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Multiple eco-efficiency solutions in tomatoes simulating biostimulant effects

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ABSTRACT

Global agricultural systems are increasingly moving towards organic farming to satisfy consumers' increased environmental awareness. Yet, shortage of fertilizers and more frequent water stresses are challenging agricultural systems to minimize their environmental impact without compromising productivity and economic sustainability. This study discusses how greenhouse organic tomato production behaves when multiple eco-sustainable solutions are applied. In particular, organic tomato cultivation was supported by a specific biostimulant treatment that included a microbial solution, based on Rhizobium, which was distributed onto faba bean seeds; once a suitable fava bean biomass had been obtained, the plants were chopped and incorporated into the soil in order to release nitrogen. In the trials considered, microbial solutions reduced organic tomato production costs by 5 %. Considering that fertilization accounted for up to 7 % of total production costs, a large-scale preparation of the microbial solution could trigger significant economic savings. The Life-Cycle Assessment shows that organic tomatoes, with a lower yield, have a lower environmental impact than conventional production only for 7 of the 15 evaluated impact categories. Combined agro-technical growing solutions are economically viable in the presence of yields in organic compared to conventional, and their environmental impact is attractive in both scenarios.

1. Introduction

1.1. Background

Global agricultural systems are increasingly moving towards organic farming (Kalozoumis et al., 2021; Gatsios et al., 2021; Lenzi et al., 2009). There are several underlying reasons, including consumers' demand (Baldi et al., 2021; Trentinaglia De Daverio et al., 2021; D'Amico et al., 2016; Bosona and Gebresenbet, 2018a) and increased farmers' environmental awareness (Schröder et al., 2019; Abdallah et al., 2021).

However, climate change and consumers' increased environmental awareness and organic agricultural products also led to unavoidable challenges for European agriculture as a result of higher temperatures, reduced availability of irrigation water (Saadi et al., 2015; Aguilera et al., 2020), decreased livestock farming, and reduced animal manure (Peyraud and MacLeod, 2020). Moreover, the shortage of fertilisers, particularly nitrogenous fertilisers, which started in the second half of 2021, is continuously worsening.

Therefore, it is becoming increasingly important to find cultivation solutions for organic agricultural products in order to achieve yields similar or equal to conventional production levels (Crowder and Illan, 2021; Barbieri P. et al., 2021, 2019, Röös et al., 2018; Ponisio et al., 2015; Lenzi et al., 2009).

Technical innovations in agricultural systems are being experimented to reduce the production gap of organic farming, and to let global agriculture evolve towards less impactful models (Karamian et al., 2021). Particular attention is currently being paid to reducing the use of mineral fertilisers, such as nitrogen (Barbieri P. et al., 2021,

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2019). Organic farming requires the use of manure to supply enough nitrogen to a crop, and the practice of incorporating a legume biomass is under investigation to assess the amount of nitrogen provided to the crop (Gatsios et al., 2021).

Multiple agroecological practices should be implemented jointly to move towards more sustainable agricultural systems. Studies have shown that a combination of different agroecological technologies increases the qualitative and quantitative performance of crops.

Faba bean has been extensively studied because it is a versatile species with interesting characteristics due to its ability to fix nitrogen, it is rich in protein, the abundant biomass it produces, and the role it can play in organic farming systems. If it was already an object of interest, it becomes even more so in this era of great problems of scarcity of energy resources, difficulties in the supply of fertilisers and drier climatic regimes (Jensen et al., 2010; Mansour et al., 2021). Its use as a pre-crop in the green manure form (Gatsios et al., 2019; 2021; Alagöz et al., 2020) or in the strip cropping (Waren Raffa et al., 2022) is also of current interest on tomato both for yield and quality. The soil mineral N level has been found to be the main yield limiting factor pertaining to organic greenhouse tomatoes (Gatsios et al., 2021), and solutions need to be found to maintain/increase the yield. In this present research, when faba beans were applied as green manure, in addition to farmyard manure, the tomato yield was significantly increased.

The introduction of microorganisms that are naturally present in the rhizosphere as a crop strengthener has also been studied recently. The results of Ye et al. (2020) suggested that a Trichoderma bio-organic fertiliser could be applied in combination with appropriate rates of chemical fertilisers to achieve optimal benefits regarding yield, quality, and fertiliser savings. Other findings confirmed the robustness of microorganisms as biostimulants for plants (Rouphael and Colla, 2020). The grafting technique can also influence production (Toju et al., 2019), because it can improve the yield and quality, thus making the tomato plant more resistant to disease and stress.

Tomatoes are one of the fruit-vegetables that are studied the most to increase yield and quality, due to their importance as a commodity and to their widespread use, both fresh and processed, in a wide range of products. Trends show that their total production, cultivated area, and their consumption are expected to increase (FAOSTAT, 2021). In fact, global tomato production in the 2017–2019 period was estimated as 180.766.329 tons, a 7 % increase relatively to the 2012–2014 period. A positive trend was also observed for the cultivated area, with 4.943.417 ha, +1.2 %, being cultivated in the 2017–2019 period. In Europe, tomato production in the 2017–2019 period amounted to 23.264.227 tons, a 7 % increase compared to the 2012–2014 period, over a cultivated area of 439.610 ha, in decline (−12 %) from the previous period. The consumption of organic and conventional tomatoes has shown a stable or even a slightly increasing trend.

In the literature, there are few economic analyses that have examined tomato production in the field, combined and not, with LCA-type environmental impact analyses. A recent study (Guo et al., 2021) used a methodology to calculate environmental damage from fertilisers and pesticides employed in intensive agriculture, and that made use of environmental cost indicators (Annaert et al., 2017). This study is spatially wide-ranging, as it refers to a provincial area (Tianyang County, Guangxi Province, China) where the cherry tomato type is widely cultivated in open fields due to the favourable climate. A most recent work was carried out in India (Kumar et al., 2023), where open field production in a district area of conventional tomatoes was compared with organic production. In both studies (Table 1), the economic analyses aimed to determine the profitability of tomatoes under conditions of lower impact production, starting with the conventional system and reducing inputs (the former) and converting to organic (the latter). In these cases, the economic analyses followed the LCC approach, with the use of variable production costs to determine whether cultivation with less environmental impact allowed an adequate level of revenue to be maintained. Another contribution considers tomatoes grown under urban agriculture conditions, in which the greenhouse is placed on the rooftop of the building (Table 1). A recent work by Pena et al. (2022) analyzes the economic viability of tomato production cycle in an innovative building with an integrated urban agriculture system in rooftop by applying the life cycle cost methodology. In this case, the focus is on the economic viability of production, which is achieved with a special investment in fixed capital (the greenhouse infrastructure) in a vertical production condition, and its profitability. Another study (Sanyé-Mengual et al., 2015) analyzes this new urban horticulture system from its greenhouse structure to its final product level.

This literature review highlights that in studies of urban greenhouse production embedded within buildings, economic analysis focuses on determining significant fixed costs. These costs have a substantial impact on the outcome, as the greenhouse infrastructure is newly constructed atop existing buildings using innovative technologies. Economic scenarios consider variables like tomato yield and other parameters, especially when input prices, such as water, can significantly influence the economic results.

Environmental assessments of tomato crops (organic vs. conventional) have recently been conducted in Europe. The study of Ronga et al. (2019), which focused on comparing organic and conventional techniques, concluded that the new genotypes and innovative management methods should reduce the yield gap without increasing the environmental impact on the agroecosystem.

The Life Cycle Assessment (LCA) approach, defined by two ISO standards (ISO 14040 and ISO14044) (ISO, 20061; ISO14040, 2006b), is the reference methodology for the assessment of the environmental performance of products, processes, and services. Although originally developed for industrial processes, LCA has proved to be a useful and

Table 1
Recent tomato studies where economic evaluations are carried out with or without LCA analysis.

