Effect of Water Supply Regimes on Physiological Parameters and Productivity in Eggplant grown under Mediterranean Climate Conditions.

Maachi Dina[a], Toppino Laura[b], Ezquer Ignacio[c], Cebeci Esra[d], Boyaci Hatice Filiz[e], Rotino Giuseppe Leonardo[b], Aberkani Kamal[a]*

[a]Research Team on Applied Biology and Biotechnology, Laboratory of Bioresources, Biotechnologies, Ethnopharmacology and Health, Multidisciplinary Faculty of Nador, University Mohammed First, Selouane, Maroc

[b]CREA Research Centre for Genomics and Bioinformatics, Montanaso Lombardo, Italy

[c]Departments of Life Sciences, University of Milan, Milan, Italy

[d]Bati Akdeniz Agricultural Research Institute, Muratpasa/Antalya, Türkiye

[e]Recep Tayyip Erdogan University, Faculty of Agriculture, Department of Horticulture, Rize, Türkiye

ABSTRACT:

Drought caused by climate change has affected agriculture and intensified water scarcity. The effect of two irrigation regimes was evaluated on 13 eggplant genotypes selected as diverging for several fruit/plant qualitative traits, yield and drought tolerance. In addition, two commercial varieties commonly used by growers in Morocco were employed to comparison. The irrigation treatments consisted of two different conditions: (i) control irrigation (Tr-C) adopted by the grower; (ii) water shortage of 50% of the amount of this irrigation (Tr-50%). Results showed that reduced water supply significantly impacted growth and quality parameters of each genotype/variety ($p < 0.001$) between treatments, particularly, traits such as plant height, number of flowers and leaves. Non-significant differences between treatments were observed for the chlorophyll-a fluorescence parameters such as F_v/F_m, DI_0/CS_0 and ABS/CS_0 ratios. In terms of relative water content (RWC), genotype C10 showed remarkable drought resilience, with only a 4.12% reduction. Water stress resulted in significant reductions in the number of fruits for the genotype C8 by 49.58% and yield per plant for the genotype B1 by 39.19%. Notably, genotypes C10 and C13 demonstrated significantly better performance compared to the other genotypes, yielding 1.48 and 1.53 kg/plant, respectively, while commercial varieties A and V produced 1.98 kg/plant and 1.86

kg/plant. These results provide valuable information for the selecting and breeding of tolerant eggplant genotypes under drought-prone environments.

Keywords: Solanaceae, crops resilience, crop production, chlorophyll *a* fluorescence, drought, irrigation, photosynthesis, quality, relative water content.

Introduction

Climate change is currently one of the main issues in the world, because of its effects on rising temperature and drought, which have resulted in a shortage of water for agriculture (Malhi et al., 2021). It provokes significant changes in air temperatures, precipitation, gas emission and seasonal mutation which heavily affect the productivity of all crops (Vicente, 2022; Malhi et al., 2021). For this reason, global agricultural production is expected to decrease between 3% and 16% by 2080 (IPCC, 2007), with similar drops expected in the Mediterranean region area as a result of water scarcity (Jat et al., 2018; Muñoz-Rojas et al., 2017). Therefore, the necessity of increasing food production to ensure future food security represents an important challenge because of the rapid growth of the world population (Yadav et al., 2018). Many researchers reported that water scarcity has a significant impact on the physiological and biochemical processes of plants, directly affecting their growth and productivity. (Sánchez-Rodríguez et al., 2010; Noorka & Tabasum, 2013; Fahad et al., 2017) Physiologically, water stress can lead to decreased water availability, causing stomatal closure to minimize water loss, which in turn limiting carbon dioxide uptake and reducing photosynthetic efficiency (Sourour, 2017; Kamanga et al., 2018). According to (Giordano et al., 2021), biochemical activities are similarly affected by prolonged drought stress, such as the efficiency of carboxylation, the regeneration of Rubisco, high proline levels and ABA accumulation, oxidative damage and ROS production (Seleiman et al., 2021).

Annual crops, particularly vegetables, are severely affected by water deficiency. The reduction in irrigation water quantity is reported to mostly impact total yield and fruit weight (Akhoundnejad and Dasgan, 2020). Reducing water irrigation by 50% and 25% significantly decreased the fruit size, fruit diameter, chlorophyll content, fruit number and yield of many varieties of tomato (*Solanum lycopersicum* L.), melon (*Cucumis melo*) and eggplants (*Solanum melongena* L.). Drought can restrict plant growth by preventing the division of leaf meristematic tissue cells and cell expansion in elongation areas (Nelissen et al., 2018). The

40% of water added to a pot relative to the 100% control applied to tomato plants was able to induce a reduction in plant height by 24% and stem diameter by 18% (Sibomana et al., 2013). Under drought stress, significant reduction was also noted as compared to control in terms of shoot fresh and dry weight, leaf area and relative water content in tomato (Zhou et al., 2017). Similar results were found by Bismillah Khan et al. (2015) for maize which water stress limited, the plant height, leaf size, and stem diameter. Also, it was reported that water stress restricts plant growth and development by decreasing relative water content (RWC), and photosynthetic rate in potato (*Solanum tuberosum* L.) and wheat (*Triticum aestivum* L.) (Zhang et al., 2018; Mustafa et al., 2021; Wasaya et al., 2021). In plants, the photosynthetic response to drought is extremely complicated. During drought stress, the increase of plant evapotranspiration causes stomatal closure and decreases photosynthetic activity and yield (Rasouli et al., 2023). The photosynthetic rate is delayed because the captured light cannot be completely transformed into chemical energy (Chatterjee & Solankey, 2015; Jamalluddin et al., 2019). Chlorophyll fluorescence is an effective and non-destructive method for measuring the photochemical efficiency of PSII (Mathur et al., 2013). The maximal quantum efficiency of PSII is estimated by its maximum potential quantum efficiency (Fv/Fm), which is predominantly impacted by drought stress (Ahmed et al., 2002). Several investigations have been reported on the impact of water stress on chlorophyll fluorescence in different horticultural crops. The Fv/Fm ratio in tomato was considerably greater for 10-day, 20-day, and 30-day intervals (Bahadur et al., 2015). Conversely, (Yuan et al., 2016) observed a notable decrease in the Fv/Fm ratio in tomatoes under severe water stress.

Eggplant (*Solanum melongena* L.) is one of the common vegetable crop, mostly cultivated in tropical and subtropical regions (Hanifah et al., 2018; Plazas et al., 2019). The total world production has been estimated at 58.64 million tons in 2021, ranking 6th as the most vegetable production after tomatoes, onions, cucumbers, gherkins and cabbages (FAO, 2021). Eggplant is one of the most popular crops in the Mediterranean area, with major producers being Egypt (1.28MT), Turkey (832,938T) and Italy (306,440T) (Tani et al., 2018; FAO, 2021). Africa represents 3.5% of global eggplant production. In Morocco total production of eggplant was 81044 tons from the total harvested area of 2.910 hectares with an average yield of 27.8 t/ha. Eggplants require water during their plant growth and the entire productive phase (Fu et al., 2013). Although, it is considered among the plant species generally affected by environmental conditions (Setyadi et al., 2020) impacting its quality, productivity and post-harvest (Sękara et al., 2012; Toppino et al., 2022), eggplants have been

considered moderately tolerant to drought stress (Carlos Díaz-P Erez & Eaton, 2015). The water stress affects photosynthetic rate in eggplant when compared to full irrigation regime (Mohawesh 2016). Moreover, increasing the water deficit rate from 20% to 40% was reported to cause up to 60% decrease in eggplant yield (Karam et al., 2011)**.**

Drought stress exerts a profound negative influence on fruit weight in eggplant, as evidenced by recent studies (Flores-Saavedra et al., 2023; Kiran et al., 2022). Under drought conditions, both the weight and size of eggplant fruits significantly decline, primarily due to restricted water uptake and metabolic disturbances within the plant. This water stress limits the transport of essential nutrients and disrupts the maintenance of cell turgor, both of which are vital for optimal fruit development. Additionally, irregular water availability in tomato caused by drought can lead to internal pressure imbalances, which decrease the rate of transpiration, compromising fruit skin integrity, and resulting in surface cracking. This further reduces yield (Cantore et al., 2016; Wakchaure et al., 2020). This physiological disorder often associated with calcium deficiency, where the cells in the fruit become weaker and more susceptible to damage, posing significant challenges to commercial production (Haider et al., 2024). Moreover, research indicates that various eggplant cultivars respond differently to drought stress, with some showing greater resilience in fruit weight retention. This variation under-scores the critical importance of selecting drought-tolerant cultivars to sustain yields in water-limited environments (Tani et al., 2018). Kiran et al., (2022) further support these findings, demonstrating that as water scarcity intensifies, the detrimental impact on fruit weight becomes increasingly pronounced. The limited water availability not only reduces photosynthetic rates but also constrains the carbohydrate supply necessary for fruit growth, ultimately leading to diminished overall yield. Together, these studies highlight the severe implications of drought stress on eggplant productivity, particularly regarding fruit weight. They suggest that prioritizing the selection of resilient cultivars will be essential for mitigating the adverse effects of drought in arid and semi-arid regions, thereby enhancing agricultural sustainability.

