means of the Penman algorithm (WW), one was rainfed (R), one was mulched and regularly irrigated (WM) and the fourth was mulched and rainfed (RM). The replications were placed in a randomised block scheme. The density of plants per unit area was 10 per square metre. The crop precession was pea. The crop was regularly fertilised by burying before transplanting the equivalent of: N (100 kg ha^{-1}), P_2O_5 (70 kg ha^{-1}) and K_2O (100 kg ha^{-1}) (Delfine, 2009). Mulching treatment was carried out with wheat straw in the amount of 1 kg per square metre. Weed species were controlled manually. Less than 10 mm of rain fell throughout the field trial. In addition to the quantity of dry biomass (obtained by drying the plants at 105 °C), eco-physiological parameters were measured (relative water content, photosynthesis, stomatal and mesophyll conductivity to CO_2, intracellular CO_2 concentration, soil water content, quantity and quality of essential oil). Cultivation management and sampling activities were carried out in a sustainable way, respecting the crop and the environment.

Results

As shown for other crops of agronomic interest, mulching is widely used to improve crop productivity in semi-arid and inland regions of Mediterranean environments. The rainfed mulching treatment (RM) significantly improved yields (+ 25%) and eco-physiological activity (+ 40%) of spearmint compared to the rainfed treatment (R). Under rainfed conditions (R) soil water content was significantly reduced (-20%) compared to mulched (RM) and well-watered treatments (WM and WW). The average essential oil content was significantly lower (- 20%) in treatments W, WM and RM, compared to treatment R, during the full bloom stages (40 DAT). On the other hand, at the end of the cultivation cycle, the essential oil content of the mulched plants (RM and WM) was not significantly different from that of the irrigated treatment (WW), while the rainfed plants (R) showed a strongly reduced (- 65%) essential oil content. Furthermore, the reduction in water availability shown in the rainfed treatment influenced the percentage of the three main monoterpenes and decreased the formation of carvone from limonene.

Conclusions

From the experimental field evidence presented, it is clear that not only the production of spearmint biomass, but also that of essential oils is affected by the availability of water in the soil. In particular, the study concludes that mulching is an effective management practice to increase yields of spearmint in inland areas even under rainfed conditions.

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Water Salinity And Biostimulant Application Affect Hemp Growth And Phytochemical Composition

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Introduction

Phytocannabinoids, a class of over 200 meroterpenoids, show a surprising diversity of biological targets and qualify as privileged structures for biomedical research. Their chemical variability and relative content are the result of genetically encoded pathways optimized by evolution and can be affected by agrotechnique (irrigation, fertilization, cultivar) and modulated by pedo-climatic factors acting as elicitors. For example, salt stress can modify plant morphology, anatomy and physiology (Akram et al., 2020; Guerriero et al., 2017) while inducing a total of 1258 differentially expressed genes (DEGs) in hemp, including 394 upregulated and 864 downregulated transcripts (Gao et al., 2018) associated to the sytnesis of phytocannabinoids. According to this evidence, hemp cultivation addressed to the production of biomolecules for pharmaceutical applications can involve poor fertile saline-degraded soils that are not suitable for food production.

Materials and Methods

Mesocosms (Ø=50 cm) sowed with Hemp (*Cannabis sativa* L.) Finola genotype (300 pt m^{-2}) were arranged in an open field experiment carried out in the facilities of the University of Naples, Dept. of Agricultural Sciences (Portici, Italy; 70 m a.s.l.). A medium fertility sandy soil (91.0% sand, 4.5% silt, 4.5% clay; OM=2.6%) was used and 4 water salinity levels (NaCl soulitions with an Electrical Conductivity of 0, 2.0, 4.0 and 6.0 dS m^{-1} - EC0, EC2, EC4 and EC6, respectively) of irrigation water were tested in combination with 2 biostimulant treatments (untreated – NoB or treated – NB with Trainer®, a plant protein hydrolysate by Italpollina S.p.A., Italy) over a randomized complete block design (3 replicates). Hemp biometric parameters were monitored at full flowering.

Dried plant materials have been separated in leaves, flowers and stems and used for chemical analyses. Powdered leaves and flowers (100 mg for each) were extracted, separately, with 10 mL of methanol for LC-MS analysis, placed in an ultrasound bath at 37 kHz and 800 W, for 15 min, and centrifuged for 10 min at 6000 g. After filtration (PTFE 0.22 um), the pooled filtrates were evaporated to dryness under vacuum with a rotary evaporator to obtain the dried extracts.

All LC-MS/MS experiments were performed on a LTQ-Orbitrap mass spectrometer equipped with an ESI interface coupled to a Thermo Ultimate 3000 HPLC system. The LC-MS was carried out on a Kinetex 2.6 µ POLAR C18 100Å (100x3mm) column, using a gradient elution of 0.1 % v/v of HCOOH in H_2O and CH_3CN as mobile phase. The injection volume was 5 µL. The MS and MSn spectra, in positive mode, were recorded in Data Dependent Acquisition mode inducing fragmentation of the most intense 5 peaks for each scan. The acquisition range was *m/z* 150–1500.

A 2-way ANOVA was performed for biometric parameters (mean separation with LSD test at $p<0.05$). The statistical analysis for phytochemical composition consisted in two approaches. First, a univariate analysis compares each spectral region of interest with the reference data set and detects deviations in compound concentrations. The second approach consists of an unsupervised multivariate analysis technique called Principal Component Analysis (PCA) that was employed to detect the presence of interesting trends in the dataset which cannot be revealed in univariate analysis (Bro et al., 2014).

Results

Plant growth parameters were significantly affected by both tested treatments. Biostimulant application promoted total biomass accumulation (+40%), with a 38% increase for stems and leaves. Inflorescences showed a more intense biostimulation effect (+50%) as well as total N uptake (+60%), while a slight but significant increase was recorded for stem diameter and plant height. Water salinity significantly affected all the abovementioned parameters for EC6 with a decrease of biomass accumulation and N uptake ranging from 42% to 57% as compared to tap water. EC0 and EC2 treatments did not show differences, while EC4 in some cases (i.e. leaves biomass, stem diameter and N uptake) was not different from EC6.