Reference	Type of tomato growing/ORG-CONV/tomato cv/processing	Economic methodology assessment	LCA	Sensitivity assessment (scenario analysis)	Country/Territorial level/City level
*Kumar, R., Bhardwaj, A., Singh, L. P., Singh, G., Kumar, A., & Pattnayak, K. C. (2023); *preprint under submission	Open-field tomato/ORG-CONV	Life Cycle Costing (LCC); variable costs	yes	no	India/Jalandhar District of the Punjab Province
Pena, A., Rovira-Val, M. R., & Mendoza, J. M. F. (2022)	Rooftop Greenhouses (RTGs) and i-RTGs (integrated RTGs)/CONV/Coeur-de-boeuf	Life Cycle Costing (LCC); total costs (variable + fixed) and BEP (break even point)	no	yes	Spain/Metropolitan Area of Barcelona
Guo, X. X., Zhao, D., Zhuang, M. H., Wang, C., & Zhang, F. S. (2021)	Open-field/CONV/Cherry tomato	Economic analysis of production cost (variable), revenues and net income Environmental costs of damage (emissions)	yes	no	China/Tianyang County of the Guangxi Province
Sanyé-Mengual E., Oliver-Solà J., Montero J. I. & Joan Rieradevall J. (2015)	Rooftop Greenhouses (RTGs)/CONV	Life Cycle Costing (LCC); total costs (variable + fixed)	yes	yes	Spain/Metropolitan Area of Barcelona

objective tool to evaluate the environmental impact of the activity of agricultural processes, including by-products (Ronga et al., 2019; Mancuso et al., 2019; Bosona and Gebresenbet, 2018b; Bacenetti et al., 2015; Torrellas et al., 2012). Torrellas et al. (2012) applied an LCA to tomato production in Almeria, Spain, to assess and suggest cleaner production alternatives in greenhouse areas. The study observed that, from an environmental point of view, the reduction of fertiliser use would be the most efficient and economical way of improving the production process. Bosona and Gebresenbet (2018b) focused on organic tomato cultivation in Sweden, applying an LCA cradle-to-consumer gate approach to two supply chains, that is, fresh and dried tomatoes. They investigated two impact categories, that is, the cumulative energy demand and global warming potential, and highlighted a lack of studies on the impact of the organic tomato value chain (Table 2), especially concerning such parameters as “energy demand” and “greenhouse gas emissions”. Naseer et al. (2022) found that on greenhouse fresh tomatoes, the considered environmental effects should not limited to the GW category.

Table 2
Literature on the environmental assessment of the tomato supply chain.

System boundary	Functional Unit	Production Country	GWP (kg CO_2 eq)	Reference
Conventional tomato production and supply to wholesalers	1 kg of tomatoes	Sweden	0.5–2.75	Karamian et al. (2021)
Conventional tomato production in a greenhouse (including raw material input and material disposal)	1 ton of fresh tomatoes at the farm gate	Spain	250	Torrellas et al. (2012)
Conventional tomato production in a greenhouse	1 kg of fresh tomatoes	Sweden		Carlsson-Kanyama et al. (2003)
Conventional tomato production	1 kg of fresh tomatoes	Southern Europe		Carlsson-Kanyama et al. (2003)
Tomato production	1 kg of fresh tomatoes at farm gate	Denmark	3.5	Mogensen et al. (2009)
Tomato production and harvesting	1 ton of fresh tomatoes at farm gate	Iran	65.8	Zarei et al. (2019)
Conventional tomato production in a greenhouse	1 kg of tomatoes	Norway	0.6–3.1	Naseer et al. (2022)
Conventional tomato	1 ton of harvested tomatoes	Italy	59.5	Bacenetti et al. (2015)
Conventional and organic tomato	1 ton of tomatoes at farm gate	Italy	67.7 for organic 55.2 for conventional	Ronga et al. (2019)

1.2. Goal of the study

In the present study, economic and environmental data, pertaining to both conventional and organic tomato greenhouse trials, have been collected in Greece. The trials were carried out to evaluate the combined effect of an appropriate *Rhizobium* administration rate to faba bean seeds and an agricultural practice, that is, the application of faba beans as a green manure and as pre-crop. Grafted plants of tomato involved in an organic production process (henceforth OR) subsequent the faba bean. To the best of our knowledge, no environmental and economic evaluations have yet been carried out on this particular cropping system. Therefore, the aim of this study has been: i) to carry out an environmental and economic assessment of organic tomato cultivation in the presence of two combined management practices of the preceding crop (faba bean); ii) to compare the environmental and economic results of organic cultivation with those of conventional cultivation (CB) performed in a similar environment. The economic analysis of the OB and CB production processes was implemented in order to define and compare the level of profitability. The LCA approach was applied to evaluate the environmental performances of the two cropping systems and a complete set of environmental indicators was considered.

2. Materials and methods

2.1. Trials growing conventional and organic tomatoes in a greenhouse

The experiment of growing tomatoes was conducted in two locations in Greece. The organic experiment was conducted in Preveza, in the Northwest of Greece, in a plastic covered greenhouse and in a sandy-loam soil (Table 3). Faba beans (Vicia faba L.), inoculated with rhizobia, were cultivated and incorporated into the soil as green manure (Gatsios et al., 2021) prior to planting the tomato crop. The ‘Nissos F1’ tomato hybrid was grafted onto a Maxifort rootstock, and plants were cultivated to obtain a spring-summer crop. The conventional experiment was conducted in Tympaki, Crete, which is located in Southern Greece, in a plastic-covered greenhouse in a clay soil (Table 3). A non-grafted ‘Elpida F1’ tomato hybrid was cultivated to obtain an autumn-winter crop.

2.2. Economic assessment of tomato organic versus conventional growing

Economic data and environmental inventory data about the two cropping systems were collected, by means of a direct survey, from the farmers and technicians involved in the greenhouse trials in 2019 (Table 4) to calculate the production costs of a commercial conventional cultivar and compare them with the costs of organic tomatoes including of a biostimulant treatment.

The CB was considered as a benchmark and compared with the OR data.

Table 3
Features of the two locations of the greenhouse experimentation in 2019 (Greece).

Items	Unit	Data	Data
Trial site		GREECE	GREECE
Tomato variety		Elpida F1	Nissos variety Maxifort rootstock
Administered quantity of water		100 %	100 %
Administered quantity of N/P fertilisers		100 %	n.a.
Cropping system		Conventional	Organic
Total cultivated plot surface		676	960
Cultivated plot surface	m^2	328	960
Yield	Kg m^2	15.9	8.7
Soil type		Clay	Sandy-loam

Table 4
Calculation of the microbial inoculant preparation times and costs (KRH): raw materials and labour.

Items Microbial inoculant preparation	Operational time (OT)	Labour Cost (€)
Preparation of the culture media	1 h	16
Microbial cultivation	3 h	48
Seed coating	2 h	32
Seed inoculation	30 min	8
Total cost of labour	6 h and half	104

The collection of economic data made it possible to calculate the variable cost in the three phases for organic tomato production and the variable cost for conventional tomatoes. The economic analysis was of the "from cradle to farm gate" type and the results obtained can be useful in any farm context, because they are unrelated to the fixed capital owned. The local market price of the tomato was applied to evaluate the production and determine the revenue. Thus, the difference between the costs and revenues of the production process led to the determination of the gross income.

From the information gathered regarding the CB production process, the followings were calculated for each trial under greenhouse conditions (Fig. 1): the cost of production at variable costs, the revenue and gross income of each management strategy implemented by the farmers.