Understanding the genetic basis of adaptive traits in eggplant's wild relatives has long been the main goal of the breeding effort for eggplant (Oladosu et al., 2021). Breeders are currently focusing their effort on (genotype x environment) interactions with variation in morpho-physiological variables to identify breeding methods to create more drought tolerant crops (Czyczyło-Mysza et al., 2019; Toppino et al., 2022). Plant breeding of eggplant and other crops has focused on developing high yield production with good fruit quality and

tolerance to environmental stress (Daunay and Hazra, 2012). Therefore, major objectives of eggplant breeding efforts were finalized to enhance agronomic characteristics such as, high adaptation to climatic conditions and improvement of resistance to biotic and abiotic stresses (Kashyap et al., 2003; Kumar et al., 2014; Tani et al., 2018) by exploring the available germplasm aimed at identifying new potential sources of adaptation traits. Finding the best method for maximizing genetic gain presents a significant difficulty for breeders working in arid conditions (Mohammadi, 2018). Although drought tolerance is a quantitative trait, some single genes, such as those that regulate flowering time, plant height, spike type, and osmotic adjustment, may be crucial in helping adaptation to drought situations as suggested by Forester et al., (2004). Additionally, research has been conducted to enhance seed germination and improve seedling emergence (Forti et al. 2020). In a study by Guo et al. (2019), the activation of genes in tomato plants demonstrated drought tolerance by maintaining their photosynthetic apparatus and antioxidant defense system under drought conditions. In another study, numerous genetic factors affecting root architecture were identified, some of them which may be able to reduce crop loss caused by unfavorable environmental conditions (Jung & McCouch, 2013).

The objective of this study was to determine the effects of a shortage in water irrigation on physiological and agronomical parameters of different eggplant genotypes displaying phenotypic and genetic variability for productivity, and plant/fruit phenotypic traits of interest for breeding in the Mediterranean area. These selected accessions have been shared among partners in the framework of the ERANET-FOSC C4C project and have been grown along with two common commercial varieties in field under the Mediterranean climate conditions in the northeast of Morocco, and characterized for their phenotypic, physiological response to drought.

Materials and methods

Plant material

Fifteen genotypes including inbred lines and varieties of eggplants as detailed in Table 1 were used. Thirteen genotypes selected for their expected drought tolerance, and high genetic and phonotypical diversity of which 9 genotypes (C6, C7, C8, C10, C11, C12 C13, C14 and C15) were selected from the collection at the Research Centre for Genomics and Bioinformatics, Montanaso, Italy (CREA-GB) and 4 genotypes (B1, B2, B3 and B5) were selected from Bati Akdeniz Agricultural Research Institute, Antalya, Türkiye (BATEM). Two commercial

varieties Vernal (V) (Vilmorin, Paris, France) and Aswab (A) (Seminis, Missouri, USA) were used as control (Fig.1). The fifteen lines are diverging for many plant/fruit/growth parameters; most of them were previously phenotypically characterized for plant and fruit features in field conditions as described by Cericola et al., (2014) and Portis et al., (2015).

Experimental design

Seeds were sowed on June 25th, 2021 in seed cell-multi-pots (with 77 cells for each pot) filled with peat substrate KlasmanTS3 (Klasmann-Deilmann GmbH, Germany), irrigated twice per day according to the climate conditions of the greenhouse. Seedlings of the fifteen genotypes/varieties were transplanted in the field 8 weeks later (August 21st). A field experiment was conducted in "Arid" area, Nador (35◦08*05*2.6" N 2◦57*0*40.3" W) northeast of Morocco. This region is characterized by semi-arid and Mediterranean climate with average precipitation of 200-300 mm per year. From August 2021 to January 2022, the total precipitation recorded was 123 mm (period of running the experiment). The climate during this period exhibited clear seasonal trends with varying humidity and temperatures (Fig.2). Temperatures in August and September were warm, reaching a high of 34°C, and the humidity was regularly around 80%. The average temperature decreased over the course of the months, reaching between 20 and 26°C by January. The soil is 39.17% clay, 21.25% sand and 39.58% silt with a pH of 8.53 electrical conductivity of 716.91 µS/cm at 20 °C and ratio C/N of 6.99 (AGQ Laboratory, El Mohammadia, Morocco). The distance between rows was 1.2 m, plants were spaced 0.72 m on the same row and the length of each row was 50 m. An experimental design of randomized blocks was set up, with six replicates composed by 4 plants of each of the 15 genotypes/variety for each irrigation regime (Tr-C and Tr-50%). Each row, representing a block, included 4 plants of each of the 15 genotypes (for a total of 60 plants). The planting density was 1.15 plants/m^2 (Supp. table 8). Treatments consisted of two different irrigations: control irrigation (Tr-C with drippers every 10 cm along the line) adopted by the grower and a water shortage (Tr-50%, using a line with drippers every 20 cm) of this irrigation. A tape line irrigation with 10 cm distance between two drippers was used for Tr-C and another tape line with same characteristic of the one with Tr-C, but, with 20 cm distance between two drippers was used for Tr-50%. The theorical debit for dripper was 1.5 l/h for both treatments and the distance between each dripper made the difference between Tr-C and Tr-50% in terms of the amount of water saved expected to be of 50%.

Measurements

Water consumption and flow rate

Water consumption parameter was taken considering two measurements. Firstly, it was measured by installing flow meters at the beginning of one irrigation lines of each treatment (of 50m length each, but with either 10 or 20 cm distance between drippers) and then taking readings every 2 weeks for each of the two irrigation lines. At the end of the experiment, we calculated the amount of water supplied for each line where the flow meter was installed and then a calculation was made in order to quantify the average amount of water supplied per hectare and per plant for each irrigation treatment. More details are shown in Suppl. table 8. Secondly, it was also measured by installing containers at the bottom of the dripper and for both treatments, and then it was verified that the flow rate of the dripper was the same for Tr-C and Tr-50% after each irrigation (Table 2). Three containers were used for each treatment and the objective of this method was to ensure that each dripper gave the same flow rate and that the interval (10 cm vs. 20 cm) between drippers was the only variable that determined the amount of water saved.

Plants growth

The plant growth parameters to evaluate drought stress effects were determined according to Kouassi et al. (2021). Growth parameters were measured every week, from the end of August 2021 until the beginning of December 2021, for the 2 central plants of each replication. The measured parameters were: plant height, number of flowers, number of leaves, leaf length and width, stem diameter, petiole length, and number of ramifications. For leaf measurements, the fifth expanded leaf from the apex of the plant was chosen.

Relative water content (RWC)

Leaves were used for measuring RWC according to Barrs and Weatherley`s (1962) method. Measurements were recorded on November 01st, 2021, on the fifth expanded leaf from the apex of one representative plant per each replication of the 15 genotypes/varieties for each treatment. The fresh weight (FW) of leaf samples was weighed immediately after excision, rinsed and kept in distilled water for 24 h, then turgid leaves were weighted (TW). The dry weight (DW) was recorded after drying the turgid leaves at 80 °C for 48h until reaching a constant weight. The relative water content was calculated using the following equation (Eq. 1):

$$\mathbf{RWC\ (\%) = (FW - DW)/\ (TW - DW) \times 100}\ \text{(Eq. 1)}$$

Where ***FW*** is initial fresh weight, ***TW*** is turgid fresh weight, ***DW*** is dry weight.

Chlorophyll fluorescence

This indicates the transfer of electrons during the light phase of photosynthesis from the excitation of chlorophyll by light energy to the transfer of electrons for the dark phase and they are good indicators of plant stress (Tsimilli-Michael & Strasser, 2001). Parameters were measured by a Handy Plant Efficiency Analyzer HPEA (Handey PEA, Hansatech, UK). The following indexes were recorded: maximum PSII efficiency (F_v/F_m), efficiency of light absorption per cross section (ABS/CS_0), and heat dissipation per cross-section of PSII (DI_0/CS_0). Measurements were recorded during clear sky conditions ($T._{max}$= 29 °C; RH_{max}= 80%), on September 17th, 2021 and were taken on one representative plant per each replication, on the fifth expanded leaf from the apex of the plants. To achieve these measurements, leaves were dark-adapted for 30 min using a clip. The minimal fluorescence (F_0) was recorded with modulated low intensity light (<0.1 μmol m^{-2} s^{-1}) without affecting the variable fluorescence. After the 30 min of darkness, a saturating light flash of 3000 μmol m^{-2} s^{-1} (650 nm) during 1 s (gain = x1) was applied on leaves in order to determine the maximal fluorescence (F_m). Five repetitions were used for each genotype/variety.