Table 1. Average effect of salinity and biostimulant treatments on hemp biometric parameters and N uptake

	Total		**Stems**		**Leaves**		**Inflor.**		**Diameter**		**Height**		**Total N upt.**	
Water salinity	Plant dry biomass (g m^{-2})								mm		cm		g m^{-2}	
EC0	1296	a	664	a	393	a	239	a	4,3	a	102,9	a	31,1	a
EC2	1210	ab	648	a	372	a	190	a	4,3	a	98,2	a	26,7	a
EC4	903	bc	482	ab	266	b	154	ab	3,6	b	84,6	b	19,4	b
EC6	678	c	349	b	226	b	103	b	3,1	b	69,9	c	16,0	b
Biostimulants														
NoB	852	b	452	b	264	b	137	b	3,6	b	84,1	b	17,8	b
B	1191	a	620	a	365	a	206	a	4,1	a	93,7	a	28,8	a

Tentative identification of phytocannabinoids using MS and MS/MS data in high resolution mode led to a total number of 13 compounds with an accuracy error below 10 ppm. Most of the compounds were identified in the non-polar region, with special emphasis on neutral cannabinoids. Compound reporting the most intense chromatographic peaks was cannabidiol (CBD, figure 1), in agreement with the phytochemical composition of the fiber hemp chemotype. Growing conditions can influence many biochemical processes, including those involved in the formation of cannabinoids. Methanol extracts from cultivars grown with increasing of salinity level (EC4-EC6) presented different relative content of cannabinoids with predominance of CBD, compared to EC0 and EC2 treatments where Δ^9-THC was predominant.

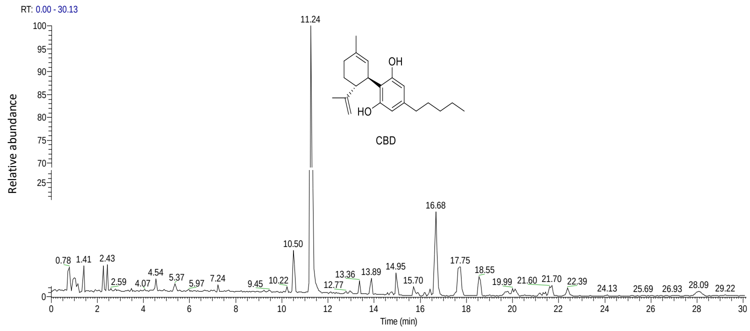

Figure 1. Base peak chromatogram of methanolic extract

Conclusions

An EC thereshold of 2 dS m^{-1} for irrigation water ensures optimal hemp growth. Biostimulation with plant protein hydrolysate can reduce the negative drawbacks of higher EC values ($\geq$4 dS m^{-1}) also modifying phytocannabinoids patterns. Compositional differences were found in the phytocannabionids profile between extracts of plants cultivated under different saline stress conditions.

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Effects Of Salinity And Intra-Specific Competition On The Growth Of Soybean (*Glycine max*), *Chenopodium album* And *Amaranthus retroflexus*

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Introduction

Soil salinization is increasingly affecting agro-ecosystems, contributing to the loss of arable land and reduction of crop yield. Sea-level rise and groundwater overexploitation, causing saltwater intrusion in coastal and inland aquifers (Chen et al., (2015), are expected to exacerbate the negative effects of salinity. Consequently the agricultural land impacted worldwide by salinization is increasing by 10% every year (Cirillo et al., 2018), expanding from arid to temperate regions, including the Mediterranean basin (Clements et al. 2004). Here the prevalent phenomenon is secondary salinization, associated with seawater intrusion in coastal areas (Daliakopoulos et al., 2016).

So far, limited attention has been given to the effects of salt stress on weed species and even less on weed-crop competition (Daliakopoulos et al., 2016). However, weeds are known to exhibit better adaptability to adverse environmental conditions compared to cultivated species (Jamil et al., 2011; Taylor et al., 2013; Lu et al., 2016), which might favour their spread in salty soils. To understand the combined effects of salinity and inter-specific competition on soybean (*Glycine max*) and two species infesting spring-summer crops, *Chenopodium album* and *Amaranthus retroflexus*, we carried out a greenhouse experiment with single- and mixed species pots.

Materials and Methods

Seeds of *C. album* and *A. retroflexus* were harvested at the experimental farm of the University of Padova (Northern Italy) in non-saline soils. Soybean seeds were selected from a salt-sensitive variety, commonly cultivated in the Po valley (cv. PD1T45). The greenhouse setup consisted of a randomized block design of 42 pots (figure 1), with or without salt treatment (100 mM NaCl), three combinations of species (soybean, weed, soybean + weed) and 3 replicates for each combination of species and salt treatment. Plants were grown at a density of 6 plants per pot: 6 soybean or weed plants in the case of single-species pots, 3 crop plants + 3 weed plants in the case of mixed-species pots. The pots with both soybean and *C. album* or *A. retroflexus* were twice those with single-species in order to obtain the same number of biological replicates per treatment. Pots (volume 50 L, diameter 40 cm) were filled with a mixture of sand (5% v/v), peat moss (35% v/v) and perlite (10 % v/v). To reach the same final number of plants per pot and obtain a homogeneous disposition within the pots, seedlings were thinned at the emergence stage. After the first ten days, salt-treated pots were continuously irrigated with equal volumes of 100 mM NaCl solution every other day. The increase in electrical conductivity was monitored with an EC tester (Hanna Instruments, Woonsocket, US) once a week.

The first trial started on 25th March 2021 and ended when signs of senescence processes were visible on salt-treated plants, on 8th June 2021. The second trial started on 25th September 2021 and ended on 8th December 2021. Once the final number of plants per pot was reached, plant height was measured weekly, and photosynthetic activity was monitored with a SPAD 502 Plus Chlorophyll Meter (Spectrum Technologies, US). At the end of the trial, leaves of 2 out of 6 plants per treatment were frozen in liquid nitrogen immediately after sampling and stored at -80 °C until further biochemical analyses. The remaining plants were separated and cleaned to assess the fresh weight of roots and aerial parts. In the case of soybean, also the number and size of root nodules were recorded. For dry weight determination, the plant material was oven-dried at 65°C for 48 h.

Results

Results show a reduction in height and biomass of roots, stem and leaves for both soybean and *A. retroflexus* plants exposed to salt stress compared to the control (figure 1 A-D). Conversely, *C. album* was not significantly affected in terms of height, fresh and dry biomass, with stem and leaves dry weight higher than the control in both spring and autumn trials. Salt-treated weed species showed no significant differences in stem and leaves dry weight between plants grown with or without soybean. In the case of *C. album*, the combination of salt-stress and competition with soybean appeared in some instances to even promote biomass growth. Particularly, in the autumn trial root biomass was significantly higher in salt-treated plants grown with soybean (figure 1 C). Conversely, salt-treated soybean showed reduced dry weight when grown in competition with *A. retroflexus* ad *C. album*, especially in the autumn trial, where stem and leaf dry weight was significantly lower compared to soybean-only pots (figure 1D).

