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Effect of water stress on the agronomic, technological, and physiological parameters of several industrial tomato varieties

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ABSTRACT
This work consists of comparing 04 varieties of industrial tomatoes, of local origins, grown in dry conditions in order to bring out the best agronomic, technological, and physiological performances in order to cope with colossal imports. The results obtained show that the Rio-Grande variety presents the best agronomic performances, such as the aerial part of the plants, the leaf surface, the number of flowers/plants, and the technological performances such as the Brix and the average weight of the fruits, the Rio-Grande varieties, followed by the Elgon. have the best performance compared to El Karma and Heinz 1350. The study of physiological parameters is carried out according to well-determined protocols, namely chlorophyll A, carotenoids, total proteins, and proline shows that the Rio-Grande variety records the greatest physiological activity, followed by Elgon, among others the Heinz1350 and El Karma varieties, which are the most influenced by lack of water (water stress). Proline shows a significant increase for Heinz 1350 and El Karma tomato plants with 0.67 and 0.56 µg/mg successively, while Rio-Grande records 0.49 µg/mg and therefore the least stressed with respect to the species' reactive oxygen (ROS) and climatic hazards. Our work was validated by statistical analysis.
Keywords: agronomic, physiological, ROS, technological, tomato

1. Introduction

Among the strategic crops in Algeria, the tomato holds a prominent place. It is a widely cultivated species and one of the most important vegetables in human nutrition, consumed both fresh and processed. Tomato cultivation plays a significant role in the Algerian agricultural economy, with substantial areas dedicated annually to its production (both for fresh market and industrial processing) [1]. Drought significantly affects plant growth and is undoubtedly one of the major factors (along with high temperatures) that limit crop production under natural conditions [2]. Numerous studies have focused on the impact of controlled or naturally occurring water deficits on crop performance. Water deficit can be defined as an imbalance between the amount of water available in the soil and the evaporative demand driven by environmental conditions [3].

Many responses to water deficit have been described in the literature at various organizational scales: phenological, morphological, physiological, biochemical, and molecular. However, although general trends are observed, these responses vary significantly depending on the duration and severity of the deficit, as well as the plant's growth stage when the stress occurs [4]. Additionally, responses differ among varieties and are genotype-dependent [5]. Tomatoes exhibit better tolerance to water stress. They can adjust their physiological processes to conserve water while continuing to grow. Water stress during the early stages of the growth cycle

makes the plant more tolerant compared to stress occurring during productive phases (flowering and maturation). However, prolonged water stress ultimately affects yield [6]. The choice between hybrid and local varieties depends on the specific priorities of producers, such as disease resistance, production costs, and adaptation to local climatic conditions. It would be beneficial to use more adapted and stress-tolerant varieties, including local or traditional varieties that are more resistant to biotic stresses (diseases and pests) and abiotic stresses (climatic conditions). These varieties can reduce the need for pesticide interventions and are less demanding in terms of agricultural practices (irrigation, fertilizers, soil tillage, etc.) [7]. Our experiment aims to compare four industrial tomato varieties (local or traditional varieties), which are cultivated without irrigation, by studying agronomic and physiological parameters after exposing the plants to water stress for a period of 4 months. The goal is to identify the best-performing varieties to address the massive imports of this strategic crop.

2. Method

In our experiment, four varieties of industrial tomatoes were studied; these are Algerian varieties of local origin, namely: Elgon, Rio-Grande, Heinz 1350, and El Karma dry driving. The parameters to be studied were carried out at the level of the plant physiology and environment laboratory at Badji Mokhtar Annaba University, Algeria, and at the Technical Institute of Market Gardening and Industrial Cultures (ITCMI) in El Tarf, with a Completely Random Device.