The production cost was calculated considering variable cost scheme. Details on the incurred costs of the nitrogen and phosphoric fertilizers and of the water used for irrigation were investigated with care. The different cost items were grouped into nine main categories: seedlings and seeds, cultivation treatments (plastic mulch and plastic covers, pollinators), pesticides, fertilization, water, labor, fuel, oil and electricity consumption, third-party labor (Equation (1)). The revenue value was considered to refer to the unitary tomato market price indicated in the questionnaires (Equation (2)). The unitary gross income was calculated by considering the difference between the revenues and costs (Equation (3)).

$$
\begin{aligned}
KCB(€\,t^{-1}) = {} & \textit{tomato seedlings}\,(€\,t^{-1}) + \textit{cultivation treatments}\,(€\,t^{-1}) \\
& + \textit{pesticides}\,(€\,t^{-1}) + \textit{fertilisation}\,(€\,t^{-1}) + \textit{water cost}\,(€\,t^{-1}) \\
& + \textit{labour}\,(€\,t^{-1}) + \textit{fuel}\,(€\,t^{-1}) + \textit{oil}\,(€\,t^{-1}) + \textit{electricity}\,(€\,t^{-1}) \\
& + \textit{thirdparty labour}(€\,t^{-1}) + \textit{plastic cover s}\,(€\,t^{-1}) + \textit{disposal}\,(€\,t^{-1})
\end{aligned} \tag{1}
$$

$$RCB(€\,t^{-1}) = \textit{tomato quantity} * \textit{price} \tag{2}$$

where $KCB(€\ t^{-1})$ is the cost of conventional tomato and $RCB(€\ t^{-1})$ is the revenue of conventional tomato;

$$GICB(€\,t^{-1}) = RCB\ (€\,t^{-1}) - KCB\ (€\,t^{-1}) \tag{3}$$

where $GICB(€\ t^{-1})$ is the gross income of conventional tomato.

Three phases were followed for the organic tomato production process (Fig. 1). Two different stages were implemented before the tomato cultivation: "OR STAGE 1-LAB" and "OR STAGE 2-FIELD"; the growth of the tomatoes, that is, "OR STAGE 3-FIELD" was then implemented.

In the OR STAGE 1-LAB stage (Fig. 1), faba bean seeds were covered with an adhesive rizhobium culture film in the laboratory. Certain raw materials, such as yeast mannitol broth, distilled water, gum arabic, compostable plastic bags, and different types of equipment (autoclave steriliser, refrigerator, vertical laminar flow, orbital shaking incubator, magnetic stirrer, analytical balance, pHmeter, etc …), as well as electricity and labour were needed to prepare the microbial inoculant preparation. Calculations were conducted to estimate the minimum amount of rhizobium culture necessary for the inoculation.

The production cost of the microbial inoculant preparation (called "KRH", equation (4)) in "OR STAGE 1-LAB" was calculated as follows:

$$
\begin{aligned}
KRH(€\,t^{-1}) = {} & \textit{yeast mannitol broth}(€\,t^{-1}) + \textit{arabic gum}\,(€\,t^{-1}) \\
& + \textit{water}\,(€\,t^{-1}) + \textit{labour}\,(€\,t^{-1}) + \textit{electricity}\,(€\,t^{-1})
\end{aligned} \tag{4}
$$

where $KRH\ (€\ t^{-1})$ is the cost of the microbial inoculant prepared in the laboratory

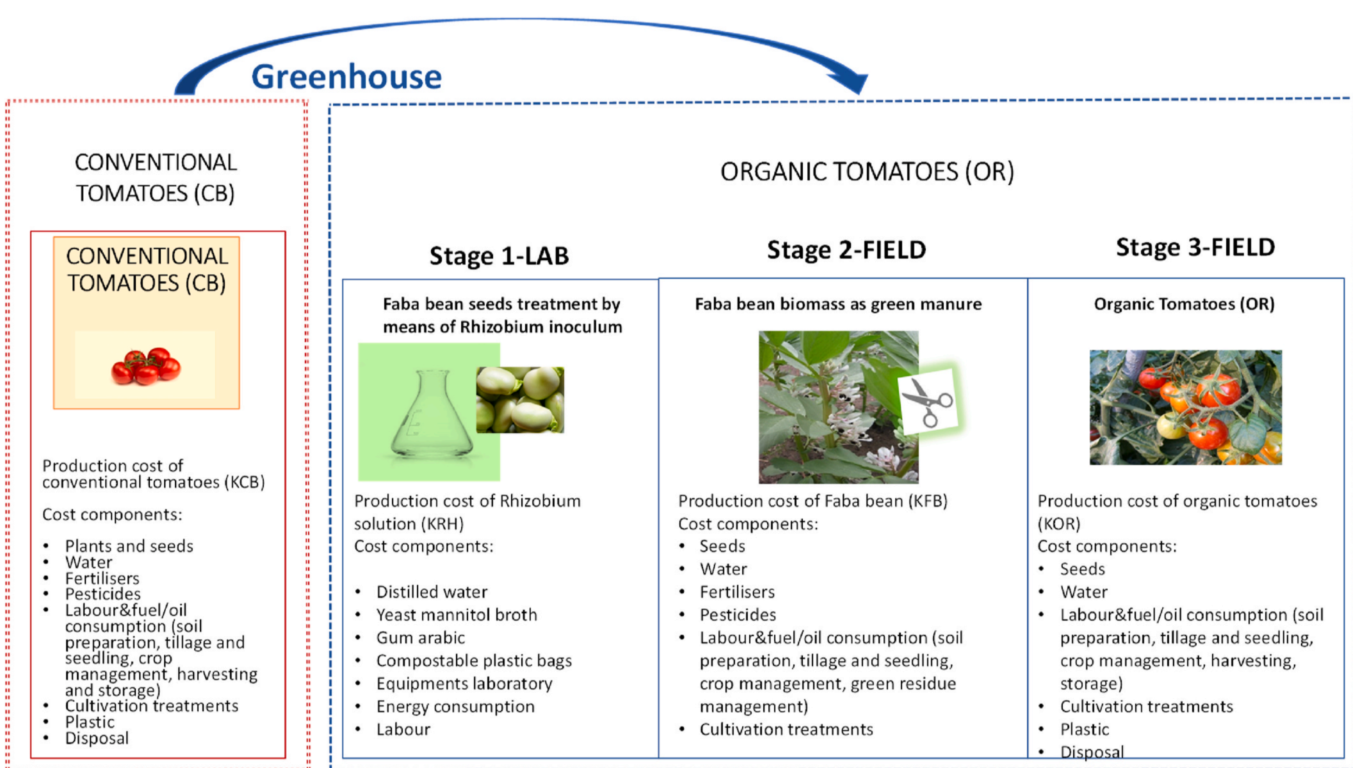

Fig. 1. Cost components for conventional "CB" and organic "OR" tomatoes grown under a plastic tunnel greenhouse in Greece (2019).

Faba beans (FB) were cultivated in the OR STAGE 2-FIELD stage (Fig. 1), and when the biomass was optimal (at the beginning of the flowering phase), the plants were chopped and incorporated into the soil. The growing of FB in the greenhouse involved such field operations as soil preparation, soil tillage and seeding, crop management and green residue management (chopping and soil incorporation). The costs related to the plastic cover and its disposal were encountered just once in the tomato cultivation process. The goal of the production process was only that of obtaining biomass for a nitrogen soil enrichment. The production cost of the faba bean biomass was calculated (called "KFB", Equation (5)) as follows:

$$\begin{aligned} KFB\left(€\ t^{-1}\right) = &\ faba\ bean\ seeds\ \left(€\ t^{-1}\right) + cultivation\ treatments\ \left(€\ t^{-1}\right) + pesticides\ \left(€\ t^{-1}\right) \\ &+ water\ cost\ \left(€\ t^{-1}\right) + labour\ \left(€\ t^{-1}\right) + fuel\ \left(€\ t^{-1}\right) + oil\ \left(€\ t^{-1}\right) \\ &+ electricity\ \left(€\ t^{-1}\right) + thirdparty\ labour\left(€\ t^{-1}\right) \end{aligned} \tag{5}$$

where *KFB (€ t^{-1})* is the production cost of the faba bean green biomass.

For the "OR STAGE 3-FIELD" organic tomato production process, the data collected from the farm allowed the following to be calculated for each trial under greenhouse conditions: the cost of production considering variable costs, as well as the revenue and the gross income of each management strategy implemented by the farmers.

The cost of the production process of organic tomatoes included the microbial (*Rhizobium*) inoculum production cost, "KRH", and the production cost of the faba beans used as green manure, "KFB". The calculations are shown below.

In the OR STAGE 3-FIELD organic tomato production process, the cost of production was calculated.

The different cost items were grouped into six main categories: seedlings and seeds, cultivation treatments (plastic mulch and plastic covers, pollinators), water, labor, fuel, oil and electricity consumption, third-party labor. The costs of the Rhizobial inoculum, "KRH", and the faba bean production cost, "KFB", were added (Equation (6)).