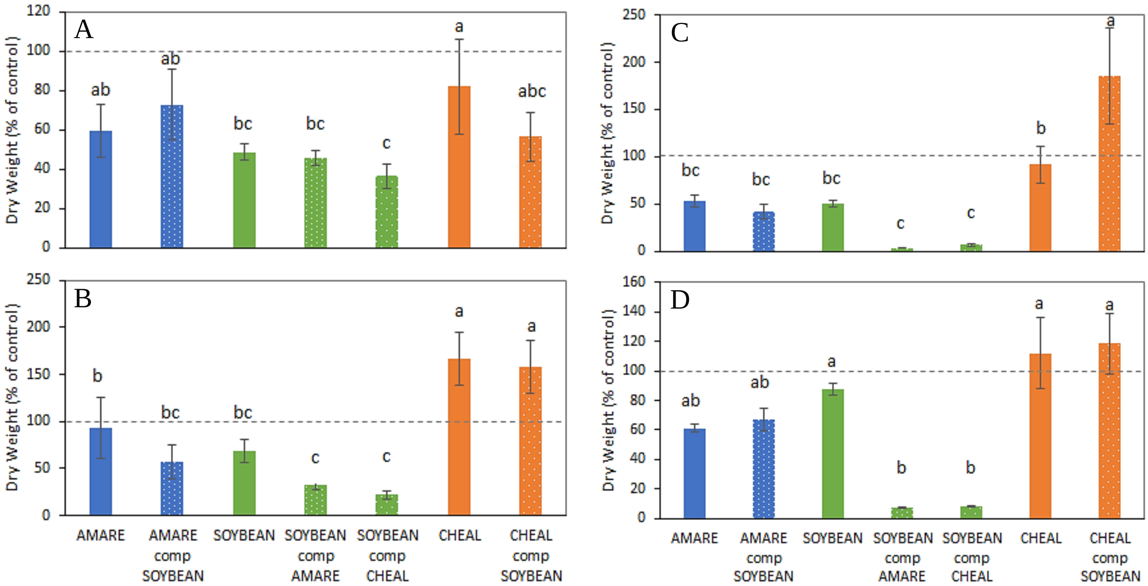

Figure 1. Dry weight of *Amaranthus retroflexus* (AMARE), soybean and *Chenopodium album* (CHEAL), expressed as percentage of salt-treated samples over the control (% of control). (A) Root dry weight, spring trial. (B) Leaves and stem dry weight, autumn trial. (C) Root dry weight, autumn trial. (D) Leaves and stem dry weight, autumn trial. Different letters within each group of bars indicate significant differences at $p < 0.05$. Vertical bars denote the standard error.

Conclusions

Although differently affected by salt stress, neither *A. retroflexus* nor *C. album* was negatively impacted by the competition with soybean. Conversely, the combined effect of salt stress and weed competition appeared to inhibit biomass production in soybean. In the long term these weeds, especially *C. album*, might represent an increasing threat to soybean productivity in salt-stressed environments.

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Increasing Agronomic Performance Under Shallow Water Table: Is There An Optimal Depth?

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Introduction

Food demand is expected to increase by 60-100% by 2050, while global production of major crops is estimated to fall due to climate change. Water management through irrigation and drainage is pivotal for filling present and future yield gap (Vitantonio-Mazzini et al. 2020). Shallow water table (WT) conditions at the bottom of the rootzone can help buffer against transitory rain-free periods (Gao et al., 2017). However, to what extent WT can increase yields is still debated, because anoxia, root diseases and nutrient unavailability can occur, generating suboptimal water status for crop yield (Florio et al., 2014). It follows that a careful WT management, and the identification of most appropriate depth conditions, are necessary to maximize yields and minimize the impacts on agroecosystems. The aim of this study was to investigate the effect of different WT depths on agronomic performances during a 7-year lysimeter experiment.

Materials and Methods

The study was conducted on 18 drainable lysimeters (1m x 1m x 1.5m) located at the University of Padova (NE Italy). Lysimeter WT depths were managed through communicating vessel principle. From 2011 to 2020, the effect of three groundwater managements was investigated: shallow water table at depths of 120 cm (WT120) and 60 cm (WT60), and free drainage conditions (FD). Furthermore, the WT effect was tested against different N fertilization levels (2011-2014) and different soil management practices (2018-2020). During the first period maize was grown continuously and the N input was 170+80 (250N), 250+118 (368N), and 170+195 kg ha^{-1} (365N) (i.e. organic+mineral, N fertilizer). From 2018, previous treatments were replaced by conservation agriculture (CA), conventional agriculture (CV) and conventional practices with cover cropping (CC), respectively. Crop rotation (in CA, CV and CC) included maize, grain sorghum and winter wheat, which N input was: 170+80, 250+80, and 250+80 kg ha^{-1}. Rye and sudangrass were used as cover crops in both CA and CC. Water inputs (868.5 mm yr^{-1} on average throughout the 7-yr experiment) were provided by a series of simulated rainfall events, applied according to the average crop water needs of FD treatments. After harvesting, grain and residues were weighted, oven dried at 65°, and analysed for N content. Furthermore, harvest index (HI) and nitrogen use efficiency (NUE) were calculated. Data were analysed through ANOVA, and when significant, differences between means were separated through Tukey post hoc test.

Results

In the first four years, maize grain yield and residues were greater under shallow WT than FD (e.g., 12.8 vs. 7.2 Mg ha^{-1} for grain) (Fig. 1). Moreover, also WT-N level interaction influenced final crop production, being higher under WT60-365N. Similarly, grain N uptake was greater under shallow WT and high N input (196 kg N ha^{-1}), resulting in an overall NUE around 50%. Residue N uptake ranked WT120>FD>WT60. Water stress decreased the HI under FD (0.32) compared to shallow WT, which averaged 0.42 with high N inputs and 0.37 with low N inputs. During 2018-2020, trends differed and WT60 grain yields were slightly lower compared to WT120 and FD (Fig. 1). The effect was more pronounced for winter wheat, which ranked WT120>FD>WT60. Moreover, the agricultural system influenced grain and residues, being CV greater than CC and CA. N uptake was greater under FD, followed by WT120 and then WT60. On the other hand, there was not a clear pattern on HI. Average

NUE dropped down to 38%, with higher values under FD, followed by WT120 and WT60 (44%, 38%, 34%, respectively).