Table 1. Variables and Parameters

Variables	Description	Parameters
Agronomic parameters	Measurement of the aerial part of the plants (MAP)	The length of the aerial part of the plants of the different Varieties with a graduated ruler.
	Leaf area	The leaf area is determined by a traditional method which consists on the one hand of reproducing the Leaf of the Plant on paper, which is then weighed, and on the other hand, by cutting a square of side 1cm from the same paper, which is then weighing, after we deduce the assimilative surface by the rule of three [8].
	Number of flowers per plant	We counted the flowers on bouquets and the total number of flowers per plant.
Technological parameters	Refracto-metric index (Brix°)	This is the sucrose concentration of an aqueous solution; this concentration is expressed by the percentage by mass. The direct reading of natural soluble matter is carried out by a refractometer [9].
	Average fruit weight in kg/plant	We weigh the average of 5 fruits per plant of different varieties by a precision balance.
Physiological parameters	Dosage of chlorophyll and carotenoid pigments	The extraction was performed according to the method described in [10], which involves weighing 0.2 g of green leaves and grinding them in a mortar after adding a pinch of calcium carbonate ($CaCO_3$) and 25 mL of 80% acetone. Chlorophyll content was measured using a spectrophotometric method with a spectrophotometric method with spectrophotometer. The optical densities (O.D.) of the extract were read at 645 nm, and the chlorophyll contents were carried out using the formulas provided in [11].
	Total protein dosage	The proteins were quantified according to the method described in [12], which uses brilliant blue coomassie G250 (BBC) as relative and bovine serum albumin (BSA) as standard.
	Proline dosage	Proline is assayed using the simplified Troll and Lindesly technique (1955), developed by Dreier and Goring (1974) and modified by [13].

The results obtained are subjected to an analysis of variance with a classification criterion. The mean values of the variables are analyzed according to a degree of significance $\alpha = 5\%$ ($p = 0.95$), $\alpha = 1\%$ ($p = 0.99$), and $\alpha = 0.1\%$ ($p = 0.999$) with Minitab 13.1.

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3. Results and Discussion

3.1. Agronomic parameter

3.1.1. Measurement of the aerial part (MAP)

The evolution of plant elongation across different varieties is shown in Figure 1. The results indicate that the highest average elongation was observed in the Rio-Grande variety, followed by Elgon. The El Karma variety ranked third with 32.5 cm, while Heinz 1350 recorded the lowest elongation at 28.3 cm (Table 1). These findings suggest that Rio-Grande and Elgon are more resilient to abiotic stress, such as water stress, compared to El Karma and Heinz 1350, which are more sensitive to extrinsic effects. This aligns with previous studies showing that water stress negatively affects plant growth parameters, including elongation [14]. However, the measurements of the aerial part (MAP) do not seem to present any significant differences between the different varieties, suggesting that while elongation is affected by stress, the overall aerial growth may not vary significantly across varieties under the same conditions. This could indicate that Rio-Grande and Elgon have developed mechanisms to maintain growth under stress, such as deeper root systems or more efficient water use, which allow them to sustain elongation even under adverse conditions.

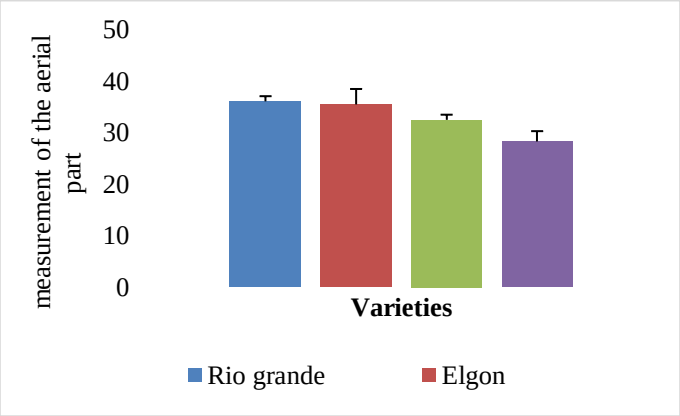

Figure 1. Measurement of the aerial part (MAP) of the different varieties

3.1.2. Leaf area

Figure 2 shows the evolution of the leaf surface over time for the different varieties. The leaf area varied significantly among the varieties, with Rio-Grande recording the highest leaf area (41.25 cm²) and Heinz 1350 the lowest (23.28 cm²). This variation can be attributed to the differing tolerance levels of the varieties to water stress. Water stress inhibits cell expansion and division, leading to reduced leaf area, as observed in previous studies [14]. The higher leaf area in Rio-Grande and Elgon suggests better adaptation to stress conditions, which is crucial for maintaining photosynthesis and overall plant productivity. The leaf area and the number of flowers per plant under water stress recorded high values in Rio-Grande followed by Elgon, while El Karma and Heinz 1350 recorded the lowest values, indicating that the latter are more sensitive to extrinsic effects due to abiotic stress [14].