Yield

It was determined by harvesting the total fruits from all plants of each replication for all genetic materials. Fruit harvest was carried out weekly starting from October 7th, 2021 and ended on January 8th, 2022 by recording the number and weight of fruits. Accordingly, the yield data presented in this study correspond to marketable yield. Marketable fruits were harvested according to Mennella et al. (2012) and Scalzo et al. (2021) with regard their developmental stages (i.e. unripe fruit well before seed maturation). Moreover, these as these fruits did not exhibit any visible cracking, deformation, or external defects, in line with commercial standards. Such issues were not present in the harvested samples. The amounts of undersized unmarketable fruit were equally insignificant in both the watering regimes and were not recorded. Consequently, all the harvested fruits were considered marketable. Then, the putative Water Use Efficiency [WUE (kg/m^3)] was calculated as follows:

WUE (kg/m^3) =Total yield (kg/ha)/ Water quantity applied (m^3/ha) as described in supplementary table 8. Since we had a single determination of the total amount of water

applied for each of the two treatments, statistical analysis of WUE, which would have been equally informative with respect to total yield, was not performed.

Fruit quality

Six representative fruit samples were selected for each genotype/variety and for each treatment and replication. Fruits samples were harvested on December 24th, 2021. All fruits were weighted and cut into two sections considering their length. Length and width were measured for the first half of the fruit. The other half was weighed (FW) and dried at 80°C until it reached a constant weight (DW). The percentage of dry matter (DM %) was determined according to Martínez-Ispizua et al. (2021) (Eq.2) :

DM%= 100 x [Dry weight (DW)/ Fresh weight (FW)] (Eq. 2)

Statistical Analysis

The significant differences between treatments or genotypes were calculated with JASP software (JASP Team (2024). JASP (Version 0.18.3) [Computer software]) following a two-way analysis of variance (ANOVA) including the genotypes × treatment interaction effect. Post-hoc means comparisons were made using the Tukey's multiple range tests at $p < 0.05$. All the statistical data was shown as the mean ± standard error. The Student's t-test was used to determine the differences between the mean values of water consumption. The results of the statistical ANOVA test performed for all parameters considered, (genotypes, treatment and their interaction "genotypes × treatment") are detailed in Supp. table 1. The subsequent Post-hoc Tukey test performed (when ANOVA results were significant), for all parameters considered are detailed in supplementary tables (2-6). PCA analysis was performed utilizing the var-covar matrix using the software Past version 2.16 (Hammer et al., 2001).

Results

Water consumption

To standardize the drought stress tests, water quantity values were calculated as reported in Table 2, showing that the water quantity values of each dripper line with 10 cm and 20 cm were similar and the percentage of variation between 10 cm and 20 cm drippers was non-significant. Therefore, the distance between irrigation lines was the factor that determined the theoretical expected water shortage of about 50% with the measurements made (see water consumption protocol in methods). Furthermore, the stress impact was confirmed by the

calculation of flow meter measurement which reported around 35% soil water shortage with the Tr-50% treatment compared to Tr-C (Suppl Table 8), during typical periods as shown in Fig. 3. In addition to the irrigation values presented in (Fig 3a), measurements of total volume of irrigation applied was found to be 2674.4 m^3/ha and 1737.8 m^3/ha for Tr-C and Tr-50%, respectively. (Supp. Table 8).

Analysis of variance

Watering regimes had significant ($P < 0.05$) effect on the morphological and physiological parameters of the fifteen genotypes as detected by ANOVA analysis (Table 3, Supp. table 1). For the comparison between Tr-C and Tr-50% treatments, highly significant differences ($P < 0.001$) were found for the majority of parameters, except for chlorophyll fluorescence parameters (Table 3). The effect of "genotypes" was significant for most of the parameters, except RWC and number of ramification (growth parameter). For the interaction, non-significant differences were obtained for the three parameters of chlorophyll fluorescence, yield per plant, and total yield of yield parameters, and fruit weight and DM% for fruit quality parameters.

PCA-analysis

All genotypes were evaluated in the field for their performance at control (Tr-C) and under 50% water shortage (Tr-50%) during the entire growing season according to various parameters regarding plant growth, RWC (average data summarized in Table 4), Chlorophyll *a* fluorescence (Table 5), yield (Table 6) and fruit quality traits (Table 7).

A PCA analysis (Fig 4) was performed provide an immediate overview of the spatial distribution of the genotypes according to all parameters and to identify their relationship, also allowing to visualize the difference between genotypes and their response under water shortage regime. According to the PCA outputs (suppl table 1), the first two components account for 90% of the variability. The first component (explaining the most significant amount of variability) is mainly represented by traits associated to the plant vigor and productivity (fruit weight, yield per plants, number of flowers and fruits, stem diameters), while the second component is mainly associated with chlorophyll *a* fluorescence. The genotypes are dispersed along the first two-component plot mainly according to their intrinsically features with no substantial distance between Tr-C and Tr-50%, even if, in some

of them a more evident separation of stressed accessions with respect to their control, mainly affecting the 1st component, are highlighted.

Plant growth

All the morphological traits recorded were significantly affected ($p < 0.001$) by the treatment (Table 4, Supp. table 2), and, generally, the Tr-50% determined a reduction of all the recorded traits. Significant effects were also evidenced also for genotypes and the interaction "treatment x genotype". The highest value of plant height was recorded for the variety V (46.2 cm) under Tr-C and for the genotype C10 under Tr-50% (41.1 cm). The genotype C12 registered the lowest plant height in both irrigation treatments, and its height significantly decreased by 21.12% under Tr-50% concerning the control treatment (Fig. 5A, Supp. table 3). For number of leaves, the values decreased significantly ($p < 0.001$) for all the genotypes (1.83% - 25.63%) under Tr-50% compared to their control treatment. The highest decrease was observed for C12 and V, with 24.06% and 25.63% of reduction, respectively. Genotypes V (28.0), C15 (26.8), C12 (27.3), C10 (26.1) and B1 (26.2) had the greatest number of leaves in Tr-C conditions. In Tr-50%, only C10 (22.7), C15 (21.8), B1 and C8 (21.2) maintained the same high values compared to the rest of the genotypes. The genotype C7 disclosed the smallest value in the two treatments (Fig. 5B, Supp. table 3). Also, the shortage in irrigation treatment significantly decreased the number of ramifications ($p < 0.01$), while for the genotypes and the interaction « treatment x genotype » were not significant. The lowest value was recorded for C7 in non-stress and stress condition (Fig. 5C, Supp. table 3); the reduction was between (2.40% - 29.89%) compared to the control treatment, with the largest reduction of 29.89% being for the genotype B3.

Regarding the flowering attitude, the number of flowers significantly decreased ($p < 0.001$) between treatments, and among genotypes, but also the interaction « treatment x genotype » resulted in statistically significant. The genotypes C10, C14 and C15 preserved the greatest number of flowers than the other genotypes under both treatments (Table 3, Supp. table 2). Compared to control, the genotypes reduced their number of flowers from 7.99% to 48.10% under Tr-50% (Fig. 5, Supp. table 3). The greatest reduction was noted for C14 (48.10%). Furthermore, the irrigation reduction had a significant decreasing effect ($p < 0.001$) on stem diameter with a significant ($p < 0.01$) difference among the genotypes which showed a reduction between 2.99% and 19.72%. The highest value was noted for the genotypes C10 (7.5mm) and C11 (7.6mm) in the control treatment and for B2, C10 and C13 under Tr-50%.

The lowest value was obtained for the genotype C15 (6.3 mm) under Tr-C, while for B1 and C8 (5.7 mm) in Tr-50% (Fig. 5E, Supp. table 3). B1 noted the highest decrease with 19.72% in stem diameter. Leaf length significantly decreased ($p < 0.001$) for most of the genotypes (2.02% - 21.98%). Under Tr-C, the shortest leaf length was scored for B2 (16.2cm), while the highest one was recorded in the genotype C15 (19.9 cm), which also displayed the largest reduction of (21.98%) in Tr-50%. For the stress treatment, genotypes C13, C6 and the commercial hybrids A, whilst V had a higher leaf length than other genotypes (17.4 cm, 17.2 and 18.1cm respectively, Table 4). The lower value was revealed for C7 (Fig. 5F, Supp. table 3).

Still, leaf width decreased significantly for the genotypes and treatments ($p < 0.001$). C6 displayed the greatest value (12.5 cm) in Tr-C, with a 17.87% of reduction in Tr-50%. C13 illustrated the highest value (10.6cm) under stress condition (Fig. 5G, Supp. table 3). Likewise, water stress causes a significant difference ($p < 0.05$) in the petiole length. The genotype C7 displayed the greatest petiole length under control and stress treatments. Also, C10 (6.3 cm) and B3 (7.8cm) in Tr-50% (Fig. 5H). Petiole length changes as a percentage ranged from 3.23% to 18.64%, showing significant variances. Nevertheless, there was no apparent change in growth parameters as a result of these adjustments. Interestingly, some genotypes showed increases in petiole length, including B3 and C10, under irrigation shortage compared to Tr-C.