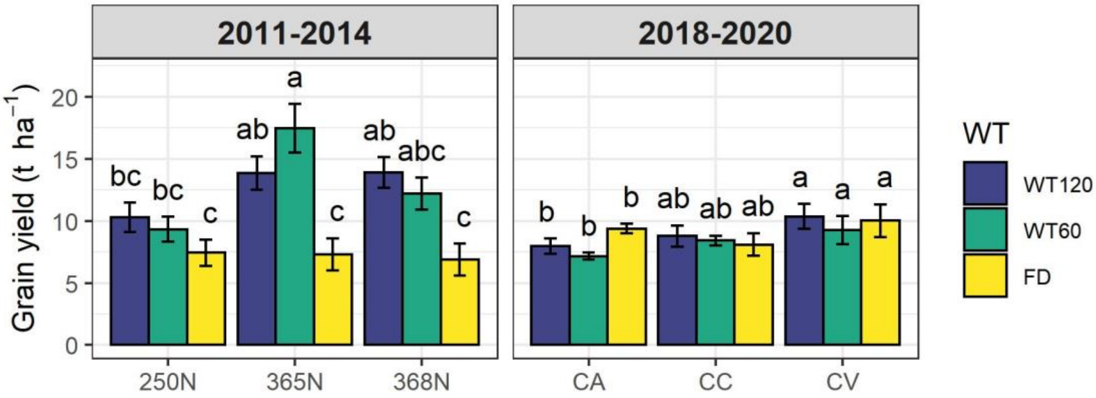

Figure 1. Average grain yield through the experiment.

Conclusions

Considering N levels, WT60 performed better only when high inputs were applied, suggesting greater losses through leaching or denitrification. WT60 was also penalized by CA treatment, probably increasing anoxic effects. Our results demonstrated how the optimal WT depth for agronomic performances highly varied depending on both N input and agricultural systems, highlighting the need for a thorough management of the water table depth. Furthermore, long-term studies to fully exploit the WT effect on yield and environmental indicators are namely requested.

Acknowledgments

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Brassica carinata As A New Cover Crop For Northern Italy: Variety Choice Effects

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Introduction

Sustainable alternatives to fossil fuels have to be found to reduce the CO_2 impact on climate change. Biomass crops, for example, can efficiently contribute to decreasing the greenhouse effect by buffering the CO_2 emission. However, it is important to avoid iLUC (indirect land-use change) and dLUC (direct land-use change) risks by growing them on marginal lands or as cover crops to replace fallow periods between food crops. Carinata (*Brassica carinata*) has been developed as a low agricultural input intensity (i.e, water and nutrients) non-food oilseed feedstock to produce advanced renewable fuels. Carinata is a member of the family *Brassicaceae* family (Edwards et al., 2000) and the species possesses agronomic traits allowing it to be grown either as a winter crop or as a spring-planted crop. It is heat tolerant, resistant to diseases and seed shattering, and has lower water-use requirements than other oilseed brassicas (Kumar et al., 1984; Malik, 1990; Raman et al., 2017; Shivpuri et al., 1997). A preliminary study has been carried out at the University of Bologna, in collaboration with Nuseed (Canada) to assess the effect of variety choice on carinata grown as a summer cover crop following the harvest of a winter cereal.

Materials and Methods

The study was carried out at the experimental farm of Bologna University at Cadriano (44°32'58" N, 11° 24'32" E) from June to September 2021. The study included 6 cultivars (Cv. 1 to 6) from Nuseed (Canada), of which 5 were breeding lines and one was a commercial variety (Var. 1, DH-129.B036), and 3 breeding lines (Cv. 7 to 9) from AAFC breeding program (Saskatoon, Canada). The seeding rate was 175 seeds m^2 and the sowing was performed on June, 4. The experimental site is characterized by silty-loam soil (25-25-50% sand, clay, loam), and winter wheat was the preceding crop. Plots were sown with a plot precision seeder equipped with carinata seed disks. Immediately after sowing a sprinkler irrigation system was installed and irrigation was applied several times to obtain a uniform seedlings emergence. Nitrogen was applied in the amount of 60 kg ha^{-1}, as urea before stem elongation. During June and July, several insecticide treatments against flea beattles (*Altica oleracea*) infestation have been applied. At the end of the growing cycle, the central portion of each plot was manually mowed and then threshed mechanically. During the carinata crop cycle, several parameters have been surveyed to investigate the suitability of the crop for this new system. Emergence was surveyed by counting the plants on a meter at 20, 30, and 40 days after sowing (DAS). Soil coverage was determined by using the Canopeo app and taking three photos at 60 cm from the soil for each plot. Soil coverage was recorded two times at 41 and 53 days after sowing (DAS). Aboveground biomass accumulation was also surveyed during the crop cycle, i.e. before the flowering start and at the end of flowering, and harvest. After thresting on representative seed sample 1000-seed weight was also determined. All the data, except those of var. 9, which did not reach maturity, were subjected to analysis of variance (ANOVA) by using CoSTAT (Cohort Software, USA).

Results

The cumulative precipitation from sowing to harvest was only 26 mm, while the historical average in the same experimental site value was 168 mm.

Results showed that cultivar 6 allowed the highest soil coverage (43% with 57 plants m^{-2}), while cultivar 5 had the lowest (32% of coverage with 45 plants m^{-2}); those findings are consistent with the literature. Moreover, when analyzing seed yield significant difference emerged among tested genotypes (Fig. 1): cultivar 2 and 5 produced more than the others (1.25 and 1.18 g $plant^{-1}$, respectively), while cultivar 8 had the lowest production (0.10 g $plant^{-1}$). Cultivar 5 presented the greatest 1000-seed weight with an average value of 4.57 g. This value which is significantly higher than those reported in the literature by (Seepaul et al., 2021), who found a 1000-seed weight 4.12 g for carinata grown as a winter cover crop in Florida, confirmed the good adaptability of the tested genotypes to northern Mediterranean climate and their feasibility as summer cover crop in Italy.

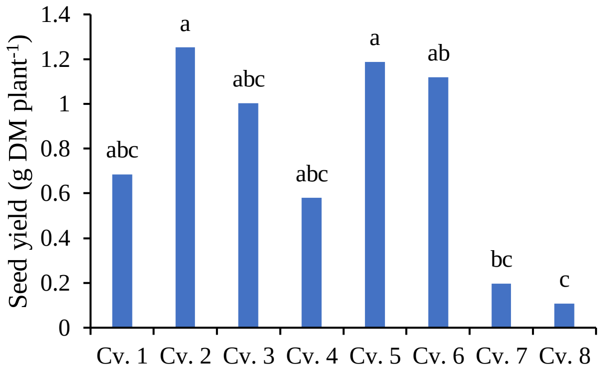

Figure 24 - Average seed production for each carinata genotype in the screening trial carried out at Bologna during summer 2021. Different letters: statistically different means for $P \leq 0.05$, LSD test.