The revenue value refers to the unitary price of market organic tomatoes indicated in the questionnaires (Equation (7)). The unitary gross income was calculated by considering the difference between the revenues and costs (Equation (8)).

$$\begin{aligned} KOR\ \left(€\ t^{-1}\right) = &\ organic\ tomato\ seedlings\ \left(€\ t^{-1}\right) + cultivation\ treatments\ \left(€\ t^{-1}\right) + + water\ cost\ \left(€\ t^{-1}\right) + labour\ \left(€\ t^{-1}\right) \\ &+ fuel\ \left(€\ t^{-1}\right) + oil\ \left(€\ t^{-1}\right) + electricity\ \left(€\ t^{-1}\right) + thirdparty\ labour\left(€\ t^{-1}\right) \\ &+ plastic\ cover\ \left(€\ t^{-1}\right) + disposal\ \left(€\ t^{-1}\right) + KRH + KFB \end{aligned} \tag{6}$$

$$ROR\left(€\ t^{-1}\right) = tomato\ quantity\ *\ price \tag{7}$$

where *KOR(€ t^{-1})* is the cost of conventional tomato and *ROR(€ t^{-1})* is the revenue of conventional tomato;

$$GIOR\ \left(€\ t^{-1}\right) = ROR\ \left(€\ t^{-1}\right)\ -\ KOR\ \left(€\ t^{-1}\right) \tag{8}$$

where *GIOR(€ t^{-1})* is the gross income of organictomato.

Since organic productions can differ to various extents from conventional ones, a low (LYO) and high (HYO) yield scenarios were included so as to consider alternative conditions and to examine a broader set of results than just the situation for which experiments and data were available (Di Vita et al., 2015) and thus, to make more informed choices concerning the economic, environmental, and social dimensions. The LYO scenario represents the organic tomato yield recorded in the 2019 greenhouse trial, which was 87 t ha^{-1}, that is, a very low production. The HYO was included to broaden the overall picture of the economic results, and thus to obtain a better view of what would happen in the case of different yields: this yield was set at 154 t ha^{-1}, a feasible yield for organic tomatoes (Gatsios et al., 2021) and which is also very close to the yield of the conventional process. The economic results of the organic production process can thus be distinguished as belonging to two different scenarios.

2.3. Environmental assessment of tomato production by means of an LCA approach

The LCA approach was applied according to the ISO standards 14,040 and 14,044 (ISO14040, 2006a; 2006b). In details, regarding the "Goal and Scope", 1 kg of fresh tomato was selected as the functional unit. The selection of a mass-based functional unit is in agreement with previous LCA studies focused on crop (Nikkhah et al., 2017; Costantini et al., 2021) as well as with the Product Category Rules for Arable and Vegetable Crop (Environdec, 2020). Concerning the system boundary a "from cradle to farm gate" perspective was considered. In detail the system boundary includes all the field operations, the manufacturing of all the inputs (e.g., fuel, machinery, fertilizers, pesticides, seed/seedlings, energy) consumed during the crop cultivation as well as different emission sources (e.g., related to fuel combustion during the field operation, due to pesticides applications or to the nutrient cycles into the soil). Packaging, distribution, use and end-of-life of the product were excluded by the system boundary. Fig. 2 reports the schematization of the system boundary.

The inventory data was built using primary data directly collected during the experimental trials and secondary data. Regarding the emissions included in the boundary, the nitrogen emissions, phosphorous compounds, and the active ingredient of the pesticides as well as the emissions related to the combustion of diesel in the tractor engines were modelled using secondary data. The ammonia emissions resulting from volatilization, nitrate leaching, and dinitrogen oxide due to denitrification were estimated with reference to IPCC guidelines (IPCC, 2019). According to Smil (2000), P losses were evaluated as 1 % of the total phosphorus applied by means of fertilizers. Moreover, 100 % of the active ingredients of the pesticides were considered as being emitted into the soil (Environdec, 2020). The pollutant emissions from the tractor engine (due to the combustion of diesel) were calculated considering fuel consumption, the engine load, and the age of the tractor (Lovarelli and Bacenetti, 2017). The virtual consumption of the tractor was evaluated by considering its mass and an optimal annual utilization.

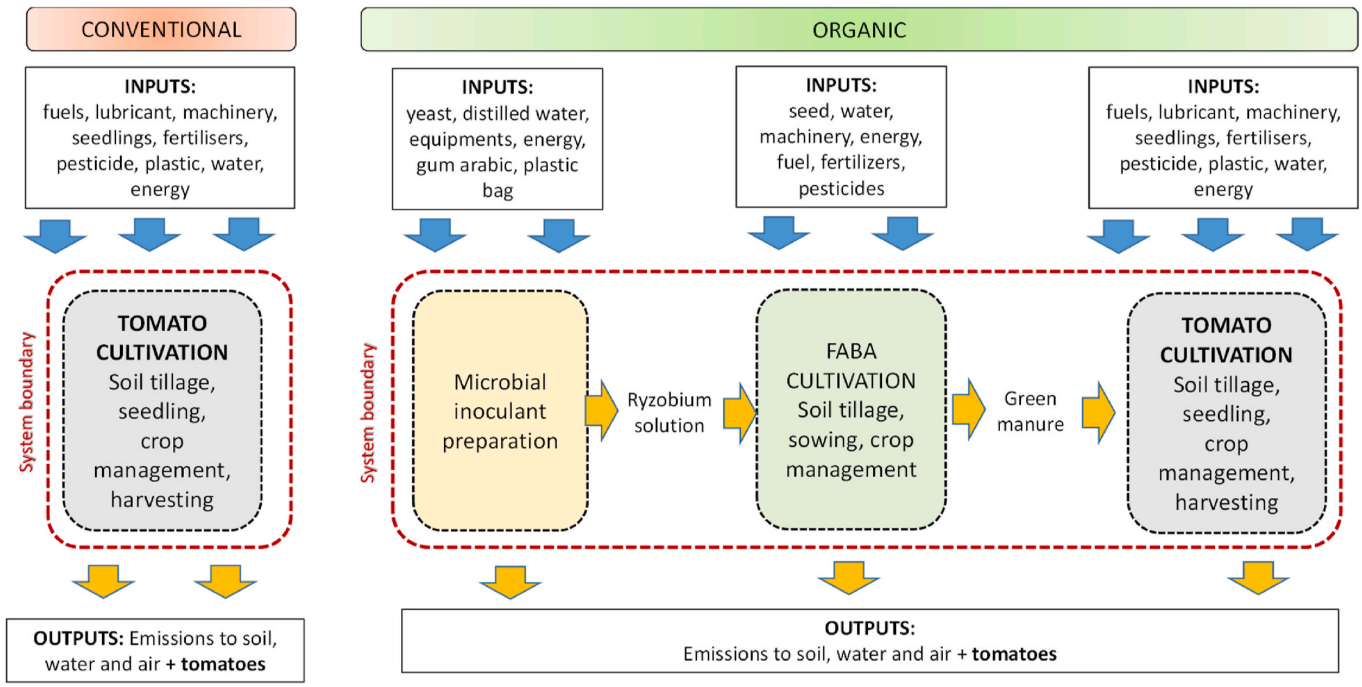

Fig. 2. Schematization of the system boundary analyzed for tomatoes in greenhouse.

The classification and characterisation of the inventory data was carried out using the ReCiPe 2016 Midpoint (H) method (version 1.04/ World) (Huijbregts et al., 2017) and 15 different midpoint impact categories were evaluated.

- Global Warming;
- Stratospheric Ozone depletion;
- Ozone formation, Human health;
- Fine particulate matter formation;
- Ozone formation, Terrestrial ecosystems;
- Terrestrial acidification;
- Freshwater eutrophication;
- Marine eutrophication;
- Terrestrial ecotoxicity;
- Freshwater ecotoxicity;
- Marine ecotoxicity;
- Human carcinogenic toxicity;
- Human non-carcinogenic toxicity;
- Mineral resource scarcity;
- Fossil resource scarcity.