RWC

Under water shortage, RWC significantly decreased for most of the genotypes compared to the control treatment ($p < 0.001$), while non-significant difference was evidenced between genotypes (Table 5, detailed Statistical ANOVA and post-hoc test performed for RWC traits available in Supp. tables 2 and 4).

All the genotypes present a slight tolerance in the control treatment (values ranged from 70.64% to 81.0%). RWC reductions fluctuated between 4.12% - 21.40% under irrigation shortage. It was observed that the genotypes C15 (81.00%) and B5 (80.92%) maintained the highest values of RWC compared to the other genotypes in non-stress conditions (Fig.6, (Supp. table 4). While their response to water shortage conditions was significantly different. The genotypes C10 (69.99%) and B5 (70.06%) interestingly preserved the greatest values of RWC under water shortage and were therefore assigned as more tolerant to stressing conditions; on the contrary, C13 (58.90%) and C15 (60.95%) displayed the lowest values of

RWC and considered to be more sensitive. The results showed that the genotypes C13 and C15 displayed the greatest reduction by 20.72% and 21.40% respectively. C10 represents the more resilient genotype affected by water stress with only 4.12% of RWC reduction.

Chlorophyll a fluorescence

Non-significant differences between the treatments were highlighted for the ratio F_v/F_m (indicating the maximum efficiency of PSII), the ABS/CS_0 ratio, (which indicates the efficiency of light absorption per cross section) and the DI_0/CS_0 (indicating the dissipation per cross-section of the photosystem II), whereas the genotypes proved important different responses *($p < 0.001$)* for the three fluorescence parameters (Table 5, Supp. table 2). All the genetic material showed the stability of the F_v/F_m ratio when plants faced water shortage (Fig. 7A, Supp. table 5). The genotype B5 displayed the lowest values (0.59 and 0.55) of F_v/F_m for Tr-C and Tr-50%, respectively, while the genotype C10 revealed the highest values (0.83 and 0.78) compared to the other genotypes. For the ABS/CS_0 ratio, the B5 genotype showed a high value without any significant difference between the two treatments (Fig. 7B, Supp. table 5). B5 was statistically different respect C10, C13, C14, C15 and C6. Moreover, C14 revealed the lowest value when compared to the other genotypes regardless of the two treatments, and it was significantly different from C7. In addition, the ratio (DI_0/CS_0) of the genotype B5 was highest and the genotype C14 had the lowest values compared to the other genotypes and treatments (Fig. 7B-C, statistical data analysis can be seen in Supp. table 5).

Yield

All yield data presented reflect marketable fruits only, as no visible defects such as cracking or deformation often linked to heavy irrigation imbalance were observed in the harvested samples. Regarding the main parameters affecting yield (number of fruits/plants and average fruit weight) the statistical analysis highlighted significant differences in recorded data between treatments ($p < 0.001$), and between genotypes ($p < 0.001$). However, a significant genotype x treatment effect was detected only for the number of fruit/plant (Table 6, Supp. table 2).

Regarding number of fruits/plants, in the control conditions it was higher in the genotypes C8 (19.00), B5 (15.17) and, as expected, in the commercial hybrids A (15.96) and V (16.79). The genotype C6 produced the significantly lowest number of fruits under both Tr-C (9.58 fruits/plant) and Tr-50% (6.42 fruits/plant) irrigation, but interestingly had a very low decrease (12.79%) in response to stress. The reduction of fruit number in all genotypes under

Tr-50% conditions ranged between 2.23% and 49.58%. Under water shortage, the genotypes B5 (10.38), C8 (9.58), C14 (9.50) and C7 (9.21) resulted the best performing, except the commercial hybrids A and V with displayed respectively 11.88 and 11.71 fruits/plant (Fig. 8A, Supp. table 6). C7 was the more "resilient" and decreased only (2.23%). This data together with C6 seems to indicate that lower performing lines in control conditions can maintain better the production upon stress while "highly performing" lines like A, V or local lines like C8 have less "plasticity" to drought stress. For the yield (kg/plant), statistical analysis of the data revealed significant differences among genotypes and treatments *($p < 0.001$)*, However, there were no appreciable changes brought about by the "treatment x genotype" interaction (Table 6, Supp. table 2). The decreases in fruit yield per plant (kg/plant) varied from 0.65% to 39.19%. The commercial hybrids A and V presented very high production as expected (2.49 and 2.7 kg/plant respectively) and this value resulted affected importantly upon stress (reduction of 20 and 31% respectively).

Regarding genotypes, C10, B5, B1, C12 and C8 were detected with higher values of yield in Tr-C compared to the rest of the local genotypes (2.18 kg/plant, 1.88 kg/plant,1.84 kg/plant, 1.82 kg/plant and 1.63 kg/plant, respectively), significantly differing from the "low performing" genotypes C6, C7, C13, C14 and C15. C7 displayed a very low impact under water shortage (10% reduction only) supporting the flexibility already reported for the number of fruits/plant analysis. Interestingly, C13 represents the more resilient genotype affected by water stress for kg/plant pattern and showed only a 0.65% of reduction indicating again that the local lines (like C6 and C7) that are targeted in certain cases the more resilient to water regime fluctuations. According to the results the highest reduction, (and therefore the greatest sensibility to drought stress), was reported for the genotype B1 (39.19%). Whereas, among the stress treatment genotypes C10 and C13 showed significantly higher yield of fruits per plant (kg/plant) (1.48 kg/plant and 1.53 kg/plant, respectively), in contrast to the remaining genotypes, although lower respect to the commercial lines A and V with 1,98kg/plant and 1,86 kg/plant, respectively). C14 had significantly lower yield in the two treatments and additionally, in contrast to the other genotypes (Fig. 8B, Table 6, Supp. table 6).

Overall, our data seems to indicate that the local lines that are targeted as "low performing", respect the "high performing lines" or the "commercial lines" have more plasticity to water regime fluctuations.

Fruit quality

Fruit weights (g), length (cm), width (cm), and the percentage of dry matter of the fruits are presented in Fig. 9 and Table 7. Significant differences were observed between treatment and among genotypes *($p < 0.001$)*, (Table 7, Supp. Table 2). Higher fruit weight was observed in C13 (293.60g in Tr-C; 236.60g in Tr-50%) and C12 (284.30g in Tr-C; 239.80g in Tr-50%) (Fig. 9A, Supp. table 7). The lowest fruit weight was recorded for the genotypes C7 and C14 in the control treatment and C14, C8, C7 and C15 in stress treatment. A significant reduction was observed in all genotypes due to water shortage, ranging between 20.79% and 35.19%. Fruit length and width were significantly lower under Tr-50% than Tr-C for most of the genotypes ($p < 0.001$) (Fig. 9B-C, Supp. table 7). Genotype C8 accounted for the highest fruit length 24.18 cm in case of Tr-C and 20.25 cm in Tr-50%, with significant reduction (16.25%), while the lowest fruit length was noted for C15 6.18 cm under Tr-C and 5.50 cm under Tr-50% when compared to other genotypes, with a notable decline of approximately 11.00% in the Tr-50% treatment. The genotype B2 was the most affected by water shortage, with a fruit length reduction of 27.20%. C12 had a comparably higher fruit width in contrast to other genotypes, (11.16 cm and 9.16 cm in control and water shortage treatments, respectively) with a significant reduction of 17.92%, while the lowest values were recorded for C8 (2.71 and 2.43 cm, respectively). The highest reduction in fruit width due to Tr-50% was recorded for C14 (34.35%). In terms of dry matter content of the fruits, significant difference was observed both between treatments and among genotypes. The genotypes varied between 2.58% and 8.35% in the two treatments. The C15 clearly had the highest significant DM when compared to the rest genotypes with a value of 7.90% in Tr-C and of 8.35% in Tr-50%. On the contrary, C12 genotype had significantly lower DM compared to the remaining genotypes (Fig. 9D, Supp. table 7).