Conclusions

As far as the authors know, this is the first Italian study on carinata as a summer cover crop, so it represented a starting point for this type of research. The possibility to identify crops able to produce valuable feedstock for biofuel production and not concurring with staple food crops will represent a great challenge for the future in Italy and Europe. This study provided evidence on the carinata water needs and on the risk of flea beetle infestation; but these aspects should be carefully consider since they can reduce the overall sustainability of the crop. With regards to productivity, some of the tested cultivars seemed highly promising due to their adaptability and their homogeneity of production, while others showed an undeterminated growing cycle so they cannot be used in Italy as a summer cover crop. In conclusion, this study confirmed the opportunity to develop carinata as a low iLUC non-food feedstock, but it is necessary to improve variety choices as well as to develop some agronomic practices to anticipate sowing (i.e., relay cropping).

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Up-Land Environment Influences The Potato Nutritional Profile

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Introduction

Securing sufficient and healthy food for all, while minimizing environmental impact is the great challenge we face already today. Local production limits and global trade challenge equal access to food. With climate change increasingly affecting food production in already disadvantaged areas, unprecedented population increase (especially in urban and coastal areas), and deterioration of usable land, these challenge will intensify. A holistic approach to transform the global food production system with the ability to adapt to regional necessities is highly needed. For these reasons, a large international consortium aimed to face the challenge of sustainable food systems to address climate change and malnutrition through an integrated approach adaptative and mitigatory strategies was created. SYSTEMIC "an integrated approach to the challenge of sustainable food systems: adaptive and mitigatory strategies to address climate change and malnutrition" (http://systemic-hub.eu/) is an EU Knowledge Hub on Food and Nutrition Security with the aim to foster the collaboration between 173 researchers from 41 research institutions from 8 countries (Italy, Norway, Portugal, Spain, France, Germany, Belgium and Latvia). The CLIMAQUALITEC sub-project is part of the SYSTEMIC network; in its frame, the impact of climate change on the nutritional content and quality features of staple crops, was investigated as a case study.

Specifically, effects of altitude on nutritional value of potato tubers was evaluated. Indeed, upper land potato satisfies consumer demand for high quality foods linked to traditional areas of origin and for new specialties and niche products endowed with added nutritional value since it is commonly thought that the crop x environment synergy improves potential beneficial properties of the tuber and gives it a special taste and a renowned quality (Pacifico D., 2018). Additionally, potato is actually a precious source of bioactive compounds that have an enormous potential. Based on these considerations, we have deemed it interesting to evaluate the metabolic and trasctiptional profile of potato in response to altitude, aware that consumer's choices might be influenced by food products' beneficial properties and "Mountain Potato" sounds good!

Plant secondary metabolites have key roles in plant physiology and contribute to healthy-value of potato tubers (Durazzo A. et al, 2019) . Over past decades, interest has focused greatly on secondary plant metabolites, such as phenols, flavonoids and carotenoids, due to their antioxidant activity conferring protection against degenerative and age-related diseases. We chosed therefore to focus this study specifically on chlorogenic acid and a key gene underlying upstream its pathways of biosynthesis.

Materials and Methods

Six genotypes were tested: three commercial potato varieties (Bleuet; purple skinned and fleshed tubers; Desiree, red-skinned and yellow-fleshed tubers and Kennebec, yellow-skinned and white-fleshed tubers), one advanced hybrid line (98-11-1, purple parti-coloured skinned and fleshed tubers) and two italian traditional ecotypes (Bianca di Starleggia, yellow-skinned and white-fleshed tubers, and Rossa di Starleggia, red-skinned and yellow-fleshed tuber). In 2019, all the genotypes were grown either at the experimental farm of CREA, located in Budrio (Bologna area, 25 m. a.s.l.) and at Starleggia

(Campodolcino, Valchiavenna, 1.560 m. a.s.l.). All the samples were collected from three single plots randomized by RDB design.

For each genotype, 15 tubers were collected from single plants from the three single plots of sampling, randomized by RDB design, and three pools of 5 tubers were generated.

Chlorogenic acid (3-O-Caffeoylquinic acid) has been characterized by HPLC-DAD and spectrophotometric analysis, together with the isomers .neo-chlorogenic acid (5-O-Caffeoylquinic acid) and crypto-chlorogenic acid (4-O-Caffeoylquinic acid). The given results are the sum of the three isomers (tot CGA) and are expressed as mg/100 g d.w.

RNA was isolated from 50 mg of the pooled pulverized tissues of tubers, treated with DNase Thermo Fisher Scientific) to remove any possible DNA contamination and retro-transcribed into cDNA with the High capacity cDNA RT (Thermofisher). According to Livak and Schmittgen (2001), the fold change in gene expression was calculated by relative quantitation method of comparative Ct ($2^{-\Delta\Delta Ct}$).

Results

The content of total GCA was significantly affected by genotype (p=0.0000), environment (p=0.0000) and their interaction (p=0.0352). The average concentrations ranged from 60,1 to 94,5 mg/g 100g d.w in flat-land and up-la, respectively. Up-land Bleuet showed the highest tot CGA content, which in Kennebec and Rossa di Starleggia almost doubled from flat-land to up-land growing environment.

Herein, GCA accumulation was also compared with the expression profile of the gene encoding phenylalanine ammonia lyase (*PAL*), involved in phenylpropanoid pathway.

Relative expression of *PAL* in up-land related to flat land growing genoypes was calculated normalizing the Ct levels of *PAL* to the housekeeping gene, cytoplasmic ribosomal protein L2 (Andrè et al. 2009). *PAL* expression doesn't change significantly among the two environtments under study. The calibrator used for relative quantification was the samples from flat-land growing and the expression was considered significantly different only for fold-change > 2. For all the six genotypes, relative expression is < 2, Thus, an absence of correlation was found between the GCA content profiling and the *PAL* expression profiling in response to environment.

Based on the above results, we can conclude that up-land environment influences the GCA content of tubers of genotypes studied but this variation is not under the control of *PAL* expression

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Effects Of LED Light Spectrums On *Erigeron canadensis* L. Germination And Growth

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Introduction

The increase in temperature due to climate change might allow some heat tolerant invasive species to spread in Mediterranean areas that were previously too cold. Among invasive species, *Erigeron canadensis* L. has considerably increased in European and Italian cropping systems, particularly where minimum or no-tillage is adopted (Fracchiolla et al., 2018). *E. canadensis* is one of the most difficult-to-manage weeds due to multiple reasons, including resilient biological features, successful ecological adaptations, strong interference ability and herbicide resistance. Unfortunately, little information exists about the effect of multiple environmental factors on *E. canadensis* germination and growth. The aim of this study was to evaluate the effects of different LED light spectrums on seed germination and seedlings growth of *E. canadensis*, which would help in estimating and modeling the invasiveness of this specie, improving the management strategies.