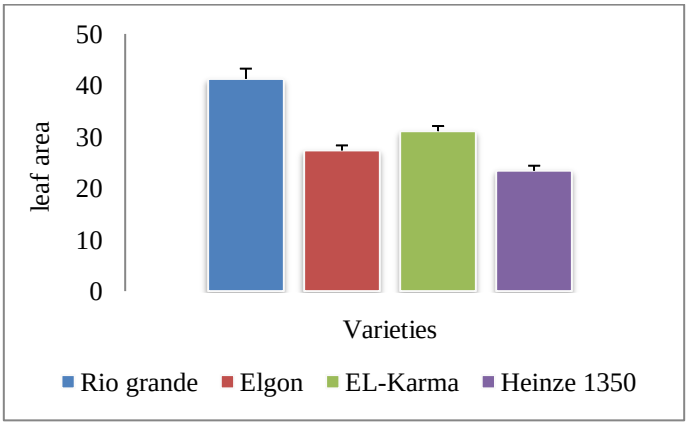

Figure 2. Leaf area of the different varieties

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3.1.3. Number of flowers/ plants

Figure 3 shows the number of flowers per plant during flowering. Rio-Grande had the highest number of flowers (57.6), followed by Elgon (53.4), while El Karma recorded the lowest (40.8). The low values can be explained by the transition from one phenological stage to another (flowering to fertilization). Water stress during pollination and fertilization stages can significantly reduce the number of flowers, as observed in [15]. The higher flower count in Rio-Grande and Elgon indicates their superior ability to sustain reproductive processes under stress, which is crucial for fruit yield. Water deficit often reduces plant size and the number of flowers per plant, and when water stress is severe at the time of pollination, fertilization and fruit set are likely to be inhibited due to reduced water flows [15]. The decrease in fruits competing for carbon assimilates can, conversely, promote the growth of the remaining fruits [16].

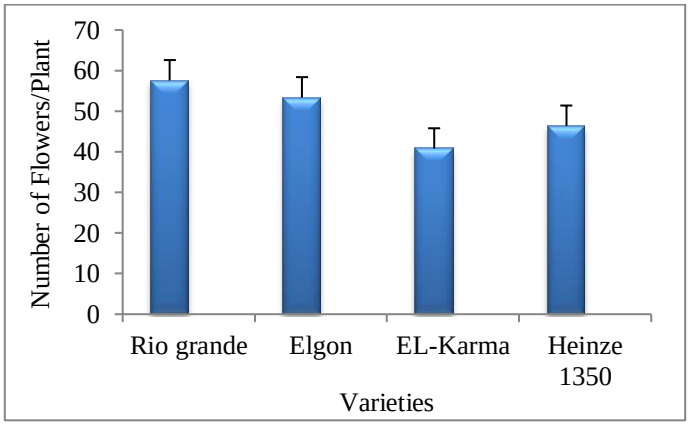

Figure 3. Number of flowers/varieties

3.2. Technological parameter

3.2.1. Refractometric index (Brix°)

Figure 4 shows the Brix rate of the four varieties, which measures the sucrose concentration of an aqueous solution expressed as a percentage. The Elgon variety had the highest sucrose rate (4.3%), followed by Rio-Grande (4.1%), while El Karma recorded the lowest rate (3.8%). The Brix index is a critical indicator of fruit quality, and the higher values in Rio-Grande and Elgon suggest better fruit quality under abiotic stress conditions. This is particularly important for commercial tomato production, where higher sugar content is often associated with better taste and marketability. The significant differences in Brix values among varieties ($p < 0.05$) indicate that Rio-Grande and Elgon are more efficient in maintaining sugar content under stress, which is consistent with previous findings that water stress can reduce sucrose content in sensitive varieties [17]. The attractive varieties are those with a high Brix index and therefore higher fruit yield because they significantly increase the sucrose content under abiotic stress conditions [17]. In tomatoes, the interest in traditional or local varieties is revealed as sources of genetic variation due to their improvement in tomato fruit quality without production losses under abiotic stress [18].