Discussion

Plant growth is one of the physiological processes most vulnerable to drought, and water scarcity is a limiting factor for plant growth and development (Shao et al., 2008). The results obtained in this experiment indicate that the reduction of 50% of the irrigation regime affected the growth parameters of a great part of eggplant genotypes and varieties selected for this study. The panel of accessions tested in this field trial, which represents a part of the whole genetic diversity of the *S. melongena* genus, was usefully exploited to find out potential biomarkers and genotypes that could be employed in a breeding program. We identified a

general trend in our eggplant populations submitted to an estimated 35% cut of the irrigation regime, showing an overall developmental reduction of the aerial structure and presenting a variable range of responsiveness among eggplant lines. PCA analysis highlighted that the main traits explaining the observed variability were some related to plant features (plant height, number of flowers, and stem diameter which are associated with plant vigor) along with those regarding plant productivity (number and weight of fruit, and yield per plants). The second component, influencing to a lesser extent the variability, accounts for traits related to chlorophyll fluorescence. Accordingly, ANOVA analysis evidenced, among the traits studied, that the most evident effects of treatment were the reduction of i) number of ramifications (6 lines) ii) number of flowers (7 lines) iii) leaves length (6 lines), leaves width (4 lines) and petiole length (4 lines). In addition, parameters such as plant height or number of leaves seem to be even more proper indicators of stress and plants may have certain plasticity to maintain this phenotypic feature under different water availability. Significant difference on plant height was obtained for all genotypes compared with the control. These results are different from those found by Kamrun, et al. (2011) since they observed no difference in the height of some tomato cultivars when subjected to different water stress treatments. As compared to controls of all genotypes at Tr-50% water stress, there were significant differences matched with the results obtained by Kirnak et al. (2001), in their study water stress was applied by irrigating the plants with 80%, 60% and 40% of water needed to reach pot capacity and severe water stress (40% of pot capacity) reduced the plant height by 46%, therefore confirming that water limitation reduced significantly the plant height in eggplant. The decrease in plant height was also shown with tomato (Zhang et al., 2020) and potato crops (Pino et al., 2013). The main physiological causes of plant height reduction under water stress include reduced cell turgor pressure and restricted cell expansion and increased leaf senescence. In order to conserve moisture when there is little water available, plants usually close their stomata. This restricts photosynthesis and causes slower growth, particularly in plant height. Hormonal reactions brought on by stress also hinder growth, such as elevated levels of abscisic acid, while reduced gibberellins, result in shorter internodes and an overall in height (Lisar et al. 2012; Ilahi et al., 2018). Water stress can lead to increased levels of ROS, which can cause oxidative damage to cellular components impairing cell division and growth (Sah et al., 2016). Likely, all or some of these mechanisms operate in eggplant as well. The number of flowers decreased significantly with Tr-50%, the most affected was noted for the C14 (48.10%), which is similar to the results found by Amiri Rodan et al. (2021) who demonstrated that 40% of water reduction decreased the number of flowers in eggplants.

According to Wahid et al. (2007), stomatal closure is a major response to water conservation, significantly reducing the absorption of carbon dioxide. This decrease affects the plant's capacity to produce flowers and may cause early death of current flowers since it results in less photosynthesis and less energy production (Potopová et al., 2016). In addition, abscisic acid (ABA) levels in plants are elevated during water stress, as it is produced when ROS amounts increase in response to stress. As a result, flowers and fruits may drop. Additionally, low water availability limits nutrient absorption and ion balance, leading to poor flower formation and fewer flowers in stressed plants (Chaves et al., 2002; Takeno, 2016). The number of leaves, leaf length and width, number of ramifications, and length of the petiole were significantly affected by Tr-50%. Petiole length varied significantly between genotypes and treatments in our study. Our results align with those found by Rady et al. (2020) in tomato stating that the number of leaves decreased by approximately 29.6 and 27.4 % in the 2017 and 2018 growing seasons respectively under 60% water limitation with respect to normal irrigation. The main response to water scarcity is the restriction of active plant cellular growth, which lowers the number and growth of leaves as a drought tolerance mechanism (Ghodke et al., 2018), the plant minimizes transpiration by closing stomata, which is prompted by the hormone abscisic acid (ABA), which promotes deeper root growth. Stomatal closure reduces water loss by sealing small apertures that facilitate gas exchange, even though it does not directly reduce leaf area (Basu et al., 2016). Furthermore, because the plant prioritizes survival under water stress, it frequently experiences stunted growth, which further reduces the production of new leaves and causes leaf wilting (Anjum et al., 2011). Semercı et al., (2017) reported that low turgor pressure causes the plant to grow stunted under drought stress, resulting in a significant reduction in growth, including leaf number. Also, previous studies reported that water stress decreased the number of ramifications (Limousin et al., 2012), and petiole length (Devkota and Jha, 2011). Medyouni et al. (2021) reported that the length and width of leaves were reduced by 37% and 36% respectively in tomato and under water scarcity. Also, stem diameter is another factor frequently impacted by water stress (Albert et al., 2016) and by reducing irrigation, stem diameter was significantly reduced (Zhang et al., 2020). This indicates that phenotypic monitoring of these values in commercially valuable lines may be a biomarker of field stress that may have practical utility in future agronomic practices to prevent irrigation problems in the field.

Relative water content (RWC) which is a measure of the physiological water status (Sekmen et al., 2014; Siddiqui et al., 2015) of a plant had a higher value for all genetic

material at Tr-C compared to Tr-50%. In our study, genotypes C10 and B5 successfully maintained a constant RWC when submitted to the irrigation reduction, thus indicating their better ability to cope with drought stress tolerance. C10 represents the more resilient genotype affected by water stress with only 4.12% of RWC reduction. On the contrary, C13 and C14 are meant to be the most sensitive to drought stress according to their greatest decrease under Tr-50%. Similar trend was observed in the Mohawesh & Karajeh, (2014) study who observed that under greenhouse condition, leaf RWC significantly reduced with irrigation shortage both in tomato and eggplant. Also, Kirnak et al., (2001) and Bian et al. (2019) already reported that significant reductions in the amount of leaf relative water content and vegetative growth could be caused by the water stress in case of eggplant and tomato, respectively. The genotype C10 and B5 were preserved as the most tolerant under stress water condition, considering the other phenotypic and physiological traits. The high Fv/Fm value ratio obtained for C10 under water stress indicates that this genotype could be considered as a tolerant accession in this irrigation study. This result is consistent with other studies indicating that tolerant varieties get better RWC under water stress (Cia et al., 2012). In conditions of stress, plants could maintain their physiological balance by increasing RWC, especially when the transpiration rate is high (Raja et al., 2020).

On the other side, the plant photosynthesis process is influenced by environmental factors. This may impact each phase, including the absorption of solar energy, the transmission of electrons, and the final acceptors (Ripoll et al., 2016). Analyzing the chlorophyll *a* fluorescence parameters is a specific and quick method for determining how effectively the photosynthetic apparatus's composition and function respond to abiotic stresses (Killi et al., 2020). The F_v/F_m ratio had no significant differences between the control irrigation and water shortage treatment. This result agrees with the results of Penella et al. (2014), since no effect of water shortage was found on F_v/Fm ratio on different pepper genotypes. This response is also linked to microclimate conditions such as deficit vapor deficit (VPD), leaf and air temperature and relative humidity. The ratio could change during the day; it could be decreased in the moment of the day when the dry and temperature conditions are high, and the ratio could back to normal value at the end of the day where the microclimate stabilized to normal conditions (Wu and Yang 2024). Also, it was reported by Bahadur et al. (2015) the tomato Fv/Fm ratio was considerably greater for 10-day, 20-day, and 30-day intervals after the application of water stress, and that means that crops could recover from water stress.

Interestingly, it was observed that, the F_v/F_m ratio was higher for C10 under water stress conditions, meaning that this genotype was more tolerant as reported by Poudyal et al. (2019) in tomato drought tolerant genotypes under high temperature conditions. In this study, under water stress, the majority of genotypes and particularly B5 had an increase in DI_0/CS_0 ratio under water stress. This increase could be the effect of the existence of less energy available for photochemistry, supported by an increase in energy dissipation at elevated temperatures (Mathur et al., 2013). This parameter is usually high with stress conditions because of the energy loss by heat dissipation instead of electron use for photosynthesis and carbon fixation. In addition, the reduction in chlorophyll fluorescence of B5 under the two-treatments seemed to show that there is a loss in the yield of PSII photochemistry because of the reduction of the photosynthetic rate (Hannachi et al., 2022). This can also suggest that the defensive mechanism (heat dissipation) is activated by the reaction centers in response to drought stress (Wang et al., 2019). For the ratio ABS/CS_0, no difference was recorded between both treatments, evidence already reported by Luo et al. (2023). This could mean that the number of electrons received with the chlorophyll antenna was the same with Tr-C and Tr-50%.

For plant yield, the Tr-50% condition caused a significant decrease in the fruit yield (g) and the number of fruits per plant and total yield (kg) on the majority of the eggplant genotypes. C8 represents the genotype most affected by water limitation (-49.58%), for the number of fruits. These results agree with Lovelli et al. (2007) who reported that reducing irrigation by 50% in eggplant decreased the number of fruits per plant by 37%. The fruit yields per plant (kg/plant) of C10 and C13 were noticeably higher under stress treatment with respect to the other genotypes, so that they might be regarded as the most tolerant genotypes in this panel of accessions. The same comparison revealed that C14 had a lower yield in the two treatments, so it was considered a sensitive genotype with water limitation. This matched with the results reported by Karam et al. (2011) and showed that eggplant yield was reduced by 33-35% by water scarcity; moreover, Carlos Díaz-P Erez and Eaton (2015) found that eggplant can tolerate water limitation, as plants watered at 33% reduction of evapotranspiration rate (ETc) had fruit yield similar to those irrigated at 100% ETc. Other research studies also showed that the yield and fruit weight of various crops such as tomato and melon decreased as water limitation increased (Du et al., 2015; Akhoundnejad and Dasgan, 2019; Darko et al., 2019). Water stress induced reduction in the yield might be due to various factors such as reverse osmosis formation and stomatal closure (Zaib et al., 2023).