Materials and Methods

E. canadensis seeds were collected from naturally senescing plants in an experimental field at the University of Perugia (42°57'21" N, 12°22'21" E). Seeds were stored and then selected as described in Ottavini et al. (2019). For seed germination tests, 50 seeds of *E. canadensis* were placed on a single layer of filter paper in plastic Petri dishes (Ø = 90 mm), moistened with 5 mL of deionized water. Petri dishes were exposed to different light treatments (Table 1) (12h:12h light/dark photoperiod, T=20±1°C, RH=70±5%), according to a randomised block design with three replicates and using the Led lamps described in Tosti et al. (2018). Seeds were considered as germinated when the radicle protrusion was > 1 mm. Germinated seeds were counted daily and removed from Petri dishes, until no more germinations could be observed for two consecutive days. Seed germination test was repeated twice (Exp. 1 and Exp. 2). For the seedling growth test (Exp. 3), plastic pots were filled with 65 mL of quartz sand (0.2–2 mm mesh size, 1.24 g mL^{-1} bulk density and 38.5 mL 100 mL^{-1} maximum water holding capacity) and were sown with 25 seeds per pot of *E. canadensis.* These pots were subirrigated to maximum water holding capacity with distilled water and then kept in a growth chamber (12:12 h light/dark photoperiod, T=20±1°C, RH=70±5%). After emergence, seedlings were thinned to 5 plants per pot and exposed to different light treatments (Table 1), at the same above-mentioned conditions applied in the germination test. Water content was daily adjusted to maximum water holding capacity using a nutrient solution containing all necessary macro and micro-elements. Three weeks after emergence, plants were harvested and the above ground fresh and dry weight per pot were recorded. The data collected in the two germination tests were used to parameterize a time-to-event model, assuming a log-logistic distribution of germination times. The fitted curves were used to derive the Final Germinated Proportion (FGP) and

Table 1. Incident photon flux density (PFD) in the light treatments

Radiation wavelengths	Colour	LIGHT TREATMENTS Incident PFD (µmol m^{-2} s^{-1})					
λ (nm)		SUN	BLUE	RED	BR	BGR	DARK
447.5	Royal blue	24.5	100	0	50	50	0
470.0	Blue	26.1	100	0	50	25	0
505.0	Cyan	28.2	0	0	0	0	0
530.0	Green	29.2	0	0	0	50	0
590.0	Amber	30.6	0	0	0	0	0
627.0	Red	30.8	0	100	50	25	0
655.0	Deep red	30.6	0	100	50	50	0
Total	-	200	200	200	200	200	0

the time to 30% emergence (T_{30}), which were taken, respectively, as a measure of germination capacity and germination velocity. Data of plant biomass and FGP were subjected to ANOVA and means were separated using Fisher's protected LSD at p=0.05 level.

Results

In both seed germination experiments, FGP showed no significant differences among light treatments except for BLUE and DARK (Table 2), that caused a reduction of germination capacity of *E. canadensis*. In particular, DARK decreased the FGP with values ranging from 0.47 to 0.56, confirming that germination capacity in the dark was lower than in the presence of light (Ottavini et al., 2019).

Table 2. Effects of light treatments on maximum proportion of germinated seeds (FGP, Final Germination Proportion), time to 30% germination (T_{30}) and plant biomass for *E. canadensis*. Standard errors are in parentheses.

Light Treatments	FGP		T_{30} (days)		Fresh weight biomass (g plant^{-1})	Dry weight biomass (g plant^{-1})
	Exp. 1	Exp. 2	Exp. 1	Exp. 2		
SUN	0.75 (0.02) a	0.70 (0.05) a	2.83 (0.06)	2.86 (0.14)	93.3 (8.0) b	10.2 (1.1) b
BLUE	0.20 (0.04) c	0.19 (0.03) c	n.e.	n.e.	170.9 (9.3) a	17.2 (1.0) a
RED	0.70 (0.03) a	0.71 (0.13) a	2.51 (0.10)	2.44 (0.11)	145.0 (34.4) a	15.0 (3.0) a
BR	0.71 (0.02) a	0.70 (0.07) a	3.14 (0.04)	2.85 (0.13)	84.6 (11.8) b	8.7 (0.9) b
BGR	0.75 (0.02) a	0.68 (0.03) ab	2.81 (0.07)	2.64 (0.11)	69.2 (6.4) b	7.2 (0.7) b
DARK	0.47 (0.01) b	0.56 (0.08) b	3.65 (0.09)	3.00 (0.11)	0 c	0 c

In each column, values followed by at least one letter in common are not significantly different according to a multiple comparison test (Fisher's protected LSD, P = 0.05). n.e.: not estimable.

SUN, RED, BR and BGR affected FGP in the same way, confirming that phytochrome and, as a consequence, red and deep red radiation wavelengths are involved in the germination process, being *Erigeron* a genus with positive photoblastic species. On the other hand, BLUE inhibited the germination capacity more than the other treatments, because it does not directly affect the phytochrome, but other receptors, such as cryptochromes and phototropins, which are not involved in the germination process. Considering T_{30} (Table 2), the following ranking was observed: RED < BGR < SUN < BR < DARK < BLUE. Plant growth showed the highest biomass values under BLUE and RED treatments, while the plant weight decreased under SUN, BR and BGR treatments, without significant differences among them; no biomass was recorded in the DARK treatment (Table 2). The increasing of *E. canadensis* plant growth at the extreme radiation wavelengths of the PAR spectrum (*i.e.* RED and BLUE), with respect to SUN (similar to sunlight), BR and BGR (with mixed radiation wavelengths), could represent a further ecological adaptation of this specie to the different environmental conditions, also in terms of incident radiation.

Conclusions

These findings concur to increase the knowledge on the interactions between environmental variables and *E. canadensis* that are useful to improve the management of this weed also under climate change conditions. Furthermore, all the *E. canadensis* traits, in addition to increased resistance to glyphosate, seems to confirm that this species holds a high potential to show exponential population growth in the near future.