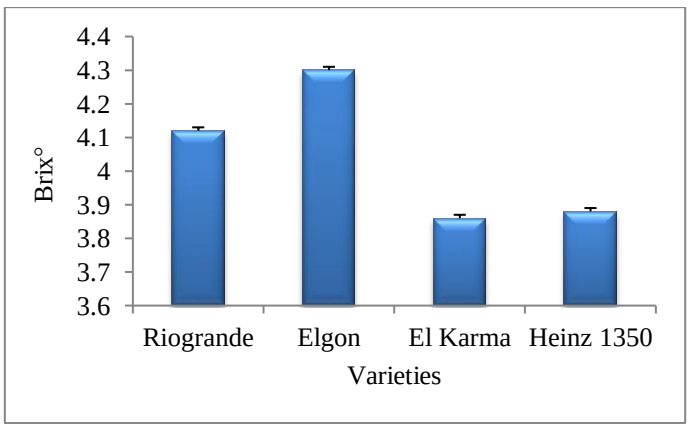

Figure 4. Brix of the different varieties

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3.2.2. Average fruit weight in kg/ plant

The average weight of the fruits of the two varieties Rio-Grande and Elgon are higher than those of El Karma and Heinz, with averages of 19, 18, 16, and 12 kg/plant, respectively. The analysis of variance reveals a very highly significant difference ($p < 0.001$), indicating that Rio-Grande and Elgon are more productive under stress conditions. The higher fruit weight in these varieties suggests that they are better suited for cultivation in environments where water stress is a limiting factor. This is consistent with studies showing that water stress can reduce fruit weight, particularly in sensitive varieties. Additionally, the decrease in fruits competing for carbon assimilates can, conversely, promote the growth of the remaining fruits.

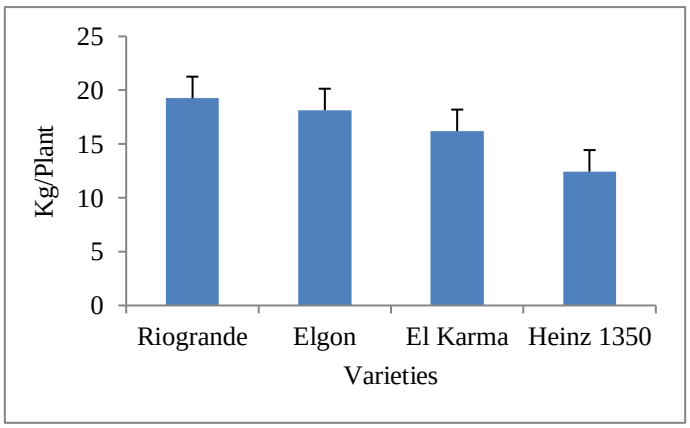

Figure 5. Average fruit weight in Kg/plant of the different varieties

Table 2. Statistical values of the analysis of variance (ANOVA) of agronomical and technological parameters

Source of variation	DF	MAP	LF	Number of flowers/plants	Brix	Fruit weight
Conc error	38	2.66^{NS}	13.4^{B}	4.33^{C}	3.25^{C}	173.31^{A}
Total	11					

Note: DF: degree of freedom; MAP: measurement of the aerial part; LF: leaf area; C: $p < 0.05$: significant differences; B: $p < 0.01$: highly significant differences; A: $p < 0.001$: very highly significant differences; NS: not significant

3.3. Physiological parameter

3.1.1. Pigment dosage

Figure 6 shows the chlorophyll (a) content of the different varieties. Rio-Grande and Elgon recorded the highest chlorophyll (a) values (1.63 and 1.5 µg/g MF, respectively), while El Karma and Heinz 1350 had the lowest (1.4 and 1.3 µg/g MF). Chlorophyll plays a crucial role in photosynthesis, and its higher concentration in Rio-Grande and Elgon indicates better photosynthetic efficiency under stress conditions. Conversely, the higher carotenoid content in El Karma and Heinz 1350 suggests that these varieties may rely more on carotenoids to mitigate the effects of reduced chlorophyll activity under stress.