Osmotic pressure changes as soil moisture levels decrease, making it harder to absorb nutrients, particularly in nitrogen (N), phosphorus (P) and potassium (K^+) causing salt buildup because of the concentration of solutes in the little water that is available. This salt accumulation may lead to an ion imbalance in the plant, which could interfere with cellular processes and the movement of nutrients (Fahad et al., 2017). Decreased transpiration, photosynthesis due to stomatal closure can lead to inadequate fruit development, reduced fruit size, and ultimately a lower overall yield, affecting both the quality and quantity of the harvest (Shahriari, 2021; Oguz et al., 2022). Calcium deficiency has been directly associated with the development of physiological fruit disorders such as blossom end rot, epidermal cracking, and tissue softening, all of which significantly compromise marketable yield particularly in tomato (Cui et al., 2019). However, in the present study, no visible defects such as fruit cracking or deformation were observed across genotypes, even under water stress. Therefore, the reported yield values reflect marketable fruits only. This distinction is particularly relevant in drought-related studies, as physiological disorders can significantly reduce commercial yield despite high total production (Egea et al., 2022). The absence of such physiological disorders in our experimental conditions enhances the validity of the yield measurements and supports a more accurate evaluation of genotype performance in water-limited environments.

As reported previously, results showed that significant differences were observed in fruit weight, fruit length and width between Tr-C and Tr-50% for some genotypes and varieties. Usually, with water limitation, fruit size decreases because of the movement of water for leaves instead of fruit and this is because of the high transpiration rate in case of high temperature and drought and also, the fruit has a trend to be smaller in case of drought even with low temperature because of the low upload rate of water by the root system and because of the water limitation in the soil (Devin et al., 2023). According to Çolak et al. (2015), changes in irrigation rate had a significant impact on the quality parameters of eggplant including fruit weight, fruit length and width, and yield per plant. Also, the results of this work, on these quality parameters, matched with those reported by Mohawesh and Karajeh (2014). Semida et al. (2021) found that fruit length of eggplant was lowered by 9.2% when irrigation was reduced by 60% ETc. In the case of our study, water limitation increased the fruit dry matter content. These results are in agreement with those of Karam et al., (2011) and Serhat (2017), who stated that water limitation considerably increased fruit dry matter content in eggplant.

Our comprehensive analysis, in particular using PCA on a diverse range of eggplant accessions, led here to identify of new biomarkers. The tested varieties showed a significant increase in ABS/CS_0 and DI_0/CS_0 photosynthetic tendency and a reduction in fruit weight in response to stress, as indicated by PCA, which showed a strong association between these biomarkers and genotypes exposed to water stress conditions. This finding is in line with previous reports that highlighted the critical importance of this chlorophyll fluorescence parameters in eggplant for agronomical significant traits such as fruit weight (Kiran et al., 2022; Plazas et al., 2019; Tsonev et al., 2011) (see figure PCA). For example, exploiting available QTL data on chlorophyll content may be valuable for improving photosynthetic efficiency and stress tolerance in eggplant (Plazas et al., 2019). That study identified specific QTL, such as chl2 on chromosome 2, with stable effects under both irrigated and drought conditions. Introgression of these QTLs from drought-tolerant eggplant wild relatives could allow for increased chlorophyll retention and photosynthetic resistance. The impact of photosynthesis for achieving high yields, especially under stress conditions has been well documented in different plant systems in recent years (Lee et al., 2022; Muhie, 2022; Rotasperti et al., 2022; Xiong, 2024). When plants face drought stress, photosynthetic rates tend to decline due to factors such as reduced stomatal conductance and compromised chlorophyll content (Ru et al., 2024). These potential biomarkers not only deepen our understanding of genetic diversity among eggplant varieties in the field but also uniquely capture their physiological response capacities under stress conditions. This discovery represents a significant advancement: i) offering innovative tools for screening and ii) identifying varieties with inherent adaptive mechanisms, thus paving the way for more resilient crop development. We found that in eggplants subjected to drought stress, the chlorophyll fluorescence parameters ABS/CS_0 and DI_0/CS_0 show notable shifts that reflect the plant's stress response. This trend was observed for commercial lines like variety V, where reduction of fruit weight of around 30% is accompanied by an increase of both ABS/CS_0 and DI_0/CS_0 values and interestingly, non-observed in the “resilient” variety C7. This is in line with previous reports showing the same trend in those parameters upon drought stress in plants (Makhtoum et al., 2023). Therefore, monitoring ABS/CS_0 and DI_0/CS_0 offers valuable insights into how eggplants cope with water deficit stress at the physiological level. DI_0/CS_0 tends to increase under drought stress, reflecting a rise in non-photochemical quenching or energy dissipation as heat. This increase represents the plant's protective mechanism to prevent over excitation and potential damage to PSII from excess light energy that cannot be used for photosynthesis. The higher dissipation may avoid photo inhibition but could also

indicate that less energy is available for growth processes, contributing to reduced fruit biomass and eggplant yield. This is concomitant to finding a potential third “biomarker” by our PCA assay: The fruit weight. In line with this observation, it is well reported the negative impact of drought stress on fruit weight in eggplant as documented by several studies. For instance, in eggplant, it was reported that drought conditions significantly reduce fruit weight and size, largely due to impaired water uptake, high photosynthetic rate associated with disruptions in the plant's metabolic processes (Kiran et al., 2022). However, the physiological relationship between these photosynthetic parameters and productivity could not be extrapolated to all varieties. For example, other sensitive genotypes, such as commercial variety A (20% decrease in fruit weight), displayed stable trends in ABS/CS_0 and DI_0/CS_0 values, so maybe other physiological mechanisms may help offset the impact of drought stress. This highlights the need for a genotype-environment interaction analysis when considering these parameters as potential biosensors of stress in the field. Notably, the use of remote sensing in future studies to assess photosynthetic efficiency offers a novel approach for detecting early stress signals in plants in field. In the future, satellite imagery could facilitate large-scale monitoring of photosynthetic efficiency, allowing for early identification of cultivars that will be vulnerable to yield reductions under drought stress and may help support proactive genotypic selection and management. Further genetic analysis of these populations will identify potential target genes involved in these response mechanisms. Overall, these trends are consistent across various studies, highlighting how drought conditions shift the balance between light absorption and energy dissipation, ultimately impairing overall plant vigor and productivity.

Conclusion

Phenotypic monitoring of easily scorable traits such as plant height or number of leaves or fruit yield in commercially valuable lines may be considered an early biomarker of field stress that may have practical utility in future agronomic practices to prevent irrigation problems in the field. Regarding fruit yield, overall, our data indicates that the local lower performing lines in control conditions can better maintain the production upon stress with respect the “high performing lines” or the “commercial lines” because they have more plasticity to water regime fluctuations. It will be challenging to identify and transfer such “stability of response” characteristics in the elite high performing varieties.

The fifteen genetic materials presented different morphological and physiological responses to the water shortage by Tr-50%. C10 and C13 genotypes were highlighted in the

panel as the genotypes which could more tolerate water stress applied in our study better than the rest of genotypes in terms of yield. C10 also preserved the highest ratio of F_v/F_m in the two treatments without significant differences; this means that the response of this genotype was greater than the rest of the genotypes. Genotypic differences in eggplant's responses to stress are issues that should be considered in breeding studies of this species. Some of the genotypes here considered resistant to water stress maybe after further validation, good sources for resistance breeding to this stress. Those results are still valid for the conditions of this current experiment (soil, water, microclimate, period of experiments, method of irrigation made by the grower, etc.). More field trials will be needed and the water shortage should be realized on the need of the eggplants which was not the case of this experiment (100% was the irrigation method made by the grower). More field trials, also under more stressful environments and enlarging the tested germplasm, will be needed to identify superior alleles able to establish eggplant cultivars highly tolerant to water shortages and drought.

Acknowledgments: The authors would like to thank ERANET-FOSC for funding the C4C project (Crops For Change; Tackling the global warming effects in crops, https://www.c4c-cropsforchange.net/)), wherein this work is part of the proposal. As well, they would like to thank CREA-Italy and BATEM- Türkiye for providing their eggplant genotypes seed samples in order to be used specifically for this field experiments. They would like to thank the students and staff for their technical help and also the growers (Mrs. El Yadiz Ali and El Yadiz Said) for supporting these trials.

Author contributions: methodology, M.D., T.L., E.I., C.E., B.H.F. R.G.L. and A.K.; software, T.L., E.I., R.G.L.; genetic material, T.L., C.E., B.H.F. R.G.L.; statistics analysis, M.D., E.I., R.G.L.; validation, M.D. and A.K.; investigation, M.D. T.L. R.G.L. and A.K.; writing-original draft preparation, M.D., T.L., E.I., R.G.L. and A.K.; writing-review and editing, M.D., A.K.; supervision, A.K., project administration, A.K. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: This research work has no conflict of interest.

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Table 1. Main fruit characteristic of the genetic materials (genotypes and varieties) used under two irrigations treatments (Tr-C and Tr-50%).