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Potential Of Biostimulants To Increase *Sorghum Bicolor* Biomass Production And Phytoremediation Efficiency

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Introduction

The cultivation of biomass crops on contaminated lands is becoming more and more relevant thanks to the possibility of producing biomass with low ILUC risk, i.e. avoiding taking land away from food production, providing for the decontamination of polluted areas in an economic way and avoiding secondary pollution phenomena (Muthusaravan et al., 2018). *Sorghum bicolor* is one of the most promising species for the biomass production and it is considered capable of absorbing some widely diffused heavy metals in the aerial biomass, such as Pb, Cd, Cu and Zn (Zhuang et al., 2009) that can be precipated in transformation plants (Gong et al., 2018). Not being an hyperaccumulator species, the effectiveness of the process depends on the quantity of the biomass produced (Lima et al., 2019). Currently, in order to improve the efficiency of phytoremediation process research is particularly focused on the use of microorganism and biostimulants capable of improving the physiological well-being of crops and the bioavailability of heavy metals for roots (Yan et al., 2020). The current study, carried out in the framework of the GOLD project, reports the results obtained by testing 6 different treatments (M, B1, B2, MB1, MB2, C) on sorghum in a greenhouse trial. The objective was to identify the best treatments able to increase the production of sorghum biomass and the relative uptake of heavy metals from the soil.

Materials and Methods

The trial was carried out between October 2021 and February 2022 in a greenhouse at the Department of Agricultural and Food Sciences of the University of Bologna. Six treatments, 3 replicates each, were tested on sorghum plants, (Bulldozer variety), grown in pots of 12l volume, after being germinated for 5 days in petri dishes (20-30 °C, 16 hours of light and 8 hours of darkness). The treatments tested were M= mycorrhizae (Symbivit, Symbiom, CZ) with a dosage of 15 g per pot applied at the start of the trial near the transplanted seedlings; B1= foliar biostimulant based on protein hydrolysates (Siapton, Agrology, GR), applied with a dosage of 3 $ml*L^{-1}$ of application water by spraying the entire aerial part every 10 days, starting from 4 true leaves; B2= root biostimulant based on fulvic and humic acids (Lonite 80SP, Alba Milagro, IT) applied once a week in the irrigation water since plants have reached 10 cm in height, 0.5 g per pot the first 4 weeks an 0.7 g per pot thereafter; MB1= combination of M and B1; MB2 = combination of M and B2; C= untreated control. The sandy-loam soil was taken from a former landfill, "Chiarini 2" (44° 50'N, 11° 28' E, 36 m a.s.l.) and was subjected to ICP-MS analysis to determine total concentrations of heavy metals and relative exceedances of the thresholds established by the Italian law (Table 1). Subsequently extraction with DPTA was performed to determine the bioavailable fraction (Table 1). The pots were randomly placed under the lamps (12 hours of light and darkness in the first month, 14 hours of light and 10 hours of darkness thereafter) and rotated every month. The temperature was kept between 18-26 °C and the soil humidity was kept at 75% of the pot water capacity. After 13 weeks form transplanting, all the plants were cut and their dry weight was determined. The biomass obtained was analysed by ICP-MS to detect the total content of heavy metals in each plant. The result were subjected to analysis of variance (ANOVA) and the LSD test was used for the separation of means ($p \leq 0.05$).

Table 9. Total concentration and bioavailable fraction of heavy metals exceeding the legal threshold of Italian law

Metal	Legal Threshold (mg/kg DM)	Total Concentration (mg/kg DM)	Bioavailable concentration (mg/kg DM)
Lead (Pb)	100	159	33
Tin (Sn)	1	8.8	Not detected
Zinc	150	455	62
Copper	120	137	45
Nickel	120	209	9,9

Results

The treatments applied in combination, MB1 and MB2, were the most productive for dry biomass: especially MB2 was found to be significantly more productive than B2(+ 66%), B1(+ 101%), M (+ 186%%) and C (+ 260%), while MB1 was significantly higher only than M (+118%) and C (+174 %) (Fig. 1). Among the treatments applied individually, B2 was significantly more productive than C (+116 %), while B1 and M were comparable to the control C. Zn and Cu were found in the aerial biomass and their total content closely followed the trend of biomass production indicating the most productive species such as those that have phytoextracted the greatest amount of heavy metals.

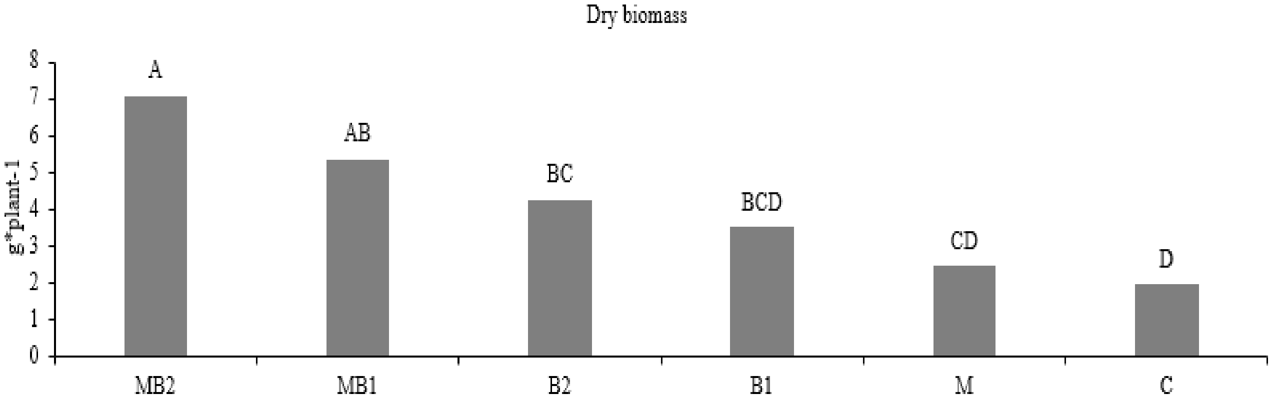

Figure 1. Dry biomass produced in each treatment

Conclusions

The combination of mycorrhizae and fulvic acids was found to be the best treatment to increase sorghum biomass production and heavy metals uptake, resulting in significant increases compared to all other treatments, apart from the combination of mychorrhizae and protein hydrolisates which was found comparable for the production of biomass. The metals absorbed were those used as micronutrients and most bioavailable in the soil used. However, the short duration of the test in a controlled environment in which the sorghum has not completed its biological cycle may have limited the adsorpiotn of other metals as the limit of quantification (> 5 mg/kg DM) prevented us to determine their actual presence (i.e. traces of Ni were detected). Further studies are ongoing to verify the results presented and the potential of the biostimulants identified in improve biomass production and heavy metal uptake in field condition.