The impact categories were selected considering the environmental effects usually related to agriculture but also based on the goal of the study. Consequently, all the impacts related to the emissions of nutrient into the atmosphere (e.g., acidification, eutrophication, particulate matter formation, global warming) and to the consumption of energy, fuel and fertilizers (e.g., Stratospheric Ozone depletion, Fossil resource scarcity) were evaluated. Besides this, being the goal of this LCA study, the comparison between conventional and organic cultivation (which differ greatly regarding the use of pesticides) all the toxicity-related impact categories were evaluated).

A contribution analysis was carried out to identify, for each impact category, the environmental hotspots (inputs, processes, and the emission sources considered the most responsible for a given impact). To this aim, the inputs and outputs were grouped as follows.

- “Mechanization”, which included the impacts due to manufacturing, maintenance, and disposal of the tractor and other equipment, as well as the impact related to diesel consumption (production, distribution and related emissions during the combustion in the engine);
- “Other production factors”, which grouped the impacts related to the consumption of seedlings and seeds, fertilisers, biostimulants, and pesticides;
- Plastic tunnel, which involved the manufacturing of the tunnel, its maintenance (mainly substitution of the plastic film every eight years), and its disposal;
- “N compound emissions”, which involved the ammonia and dinitrogen monoxide emissions into the air, and the nitrate emissions into water;
- “P compound emissions”, which encompassed the phosphate emissions into water.

3. Results and discussion

3.1. *The economic results of a comparison between conventional and organic tomatoes*

The CB 2019 trials (conventional tomatoes) were carried out with the Elpida F1 cultivar, with irrigation and 100 % fertilisation according to the protocol. Parcels of soil in the greenhouse were irrigated by means of a drip system. These trials were used as a benchmark to compare the OR 2019 trials, which involved the Nissos cultivar being grafted onto Maxifort (organic tomatoes). In line with other Greek case studies, it was found that labour and the cultivation treatments accounted for the largest proportion of the production costs.

Table 5
Calculation of the microbial inoculant preparation costs (KRH): raw materials and reagents.

Items Microbial inoculant preparation	Costs (€)
Yeast mannitol broth	4.0 € l^{-1} culture medium
Distilled water	0.03 € l^{-1} culture medium
Gum Arabic	0.28 € Kg^{-1} seeds
Compostable plastic bags	0.01 € bag^{-1}
Total cost of the raw materials	4.32€ l^{-1}

Table 6
Calculation of the microbial inoculant preparation costs (KRH): energy consumption of the used laboratory equipment.

Laboratory equipment	Energy consumption range per day[1]	Usage per experiment (time in hours per day)	Electricity prices	Cost (€)
Vertical −80 °C Refrigerator	10.7–45.6 kWh	3 h	0.06 € kWh^{-1}	1.926
Autoclave steriliser	4.6–90 kWh	3 h	0.06 € kWh^{-1}	0.828
Vertical Laminar flow	14.4–29 kWh	3 h	0.06 € kWh^{-1}	2.592
Orbital shaking incubator with adjustable temperature	1.8–23.8 KWh	7days	0.06 € kWh^{-1}	18.144
Magnetic stirrer	1.8–3.8 kWh	3 h	0.06 € kWh^{-1}	0.324
Water Distillation and Purification Equipment	2.4–4 kWh	3 h	0.06 € kWh^{-1}	0.432
Analytical balance	0.072 kWh	1 h	0.06 € kWh^{-1}	0.00432
pHmeter	0.072 kWh	1 h	0.06 € kWh^{-1}	0.00432
Total				**24.25**

[1]The energy consumption was calculated for continuous operation throughout the day (24 h).

Table 7
Faba bean cultivation costs (KFB) in the greenhouse and used as green manure for the tomato production process.

Parameters		2019	
		faba bean	
Place	Greenhouse	Greece	
Yield	t ha^{-1}	70	
Economic results	€ t^{-1}; € ha^{-1}	€ t^{-1}	€ ha^{-1}
Production cost (“KFB”)	€ t^{-1}; € ha^{-1}	7.57	530

OR followed an organic cultivation practice, and the fertilisation involved the use of organic materials, that is, the biomass of faba beans used as green manure, thus avoiding the use of inorganic fertilisers. The faba bean seeds were inoculated with a microbial solution of Rhizobium: the costs related to producing the amount of solution needed to grow enough biomass on 1 ha of soil are shown in Tables 5–7. The results of the calculation of the production cost of the faba bean biomass, related to both 1 ton of biomass and to 1 ha of soil, are shown in Table 8.

Table 9 compares the costs incurred for the greenhouse cultivation of organic tomatoes, compared to conventional tomatoes. A distinction is made between the obtained yield, rather LYO scenario of 87 t ha^{-1} and the HYO, which was assumed to be 154 t ha^{-1} (Gatsios et al., 2021).

It is easy to compare the profitability of the two techniques (conventional vs. organic), by considering these two scenarios. The two yield extremes represent the extent to which the relative profitability of organic production can vary under different conditions. The economic results show that the cost of production is higher for the LYO organic tomato, at 540 € t^{-1}, followed by the conventional tomato, at 487 € t^{-1}. The HYO organic tomato would be the least expensive to produce, that is, at a cost of 303€t^{-1}. It should be considered that the cost of chemical fertilisation in the conventional cultivation accounted for 7 % of the total cost; adding the sheep manure and a potassium supply in a form that is allowed in organic cultivation, accounted for 5 % of the total cost of the organic tomatoes. The cost of production was affected the most by the cost of the grafted seedlings, which accounted for about 17 % of the total cost.

Table 8
Tomatoes cultivation costs in a greenhouse: CB conventional process (KCB) vs OR organic process (KOR).

ITEMS	CB		OR (Organic)			
	€ t-1	%	LYO[a] (€ t-1)	%	HYO[a] (€ t-1)	%
Plants and seeds	*33.27*	*6.8*	*89.11*	*16.51*	*50.05*	*16.51*
Plants (seedlings)	33.27	6.8	89.11	16.51	50.05	*16.51*
Cultivation treatments (i.e. pollination, plastic cover, mulch, etc)	*124.58*	*25.6*	*183.65*	*34.03*	*103.15*	*34.02*
Pesticides	*19.83*	*4.1*	*31.72*	*5.88*	*17.82*	*5.88*
Herbicides	–	-	–		–	-
Fungicides	19.83	*4.1*	–		–	-
Insecticides	–	-	–		–	-
Fertilisation	*33.84*	*7.0*	*24.69*	*4.57*	*13.87*	*4.57*
- N	11.13	*2.3*	–		-	-
- P	1.17	*0.2*	–		-	-
- K	21.54	*4.4*	7.23	*1.34*	4.06	*1.33*
Farmyard sheep manure	–	-	17.46	*3.23*	9.81	*3.24*
Water costs (energy requirement, drip system equipment, water services)	*3.77*	*0.8*	*27.4*	*5.08*	*15.39*	*5.08*
Labour (soil preparation and other field operations)	*258.92*	*53.2*	*150.29*	*27.84*	*84.42*	*27.85*
Third-party labours	-	-	*10.84*	*2.00*	*6.09*	*2.00*
Fuel/Oil consumption (for machinery and heating)	*12.55*	*2.6*	*22.06*	*4.09*	*12.39*	*4.09*
TOTAL COST of tomatoes:						
KCB	***486.75***	*100.0*				
KOR (HYO[a])			***539.75***	*100.0*		
KOR (LYO[a])					***303.17***	*100.0*

[a] LYO: Low Yield organic tomatoes; HYO: High Yield organic tomatoes.

What happens, in economic terms, when a complex biostimulant treatment such as the one proposed in this study, is applied to organic tomatoes? Table 9 shows the results of the two considered tomato production processes, conventional and organic. However, in this case, the production cost of the organic tomatoes includes the production cost of the Rhizobia inoculum solution, “KRH”, and the production cost of the legume biomass, “KFB”, which account for 24 € t^{-1} in the LYO and 16€ t^{-1} in the HYO, respectively, a small share of the overall cost, that is, about 4–5 %. This means that combining several solutions makes the organisational aspect of cultivation a little more complex, but from an economic point of view it is quite sustainable in the context studied. From the profitability point of view of the two processes, organic tomatoes are very attractive when they achieve high yields, because the gross income can be almost double that of conventional tomatoes (74,000 euros ha^{-1}, compared to 40,000 euros ha^{-1}). On the other hand, if the yield is low, they are not economically interesting, because the income is only about 21,000€per hectare.