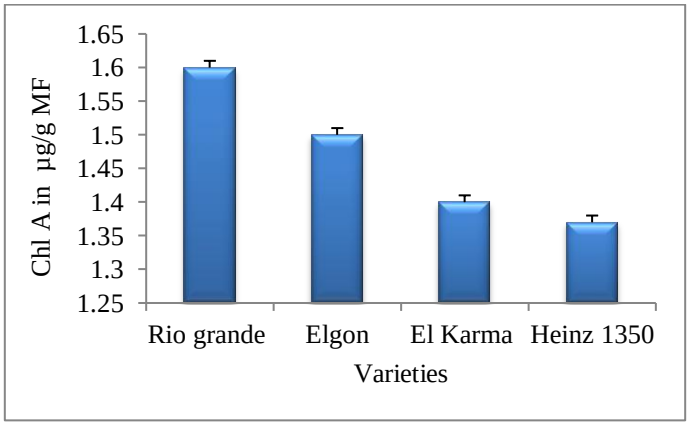

Figure 6. Chlorophyll A of the different varieties

The influence of water stress on the synthesis of these pigments is clearly observed, thus, it is clear that the varieties El Karma and Heinz 1350 are the most influenced by the lack of water, The main secondary metabolites that increased under abiotic stress were carotenoids [19], and slows down the synthesis of pigments and carotenoids are known to act as antioxidants and protect plants from oxidative damage caused by stress [20]. This metabolic interaction between chlorophyll and carotenoids under stress is described by [21].

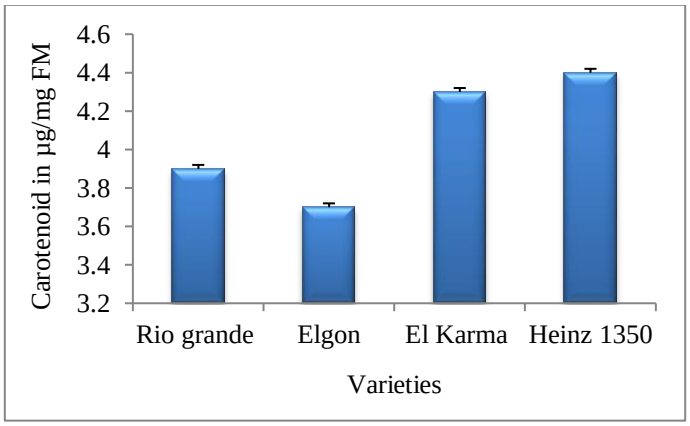

Figure 7. Carotenoids of different varieties

3.1.2. Total protein content

Figure 8 shows the total protein content in the leaves of the different varieties. Rio-Grande had the highest total protein content (0.39 µg/mg of MF), followed by Elgon (0.37 µg/mg of MF), while Heinz 1350 recorded the lowest (0.34 µg/mg of MF). Proteins are essential for various physiological processes, including enzyme activity and structural functions. The higher protein synthesis in Rio-Grande and Elgon positively affects fruit quantity and quality, as proteins are involved in the synthesis of essential molecules required for growth and development. The significant differences in protein content ($p < 0.05$) suggest that Rio-Grande and Elgon are better adapted to maintain protein synthesis under stress conditions, which is crucial for fruit development [22]. The rate of total protein and sugars recorded the highest values in Rio-Grande with 0.39 µg/mg of FM (Fresh matter) followed by Elgon 0.37µg/mg of MF, which explains why there is more protein synthesis and sugars, positively affecting the number of fruits that will reproduce [22].