Genotypes/Varieties	Fruit typology
C6	Lilac round fruits
C7	Purple long fruits –green
C8	Lilac long fruits
C10	Black round fruits
C11	Long black fruits
C12	Purple small ribbed fruit
C13	White round fruits
C14	Little violet black fruits
C15	Little round white fruits
B1	Long- purple fruits
B2	Long- green fruits
B3	Dark purple- short fruits
B5	Green purple- long fruits
A*	Purple black oval fruits
V*	Purple black fruits

Codes with (*) present commercial varieties (A=Aswab; V=Vernal) and the other codes without (*) present genotypes; Genotypes with letter (C) and (B) were selected, respectively from the Research Centre for Genomics and Bioinformatics, Montanaso Lombardo, Italy (CREA) and from the Bati Akdeniz Agricultural Research Institute, Muratpasa, Antalya, Türkiye (BATEM).

1278 **Table 2**. Water quantity measured during average amount of water dripped in 12 watering
1279 during the cultivation for each dripper of both treatments (Tr-C and Tr-50%) and percentage
1280 of variation of TR-C over TR-50%).

Date	Line 10cm (Tr-C) (l/dripper	Line 20cm (Tr-50%) (l/dripper)	Variation (%)
04/09/2021	6.50	6.66	2%
11/09/2021	6.83	6.33	7%
25/09/2021	6.50	6.16	5%
02/10/2021	6.83	7.00	-2%
09/10/2021	7.50	7.50	0%
16/10/2021	7.50	7.33	2%
30/10/2021	12.50	12.50	0%
06/11/2021	9.33	8,66	7%
13/11/2021	9.60	9.50	1%
20/11/2021	10.50	10.50	0%
09/12/2021	21.60	21.40	1%
16/12/2021	11.16	11.00	1%
Average	9.67 ± 1.22^{ns}	9.58 ± 1.25^{ns}	1%

1281 Three containers per treatment were installed under drippers; Data are means of 3 drippers' ± standard error,
1282 based on Student's t-test at 5 % level. ^{ns} indicate non-significant differences,
1283

Table 3. The percentage representing the sums of squares (SS) for every parameter, considering the effects of treatment, genotypes, their interaction "genotypes x treatment" and residual.

	Sums of squares[a]			
	Treatment	Genotypes	Genotypes x Treatment	Residual
Growth				
Plant height (cm)	10.1^{***}	73.4^{***}	2.7^{*}	13.7
Number of flowers	25.1^{***}	37.7^{***}	7.8^{***}	29.1
Number of leaves	22.4^{***}	29.2^{***}	6.8^{*}	41.4
Leaf length (cm)	25.9^{***}	19.7^{***}	8.6^{*}	45.6
Leaf width (cm)	7.8^{***}	34.9^{***}	11.1^{**}	46.1
Petiole length (cm)	1.8^{*}	21.6^{***}	14.7^{**}	61.6
Stem diameter (mm)	37.4^{***}	10.0^{**}	11.3^{***}	41.1
Number of ramifications.	4.7^{**}	8.9^{ns}	10.7^{ns}	75.4
RWC	38.8^{***}	8.8^{ns}	5.2^{ns}	47.0
Chlorophyll fluorescence				
F_v/F_m	0.8^{ns}	46.0^{***}	3.1^{ns}	50.0
ABS/CS_0	0.3^{ns}	37.6^{***}	5.5^{ns}	56.4
DI_0/CS_0	0.3^{ns}	43.5^{***}	2.2^{ns}	53.8
Yield				
Number of fruits (fruits/plant)	17.0^{***}	31.5^{***}	7.2^{*}	44.3
Yield per plant (kg/plant)	11.2^{***}	50.0^{***}	3.5^{ns}	35.3
Total yield (kg)	15.7^{***}	37.4^{***}	7.3^{ns}	39.4
Fruit quality				
Fruit weight (g)	5.5^{***}	74.5^{***}	1.8^{ns}	18.1
Fruit length (cm)	4.9^{***}	90.1^{***}	1.6^{***}	3.2
Fruit width (cm)	2.8^{***}	92.8^{***}	1.4^{***}	2.8
DM%	5.4^{***}	48.9^{***}	5.4^{ns}	40.1

[a] ^{ns}, *, **, and *** indicate, respectively, non-significant, and significant at $P < 0.05$, < 0.01, or < 0.001. For statistical data please see supplemental table (2).

Table 4. Effects of water treatments (Tr-C and Tr-50%) on growth parameters of the fifteen genotypes of eggplant.

Genotypes	Plant height (cm)		Number of leaves		Number of flowers		Leaf length (cm)		Leaf width (cm)		Stem diameter (mm)		Petiole length (cm)	
	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%
B1	33.5±1.44	29.1±1.21	26.2±0.89	21.2±1.27	2.2±0.22	1.8±0.08	18.5±0.44	16.8±0.52	10.6±0.25	10.4±0.39	7.1±0.13	5.7±0.17	6.3±0 .29	5.8±0.32
B2	33.3±0.72	31.3±0.84	21.9±1.45	18.3±0.36	2.4±0.26	1.7±0.20	16.2±0.46	14.8±0.59	9.1±0.27	8.7±0.26	6.7±0.15	6.5±0.16	5.5±0.34	5.1±0.16
B3	44.4±1.07	40.2±0.39	20.8±0.47	20.6±0.99	2.4±0.10	1.3±0.17	17.4±0.38	16.8±0.28	9.6±0.32	10.1±0.21	6.7±0.15	6.0±0.24	6.2±0.32	7.8±0.60
B5	38.8±1.08	33.9±1.14	23.7±1.64	19.7±1.00	3.1±0.36	1.9±0.08	18.4±0.62	16.2±0.41	10.2±0.44	9.5±0.27	7.0±0.20	6.0±0.12	5.8±034	5.6±0.11
C6	34.7±0.42	35.0±0.50	20.4±0.51	17.9±0.92	3.1±0.27	2.0±0.13	18.9±0.46	17.2±0.46	12.5±0.61	10.3±0.29	7.2±0.13	6.4 ±0.24	6.1±0.28	5.3±0.25
C7	42.3±1.47	37.9±0.97	18.0±1.26	17.8±0.82	2.1±0.36	2.1±0.33	17.6±0.46	14.7±0.48	9.6±0.39	8.4±0.38	6.9±0.16	6.0±0.33	6.7±0.31	6.3±0.18
C8	35.9±0.72	35.8±0.37	23.0±1.61	21.2±0.80	3.7±0.18	2.5±0.26	18.2±0.60	15.4±0.23	10.6±0.28	9.2±0.17	7.3±0.17	5.7±0.09	6.3±0.18	5.8±0.20
C10	43.8±0.83	41.1±1.16	26.1±0.92	22.7±0.96	5.5±0.40	2.9±0.19	18.8±0.39	16.2±0.43	11.2±0.30	10.2±0.14	7.5±0.34	6.5±0.26	5.1±0.82	6.3±0.44
C11	46.1±0.56	40.4±1.32	23.7±1.15	20.2±1.08	2.9±0.31	2.0±0.20	17.8±0.16	17.0±0.37	10.1±0.22	9.7±0.33	7.6±0.24	6.4±0.13	6.4±0.20	5.3±0.14
C12	31.2±0.59	24.8±0.79	27.3±1.07	20.8±0.88	3.1±0.47	1.9±0.29	17.6±0.66	16.3±0.58	10.4±0.26	9.6±0.33	7.4±0.16	6.3±0.10	5.9±0.25	4.8±0.32
C13	33.3±0.72	30.9±1.13	22.9±0.64	19.2±1.11	2.9±0.31	2.0±0.13	17.8±0.38	17.4±0.44	10.0±0.15	10.6±0.39	6.8±0.15	6.5±0.13	6.0±0.31	5.8±0.35
C14	33.4±0.47	29.8±1.05	20.7±0.24	18.8±1.18	5.0±0.36	2.5±0.49	17.5±0.32	16.8±0.48	10.2±0.26	10.3±0.47	6.6±0.10	6.3±0.30	6.2±0.26	6.0±0.36
C15	38.6±0.94	35.0±1.02	26.8±1.50	21.8±1.35	4.5±0.23	3.3±0.24	19.9±1.64	15.5±0.51	10.2±0.18	9.5±0.31	6.3±0.12	6.3 ±0.24	5.7±0.14	5.3±0.32
A	40.8±0.81	37.6±1.09	23.3±0.82	18.9±0.50	2.9±0.26	1.9±0.14	19.8±0.49	17.2±0.50	10.9±0.21	10.5±0.27	7.0±0.25	6.2±0.14	6.7±0 .22	6.2±0.37
V	46.1±0.58	40.4±0.66	28.0±1.65	20.8±0.94	3.4±0.26	2.4±0.17	19.4±0.38	18.1±0.30	10.8±0.20	10.4±0.18	7.1±0.14	6.0±0.10	6.3±0.27	5.6±0.24
Treatment (T)	***		***		***		***		***		***		*	
Genotypes (G)	***		***		***		***		***		**		***	
G*T	*		*		***		*		**		***		**	

^{ns}, *, **, and *** indicate, respectively, non-significant, and significant at $P < 0.05$, < 0.01, or < 0.001. For statistical data please, see supplemental tables (2 and 3).