Can these results be extended to the current European prices for tomatoes and inputs, as well as to different geographical areas in the world?

The outlook for the agri-food market in the EU in the short term shows input costs remaining above the long-term average, although there are positive signs of change. Energy inflation is contained with natural gas prices falling to pre-2022 levels but remaining above pre-COVID levels. This is helping to reduce pressure on the EU fertilizer market, although uncertainties remain (EU Outlook, 2023). The tomato market in the EU is experiencing rising production costs, counterbalanced by retail prices that may remain high. However, domestic

Table 9
Tomatoes cultivation in a greenhouse: conventional process (CB) vs organic process (OR) for low (LYO) and high (HYO) yield scenarios (2019).

Parameters		CB (Conventional)	OR (Organic)	
			LYO[b]	HYO[b]
Place	Greenhouse	Greece	Greece	Greece
Variety	Commercial	not grafted	grafted	grafted
Water	100 %	yes	yes	yes
Fertilisers	100 %	yes	no	no
Pesticides		yes	no	no
Economic results	€ t^{-1}	€ t^{-1}	€ t^{-1}	€ t^{-1}
Production cost of tomatoes (KCB); (KOR)	€ t^{-1}	487	540	303
Production cost of inoculum[a] (KRH)	€ t^{-1}	–	16	9
Production cost of faba bean[a] (KFB)	€ t^{-1}	–	8	8
Production cost of organic tomatoes under biostimulant[a]	€ t^{-1}	–	564	319
Revenues (RCB); (ROR)	€ t^{-1}	740	800	800
Gross income (GICB); (GIOR)	€ t^{-1}	253	236	481
Economic results	€ t^{-ha}	€ t^{-ha}	€ t^{-ha}	€ t^{-ha}
Yield	t ha^{-1}	159	87	154
Production costs	€ t^{-ha}	77,433	49,031	49,180
Revenues	€ t^{-ha}	117,660	69,600	123,200
Gross incomes	€ t^{-ha}	40,227	20,569	74,020

[a] Biostimulant treatment: faba bean seeds treatment by means of rhizobium inoculum, faba bean biomass as green manure.
[b] LYO: Low Yield organic tomatoes; HYO: High Yield organic tomatoes.

Table 10
Environmental impact of the FU for the two evaluated cropping systems (CB - conventional and OR – organic) (Δ = impact variation between CB and OR, calculated as: [(impact of OR/impact of CB)-1]*100).

Impact category	Unit	CB	OR	Δ
Global warming	g CO_2 eq	67.943	63.407	−7 %
Stratospheric ozone depletion	mg CFC11 eq	0.268	0.559	108 %
Ozone formation, Human health	g NOx eq	0.141	0.112	−21 %
Fine particulate matter formation	g PM2.5 eq	0.193	0.270	40 %
Ozone formation, Terr. ecosystems	g NOx eq	0.145	0.117	−20 %
Terrestrial acidification	g SO_2 eq	1.077	1.881	75 %
Freshwater eutrophication	g P eq	0.042	0.063	50 %
Marine eutrophication	g N eq	0.158	0.261	65 %
Terrestrial ecotoxicity	g 1,4-DCB	353.184	249.698	−29 %
Freshwater ecotoxicity	g 1,4-DCB	4.481	5.657	26 %
Marine ecotoxicity	g 1,4-DCB	5.809	7.171	23 %
Human carcinogenic toxicity	g 1,4-DCB	4.269	3.016	−29 %
Human non-carcinogenic toxicity	g 1,4-DCB	81.835	94.445	15 %
Mineral resource scarcity	g Cu eq	0.727	0.227	−69 %
Fossil resource scarcity	g oil eq	23.690	20.146	−15 %

consumption remains increasing for canned and stable for fresh. Organic production maintains a positive production and consumption trend, although influenced by inflationary dynamics that discourage significant growth in retail consumption (FIBL, 2023). For EU organic agriculture to reach the 25 % goal by 2030, as set out by the European Commission, stronger annual growth will be needed than in recent years (FIBL, 2023). All these considerations lead to the conclusion that the search for solutions to increase the cultivation of organic tomatoes and their production yields is relevant and promising. In the European Union, the use of alternative sources to classic fertilization and all the solutions that lead to exploiting the potential of microorganisms are of great interest and increasingly taken into consideration by both farmers and consumers. Therefore, the considerations made in this paper can be considered a current matter. As far as the geographical scope and validity of our results are concerned, we believe that it is realistically not appropriate to compare input markets that are far distant and where availability of raw material and industrial production may be very different. However, we can ask whether in different socio-economic contexts, tomato plant strengthening solutions, such as grafting, such as the possibility of preparing seeds with micro-organism solutions such as rhizobia, can be implemented on an industrial scale and prepare a pre-tomato crop with an ad hoc treatment (cutting and sowing) or others, which require additional efforts and costs. In the European context this seems feasible, in subsistence farming and with fewer resources of means and factors of production, this seems much less feasible.

3.2. The environmental results obtained when comparing conventional and organic tomatoes

Table 10 reports the absolute environmental impact of the production of 1 kg of fresh tomatoes for the two cropping systems (CB and OR), while Fig. 3 shows a relative comparison. The results are not univocal; OR shows a lower environmental impact than CB for 7 of the 15 evaluated impact categories, while conventional cultivation is the least impacting solution for the remaining 8 conventional categories.

The better environmental performances of the organic cropping system pertaining to Global Warming (−7 %), Ozone formation, Human health (−21 %) Ozone formation, Terrestrial ecosystems (−20 %), Terrestrial ecotoxicity (−29 %), Human carcinogenic toxicity (−29 %), Mineral resource scarcity (−69 %) and Fossil resource scarcity (−15 %) are achieved despite a considerably lower yield (87 vs 159 t ha^{-1} of fresh tomatoes, for OR and CB, respectively). The most obvious impact reduction is achieved for the environmental effects related to the application of synthetic pesticides (i.e., toxicity related impact categories) and to the consumption of synthetic nitrogen mineral fertilizers (mineral and fossil resource scarcity). Except than for Stratospheric ozone depletion, for the other impact categories where OR shows higher impact respect to CB, the impact increase is less than proportional to the yield variation (82 % higher in CB). For Stratospheric ozone depletion, the worst performance of OR is affected not only by the lower yield but also by the higher N_2O emissions.

The contribution analysis of the two cropping systems (Figs. 3 and 4) shows both similarities and differences between CB and OR. In fact, the following points emerged regarding the similarities.

- The N compound emissions are the ones that are mainly responsible for Stratospheric ozone depletion (due to the emissions of N_2O), followed by Fine particulate matter formation, Terrestrial Acidification (due to ammonia volatilization), and Marine Eutrophication (due to nitrate leaching);
- The e P compound emissions play a minor role, compared to the N compound ones;
- The contribution of the pesticides is limited: <5 % for all the evaluated impact categories (except for Mineral resource scarcity, which is 8.5 % for CB and 12.5 % for OR);
- The impacts of manufacturing, maintenance and disposal of the plastic tunnel are similar, even though they have different relative contributions, in absolute terms, and they are mainly related to the substitution and disposal of the plastic film. The impact of the plastic tunnel is not negligible for any of the evaluated impacts and for either of the cropping systems (ranging from 5 to 46 % for CB and from 6 % to 51 % for OR), except for Ozone formation, Human health, Terrestrial Acidification, Marine Eutrophication and Terrestrial ecotoxicity.