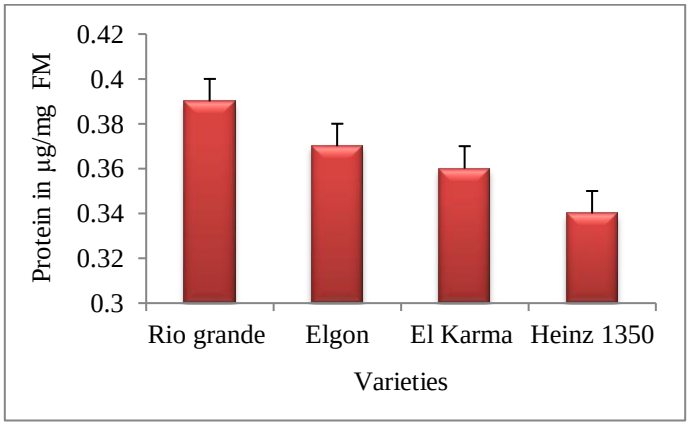

Figure 8. Total proteins of the different varieties

3.1.3. Proline content

The proline concentration of the leaves of the plants after a month of water stress varies in a very highly significant way (Table 3). Figure 9 shows that the proline content is highest for the Heinz 1350 variety (0.67 µg/mg of MF), while Rio-Grande had the lowest (0.49 µg/mg of MF). Proline is an amino acid that accumulates in plants under stress conditions and acts as an osmoprotectant, helping to maintain cellular homeostasis. The higher proline levels in Heinz 1350 and El Karma indicate that these varieties are more sensitive to abiotic stress, as they accumulate proline to cope with the adverse effects of water stress [23]. This accumulation of proline is a common response to water stress, as it helps stabilize proteins and cellular structures under adverse conditions. Proline, an amino acid like histidine and cysteine, accumulates in the plant when its metabolic balance is disturbed by unfavorable environmental conditions [23].

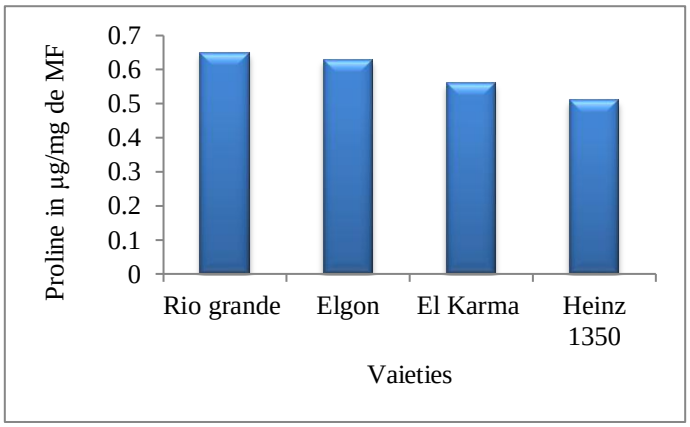

Figure 9. Proline of different varieties

Table 3. Statistical values of the analysis of variance (ANOVA) of the study of physiological parameters

Source of variation	DF	Chl A	Carotenoids	Protein	Proline
Conc error	38	18.25[a]	90.37[a]	4.5[c]	49.4[a]
Total	11				

Note: DF: degree of freedom; MAP: measurement of the aerial part; LF: leaf area; c $P < 0.05$: significant differences; b $P < 0.01$: highly significant differences; a $P < 0.001$: very highly significant differences; ns: not significant.

4. Conclusion

The study carried out on the comparison of different varieties of industrial dried tomatoes allowed us to have interesting information on the Agronomic, Technological and Physiological Performances of the different varieties Rio-Grande, Elgon, El Karma and Heinz 1350. The Agronomic Parameters such as the MAP of the plants, however, do not reveal any difference and the leaf area and flowering reveal a significant difference. The Technological Parameters, namely the Brix and the average weight of the fruits, the Rio-Grande varieties monitored by Elgon present quite remarkable characteristics. The Physiological Parameters also induced more synthesis of photoreceptor pigments, proteins for the Rio-Grande variety followed by Elgon compared to the other varieties, the proline activity recorded the highest values for the Heinz 1350 and El variety. Karma, which leads us to say that they are the most sensitive to water stress and therefore have a negative impact on yield. We can conclude on the basis of the results, that the knowledge of the limits of each tomato variety, concerning the performances studied makes it possible to recommend the development of the latter in particular the Rio-Grande and Elgon varieties, especially which are local, less demanding in cultural work, less fleshy, resistant to biotic and abiotic stress, therefore adapted to our ecosystem compared to excessively expensive hybrid varieties.

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