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Assessing Land Suitability To Sunflower (*Helianthus annuus* L.) Cultivation In Tuscany Using APSIM To Predict Yield Potential And Stability

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Introduction

Sunflower is a relevant oil crop in rainfed cropping systems of Mediterranean area. Indeed, its morphological and physio-logical traits make it suited to scarce and irregular rainfall conditions and high evapotranspiration of summer season. In Central Italy, conventional management allows achieving yields higher than 3.0 t ha^{-1}, with a reasonable variability within genotypes. Due to the high oil content (45-52%) and fatty acid profile (traditional and high-oleic varieties), the seeds are of particular interest both for food and no-food industry, moreover the co-product from oil extraction is a protein meal/cake valuable for animal feeding. In Tuscany, sunflower is largely the most relevant oil seed crop, being cultivated on and average area of about 20.000 ha, whit an average yield during the last ten years, equal to 2.1 t ha^{-1} (ISTAT, reference period 2011-2021). The crop is distributed both on flat areas of the large coastal and river plains, as well in hilly areas, where it represents one of the few alternative options to durum wheat within the crop rotation. In Tuscany region the climate is characterised by a large interannual variability of weather conditions with frequent occurrences of spring frost, that usually takes place during April, and high temperatures and prolonged drought periods in the late spring and in summer. Rainfall distribution and crop evapotranspiration are strongly affected by the orography of the region. Moreover, the different soil texture gradients determine, under the same weather conditions, a strong variability in crop responses due to their effect on the soil-water-crop system. Properly representing the spatial pattern of sunflower response to weather and soil conditions would increase the knowledge level about land suitability to its cultivation, providing support for farmer choices and supply chain organization. Thus, during the period 2019-2021 the project "SIC-OLEAT - Crop Innovation Systems for Tuscany Oilseed Crops" project, funded by Tuscany Region (PSR 2014-2020), focused on the development of knowledge tools to support Tuscan farmers towards a sustainable production of oil crops. In particular, the objectives of this research, based on the application of APSIM simulation engine on a 42-year historical series of spatialized weather data, were the evaluation of the effect of meteorological conditions and soil characteristics on sunflower yield potential and their stability over time under not irrigated conditions, in order to deliver land suitability maps to sunflower cultivation in Tuscan agricultural areas.

Materials and Methods

For the purposes of the study, the simulation model APSIM (Agricultural Production System sIMulator, version 7.10) was coupled with a PostGIS database of climate and soil input data. APSIM allows to simulate on a daily scale the production of biomass and grain of crops, starting from daily weather data, soil characteristics and input data related to the crop management. APSIM calibration and validation was based on data of the CIMAS (Conventional vs. Integrated Management Systems) long-term experiment, carried out at the Agro-environmental Research Center "Enrico Avanzi" in San Piero a Grado, Pisa, in a flat agricultural area a few km from the coast (Nassi o Di Nasso, 2011). Simulations on a territorial scale were run according to (i) time series of daily weather data (1979-2020) from AGRI4CAST (JRC, European Commission EU, Science Hub), organized on a 25 x 25 km grid covering the entire region and (ii) soil characteristics organized according to 6 prevalent soil classes as derived from the LAMMA-CRES regional soil map. In each cell of the grid, the most suited sowing date was calculated from weather data in order to allow the crop completing of the emergency within 15 days from the sowing and avoiding the occurrence of late frosts in the early development stage between emergence and V-2. Overall, 13,860 simulations (55 cells x 6 soil classes x 42 years) were run. The yield stability index s was estimated from the function slope of the linear regression between the average annual yield of sunflower in each cell and for each soil class and the Environmental Index (Del Moral et al., 2003) representing the average annual yield across all cells per soil class.

Results

The average of predicted yield for the period 1979-2020 was 3150 kg ha^{-1}. The lowest yields have been predicted in soils with clay and sandy loam texture (2.1 and 2.4 t ha^{-1}), while the highest yields were in silty loam soils (4.2 t ha^{-1}). Intermediate yields have been predicted in loam, clay loam, and silty clay loam soils, 3.6, 3.5 and 3.0 t ha^{-1} of dry matter respectively. Higher levels of instability ($s > 1$) of yields were estimated in the north of the region, on clay and sandy-loam soil, meaning that under limiting soil conditions the crop responsivity to increasing rainfall is higher. The opposite was observed in less constrained soil conditions, where rainfall levels are sufficient to sustain stable high yields potential, as in the north ($s < 1$). On the other hand, in south areas the lower rainfall levels as well as the high evapotranspiration limit the crop response at stable but low yield potentials, regardless the soil class.

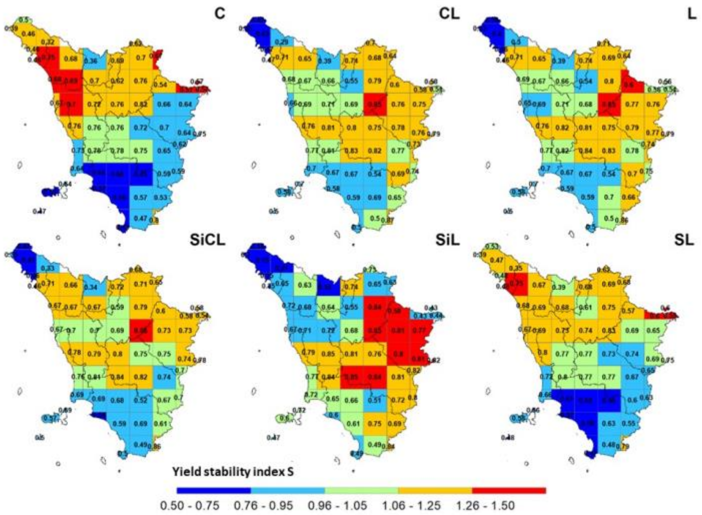

Figure 1. Maps of yield stability index (*s<1 = high stability and low responsivity; s= average stability; s>1 = low stability and high responsivity*) by soil texture class (C = Clay; CL = Clay Loam; L = Loam; SiCL = Silty Clay Loam; SiL = Silty Loam; SL= Sandy Loam). The labels in each cell show the coefficient of determination of the linear regressions between yields and EI.

Conclusions

The study allowed to delineate the combined effect of climate and soil condition on sunflower yield potential in different areas of Tuscany. Higher yields potentials are achievable in the north of the region and on soil characterized by higher water capacity. The stability of the yields over time is strongly influenced by the interaction between the geographical factor (climate) and the soil factor. Indeed, on soils with lower available water capacity, the variation of rainfall regimes in May-June strongly affects the variability of yields.

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