Regarding the results of the contribution analysis, between the two

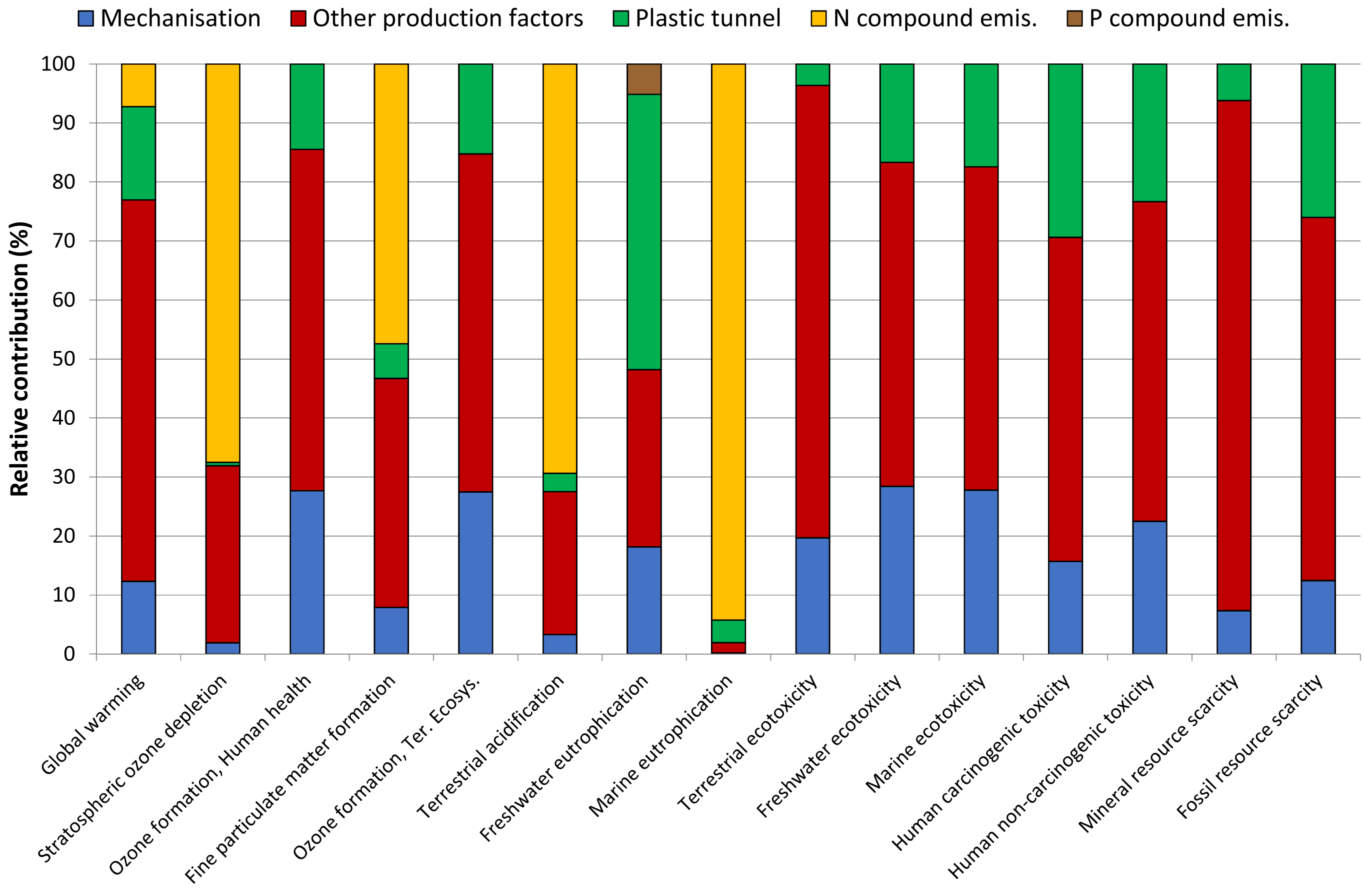

Fig. 3. Results of the contribution analysis for CB – Conventional tomatoes cultivation.

evaluates systems (conventional and organic), the main differences concern the role of fertilizers and mechanization. The contribution of the fertilizer production, which is higher, both in relative and in absolute terms, for CB (where synthetic fertilizers are applied) than for OR (where only organic fertilizers, such as manure, are used). The role of mechanization, which is higher in organic production (from 1 to 81 % of the impact with an average contribution of 41 % compared to a 2–28 % range and an average contribution equal to 16 % in CB). As the mechanization roles are quite similar (except for the type of fertilizer application and the number of pesticide applications), these relative differences are mostly related to the variations in the other environmental hotspots (e.g., synthetic fertilizers).

3.3. Limitations of the study and further research

The main limitation of this study is that it has only examined results from one trial carried out in 2019. However, since no specific funding was foreseen to develop an environmental analysis, a high and low yield (HYO and LYO) scenario study of greenhouse tomatoes was undertaken to make realistic assumptions on the production impact resulting from the multiple use of solutions simulating a biostimulants effect. We hope that different solutions can be tested on tomato plants, at the same time, in the future, and that different biostimulants on grafted seedlings can hopefully create important synergies, capable of a high production and of creating economically satisfactory quantities.

4. Conclusions

Organic tomato cultivation was supported by a specific biostimulant treatment that included a microbial solution, based on Rhizobium, which was distributed onto faba bean seeds; once a suitable faba bean biomass had been obtained, the plants were chopped and incorporated into the soil in order to release nitrogen.

However, the production yield of the trial (LYO) was not economically viable. Since this result was obtained from only one trial, we cannot claim that these technologies have a positive impact on tomatoes production. In addition, the organic tomato plants were grown from grafted seedlings, a treatment that usually has a positive impact on production. However, what does emerge, from the economic point of view, is that this treatment has a mitigating impact on the cost of tomato production, which, in the trial, amounted to only 5 % of the production cost, and was even lower than the cost of the fertilizer application in the conventional case, which was as high as 7 %. This means that when the microbial solution is prepared on an industrial scale, rather than at a laboratory level, the production costs could be significantly reduced. As the LCA analysis has shown, organic tomatoes, with a lower yield, cannot be defined as having a low environmental impact. Therefore, the importance of being able to improve the yield is evident (Crowder and Illan, 2021; Barbieri P. et al., 2021, 2019), not only for obvious economic reasons, but also to limit the environmental impact. Consecutive organic tomato cultivation, with the use of green manure, has shown that the yield can in fact increase after 2–3 years of cultivation (Gatsios et al., 2019). Therefore, another element of interest is that as the organic tomato yield increased (reaching the high-yield scenario simulation, HYO, which was included in the analysis) and approached the conventional yield, an important increase in profitability occurred, which could have covered the costs of any furthermore environmentally friendly treatments, such as biostimulants. An organic tomato production, repeated over the years, did not lead to a decrease in yield (Li et al., 2019). In addition, this rules out the necessity of having to increase the surface area allocated to organic cultivation, an aspect that is of particular interest when greenhouse coverage is used, which requires