Table 5. Effects of water treatments (Tr-C and Tr-50%) on chlorophyll fluorescence parameters (Fv/Fm, ABS/CSo and DIo/CSo) and RWC% of the fifteen genotypes of eggplant.

Genotypes	Fv/Fm		ABS/CSo		DIo/CSo		RWC%	
	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%
B1	0.71±0.023	0.68±0.023	528.60±81.90	645.40±66.25	153.49±29.43	208.88±35.12	74.69±1.75	69.07±1.26
B2	0.71±0.013	0.76±0.011	636.60±32.59	505.00±46.89	184.04±17.80	119.76±14.88	76.32±1.32	63.54±1.19
B3	0.76±0.017	0.72±0.019	572.20±8.30	619.66±51.91	136.40±10.88	173.71±25.81	75,14±1,29	65,37±1,28
B5	0.59±0.051	0.55±0.062	830.40±70.92	798.40±135.47	354.10±68.62	388.72±105.53	80.92±1.11	70.06±1.02
C6	0.72±0.031	0.72±0.009	381.20±103.61	548.60±11.12	105.47±38.03	152.45±3.45	77.25±1.03	69.63±0.81
C7	0.65±0.057	0.59±0.071	757.40±78.53	698.40±131.34	281.30±74.06	313.50±113.06	74.68±0.86	68.14±0.77
C8	0.65±0.039	0.65±0.049	616.40±52.33	558.40±94.60	222.80±40.41	205.05±50.75	74.56±1.40	67.87±1.10
C10	0.83±0.042	0.78±0.010	406.80±103.30	455.20±53.43	85.03±21.63	101.71±14.83	73.00±1.32	69.99±2.19
C11	0.67±0.027	0.69±0.048	577.40±90.20	584.00±88.67	195.98±37.68	192.68±57.15	70.64±1.82	64.28±1.99
C12	0.65±0.043	0.66±0.015	597.20±84.39	512.20±91.69	218.50±56.29	176.21±35.27	70.70±2.99	64.05±1.24
C13	0.74±0.021	0.75±14.02	474.00±28.68	478.80±61.63	120.23±14.08	118.41±18.88	74.29±0.88	58.90±1.89
C14	0.74±0.023	0.73±0.015	284.00±14.39	326.60±40.15	71.58±5.19	86.81±13.53	73.68±2.29	60.95±0.91
C15	0.78±0.013	0.76±0.018	453.40±39.33	451.00±50.54	97.23±11.76	109.25±19.84	81.00±1.21	63.67±1.24
A	0.80±0.007	0.78±0.021	471.00±14.00	502.80±29.94	94.38±5.60	109.44±18.31	80.90±0.25	66.72±0.96
V	0.81±0.049	0.72±0.014	373.60±118.96	596.40±48.42	91.09±32.33	165.22±20.59	73.79±1.62	66.12±1.82
Treatment (T)	ns		ns		ns		***	
Genotypes (G)	***		***		***		ns	
G*T	ns		ns		ns		ns	

^{ns}, *, **, and *** indicate, respectively, non-significant, and significant at $P < 0.05$, < 0.01, or < 0.001.

(Details on statistic data are available at supplemental tables (2, 4 and 5)

Table 6. Effects of water treatments (Tr-C and Tr-50%) on number of fruit (fruits/plant) and yield per plant (kg/plant) of the fifteen genotypes of eggplant.

Genotypes	Number of fruits/plant			Yield per plant (kg/plant)		
	TR-C	**TR-50%**	**Ratio%**	**TR-C**	**TR-50%**	**Ratio%**
B1	13.29±1.75	8.96±1.38	**32.58%**	1.84±0.24	1.12±0.17	**39.13%**
B2	9.42±1.45	7.96±0.85	**15.50%**	1.25±0.15	0.98±0.15	**21.60%**
B3	12.71±1.25	8.79±1.07	**30.84%**	1.38±0.10	1.03±0.21	**25.36%**
B5	15.17±1.54	10.38±1.04	**31,58%**	1.88±0.22	1.29±0.12	**31.38%**
C6	7.08±1.13	6.21±0.38	**12.29%**	1.28±0.19	1.10±0.09	**14.06%**
C7	9.42±1.29	9.21±0.88	**2.23%**	1.01±0.10	0.90±0.07	**10.89%**
C8	19.00±2.28	9.58±2.19	**49.58%**	1.63±0.21	1.08±0.18	**33.74%**
C10	13.46±1.37	8.04±0.77	**40.27%**	2.18±0.24	1.48±0.17	**32.11%**
C11	7.96±1.16	6.42±0.18	**19.35%**	1.23±0.23	0.91±0.07	**26.02%**
C12	9.58±0.85	7.79±0.66	**18.68%**	1.82±0.16	1.33±0.12	**26.92%**
C13	10.46±1.23	7.92±0.47	**24.28%**	1.54±0.19	1.53±0.13	**0.65%**
C14	11.58±1.18	9.50±2.09	**19.96%**	0.86±0.07	0.57±0.10	**33.72%**
C15	11.17±1.01	6.79±1.17	**39.21%**	1.01±0.10	0.75±0.12	**25.74%**
A	15.96±0.87	11.88±0.56	**25.56%**	2.49±0.11	1.98±0.13	**20.48%**
V	16.79±1.33	11.71±1.20	**30.26%**	2.7±0.32	1.86±0.16	**31.11%**
Treatment (T)	***			***		
Genotypes (G)	***			***		
G*T	*			ns		

ns, *, **, and *** indicate, respectively, non-significant, and significant at P < 0.05, < 0.01, or < 0.001. Statistic details are available at supplemental tables (2 and 6)

Table 7: Effects of water treatments (Tr-C and Tr-50%) on fruit quality parameters (Fruit weight (g), Fruit length and width (cm) and Dry matter (%).

Genotypes	Fruit Weight (g)		Fruit Length (cm)		Fruit Width (cm)		Dry Matter (%)	
	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%	TR-C	TR-50%
B1	195.30±9.75	138.80±10.64	13.81±0.19	11.78±0.31	6.48±0.17	5.70±0.11	6.56±0.16	6.28±0.37
B2	173.00±9.75	122.00±11.24	17.65±0.33	12.85±0.36	4.55±0.15	4.08±0.07	6.15±0.33	7.62±0.54
B3	125.80±9.21	101,30±6.88	19.11±0.50	16.76±0.63	4.30±0.09	4.33±0.08	6.69±0.27	8.21±0.59
B5	139.00±14.29	118.80±9.86	19.66±0.77	17.63±0.33	4.45±0.11	3.95±0.22	6.69±0.22	7.97±0.40
C6	232.10±18.61	165.00±15.72	9.13±0.15	8.05±0.22	8.00±0.24	6.56±0.21	4.40±0.38	4.86±0.40
C7	88.60±5.00	89.30±4.47	16.93±0.32	14.70±0.50	3.55±0.11	2.96±0.10	6.35±0.98	7.96±0.69
C8	104.30±4.16	67.60±6.27	24.18±0.74	20.25±0.26	2.71±0.14	2.43±0.08	6.84±0.23	5.69±0.74
C10	206.00±19.71	178.10±23.46	9.03±0.32	7.58±0.18	7.15±0.14	6.50±0.25	5.38±0.34	5.81±0.83
C11	205.80±15.52	183.00±17.17	15.18±0.47	13.80±0.68	6.35±0.09	5.80±0.14	5.92±0.43	6.75±0.41
C12	284.30±23.66	239.80±16.07	8.03±0.24	6.80±0.14	11.16±0.31	9.16±0.21	2.58±0.34	3.80±0.36
C13	293.60±23.08	236.60±14.02	11.56±0.24	10.23±0.11	9.00±0.15	8.13±0.08	4.90±0.40	5.63±0.18
C14	88.80±6.05	59.60±7.71	11.86±0.29	11.18±0.13	3.93±0.14	2.58±0.15	5.34±0.22	7.27±0.72
C15	93.00±3.36	87.80±2.53	6.18±0.07	5.50±0.05	5.51±0.13	5.08±0.07	7.90±0.66	8.35±0.53
A	223.80±14.49	195.30±14.08	15.21±0.22	12.95±0.30	6.90±0.14	6.15±0.16	6.17±0.32	6.29±0.36
V	212.10±12.61	189.00±13.67	16.53±0.30	12.90±0.45	6.1±0.07	6.15±0.45	5.04±0.36	6.34±0.35
Treatment (T)	***		***		***		***	
Genotypes (G)	***		***		***		***	
G*T	ns		***		***		ns	

ns, *, **, and *** indicate, respectively, non-significant, and significant at $P < 0.05$, < 0.01, or < 0.001.

Statistic details are available at supplemental tables (2 and 7).