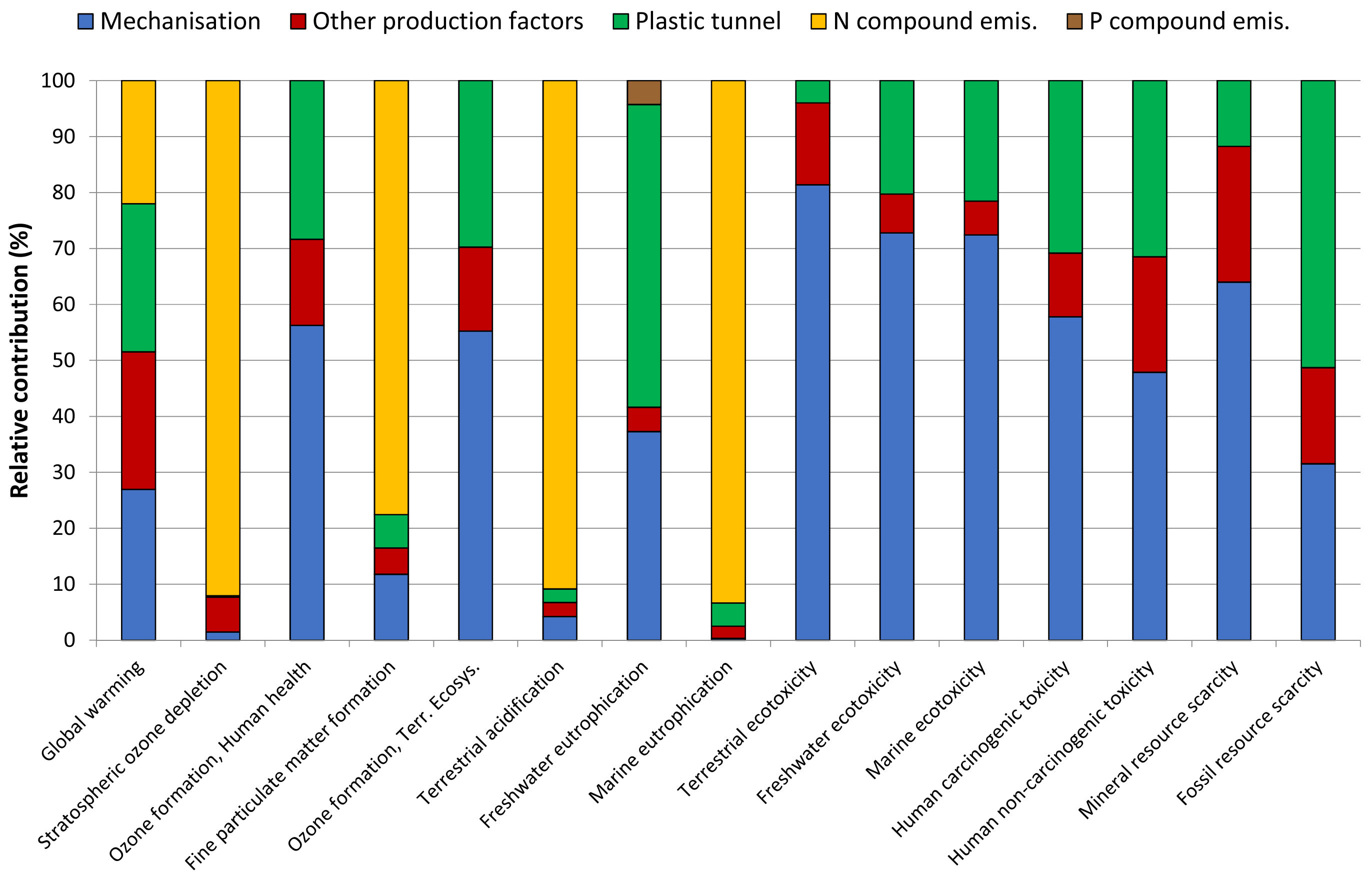

Fig. 4. Results of the contribution analysis for OR – Organic tomatoes cultivation.

high unit investments. Therefore, is it possible to avoid using more soil for organic cultivation? The answer is yes, on condition the yield is high. Another fact that should be noted is that any technological solution that can reduce the dependence of a cultivation on an external fertilizer supply should be considered in consideration of the general situation of nitrogenous fertilizer shortage.

In the context of EU agriculture, the findings presented in this study advocate for concerted actions across agricultural supply chains to enhance organic farming practices. The aim is to encourage and support EU farmers during this transition, thus aligning with the European Commission's call for an expansion of organic farming, as outlined in the Green Deal pathway and CAP 2023–2027.

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CRediT authorship contribution statement

Teresina Mancuso: Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Investigation, Conceptualization, Validation. **Panagiotis Kalozoumis:** Writing – review & editing, Investigation, Validation. **Anastasia Tampakaki:** Writing – review & editing, Resources. **Dimitrios Savvas:** Writing – review & editing, Resources. **Anastasios Gatsios:** Writing – review & editing, Investigation. **Lucia Baldi:** Writing – review & editing, Investigation. **Massimo Peri:** Writing – review & editing, Investigation. **Maria Teresa Trentinaglia:** Writing – review & editing, Investigation, Data curation. **Jacopo Bacenetti:** Writing – review & editing, Writing – original draft, Formal analysis, Investigation, Conceptualization, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Annex 1. Inputs for the cultivation of conventional tomatoes “CB” and organic tomatoes “OR” in a greenhouse (2019, Greece)

Conventional Tomatoes (CB)			Organic Tomatoes (OR)-Stage 3-Field		
Site	Greece		Site	Greece	
Variety	Tomatoes Commercial Elpida F1		Variety	Nissos variety	
				Maxifort rootstock	
Cultivated surface	ha (hectar):	1	Cultivated surface	ha (hectar):	1
Yield	kg*ha^{-1}:	159,000	Yield	kg*ha^{-1}:	86,500
Soil type	Clay		Soil type	Sandy-loam	
	Units of measure	*Total amount*		*Units of measure*	*Total amount*
Soil preparation			*Soil preparation*		
Tractor (18.6 kw, 1000 kg)			–	-	–
Ditching - Fuel consumption	kg*ha^{-1}	100	–	–	–
Soil Tillage & Seedling			*Soil Tillage & Seedling*		
Tractor (6.7 kw, 120 kg)			Tractor (80 kw, 2500 kg)		
Harrowing - Fuel consumption	kg*ha^{-1}	50	Harrowing - Fuel consumption	kg*ha^{-1}	30
Crop management:			*Crop management:*		
Tractor (3 kw, 40 kg)			Tractor (80 kw, 2500 kg)		
Mineral fertilisation - Fuel consumption	kg*ha^{-1}	10	Mineral fertilisation - Fuel consumption		Not relevant
Harvesting and storage			Harvesting and storage		
Tractor (18.6 kw, 1000 kg)			Tractor (80 kw, 2500 kg)		
Harvest - Fuel consumption	kg*ha^{-1}	48	Harvest - Fuel consumption	kg*ha^{-1}	35
Herbicide:	*No*		*Herbicide:*	*No*	
Pesticides:			*BIOPesticides:*		
Abamectin	cc*ha^{-1}	1923	Trichoderma harzianum	kg*ha^{-1}	0.7
Spirotetramat	cc*ha^{-1}	632	Paecilomyces lilacinus	cc*ha^{-1}	0.7
Spinosad	cc*ha^{-1}	1183	Spinosad	cc*ha^{-1}	781
Bacillus thurigiensis	gr*ha^{-1}	11,834	Bacillus thurigiensis	gr*ha^{-1}	16,670
Penconazole	cc*ha^{-1}	592	Azadirachtin	cc*ha^{-1}	7813
Emamectin benzoate	gr*ha^{-1}	17,012	Bacillus amyloliquefaciens	cc*ha^{-2}	12,500
Boscalid pyraclostrobin	gr*ha^{-1}	4438	–	–	–
Chloratraniliprole abamectin	cc*ha^{-1}	2663	–	–	–
Metalaxyl-M	gr*ha^{-1}	8876	–	–	–
Fertilisers:			*Fertilisers:*		
Treatment 1			Patentkali	kg*ha^{-1}	781
N	kg*ha^{-1}	98	Farmyard sheep manure	kg*ha^{-1}	21,250
P	kg*ha^{-1}	74	*Water:*		
K	kg*ha^{-1}	491	Water used	m^3*ha^{-1}	7080
Treatment 2			Plants (number)	seed *ha^{-1}	24,000
N	kg*ha^{-1}	33			
P	kg*ha^{-1}	–			
K	kg*ha^{-1}	–			
Treatment 3					
N	kg*ha^{-1}	77			
P	kg*ha^{-1}	77			
K	kg*ha^{-1}	77			
Treatment 4					
N	kg*ha^{-1}	46			
P	kg*ha^{-1}	–			
K	kg*ha^{-1}	157			
Treatment 5					
N	kg*ha^{-1}	18			
P	kg*ha^{-1}	4			
K	kg*ha^{-1}	27			
Treatment 6					
N	kg*ha^{-1}	50			
P	kg*ha^{-1}	–			
K	kg*ha^{-1}	–			
Treatment 7					
N	kg*ha^{-1}	11			
P	kg*ha^{-1}	–			
K	kg*ha^{-1}	–			
Plastic:					
Plastic cover (duration 7 years)	ha	1			
Plastic mulch (duration 1 year)	ha	1			
Water					
Water used	m^3*ha^{-1}	3820			
Plants (number)	plants *ha^{-1}	17,751			

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