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Growth and yield responses of two Tunisian pepper (*Capsicum annuum* L.) varieties to salinity and drought stress

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ABSTRACT: Growth and yield of two Tunisian pepper varieties were evaluated for their salt and water stress tolerance under the salinity levels of 0, 30 and 60 mM NaCl and water stress with 50% depletion of available soil water. The treatment were applied 10 days after transplanting and continued up to plant harvesting. The results of this study indicated that growth, leaf area, yield and marketable fruits of the pepper genotypes were clearly decreased when the plants were exposed to water stress, salt stress and, combined salt and water stress conditions. Reduction is more noticeable in 60 mM NaCl salinity combined with water stress.

KEYWORDS: Salt Stress, Water Stress, Pepper, Growth, Yield, BER.

1 INTRODUCTION

Pepper (*Capsicum annuum* L.) is widely distributed annual vegetable crop in Tunisia. In fact, approximately 20.000 hectares are planted with pepper (particularly hot pepper) with a production of 300.000 tons [1]. Pepper is the fifth vegetable speculation after tomato, melon, watermelon, potato and onion and Tunisia is the third largest pepper producer after Nigeria and Egypt, the third largest exporter (in terms of tonnage) after Morocco and South Africa [1]. All pepper is consumed in a variety of ways: fresh, cooked or after processing: by canning, salting, powdering and making into paste.

Many local pepper varieties have generated interest in Tunisia because their nutritional and industrial qualities. However, little information is currently available. Identifying variety growing under local agricultural conditions with significant levels of beneficial factors could not only provide health benefit to consumers but also promote the value-added cultivation and stimulate industrial and economic growth. All these reasons make pepper culture profitable ([2],[3]). Pepper is an excellent source of natural colours and antioxidant compounds, like vitamin C and carotenoids ([4], [5], [6], [7]).

The pepper crop is adapted to a wide variety of climates but production is concentrated in a few warm and rather dry areas: more than 30% of world production comes from countries around the Mediterranean sea ([8],[9]). However, these areas are vulnerable to climate change impacts and have been qualified as the « hot spot for climate change» [10].

Water is at the heart of the main expected impacts of climate change on the natural environment in the Mediterranean [11]. Water scarcity will be one of the most critical problems facing these regions in the next few decades [12] and Tunisia is seriously threatened by drought and salinity [13].

The decline in availability of good water for irrigation, especially in arid and semi-arid regions results in the use of low quality water (saline, reclaimed) or in restrictive irrigation to satisfy the increasing demand for irrigation.

Pepper (*Capsicum annuum* L.) plants are sensitive to drought stress and moderately sensitive to salt stress ([14],[15]). In fact, pepper irrigated with saline water or subjected to water deficit will be affected in its growth, survival and yield [16].

Salts in the irrigation water causes severe problems like the reduction of fruit size [17] and the increase of blossom-end rot (BER) incidence [18]. Water stress also causes yield reductions ([19],[20]). The limitation of pepper growth under abiotic stress (salinity and drought) was mentioned by several authors ([21], [22], [23], [24], [25],[26]).

The objective of the present study was to quantify the responses of two local pepper varieties to abiotic stress generated by water salinity, deficit irrigation and combined salt and water stress conditions.

2 Material And Methods

2.1 Plant Material

Two Tunisian pepper (*Capsicum annuum* L.) varieties were used in this experimentation.

Doux de Teboulba: it's a bell pepper. Plant is vigorous with dense leaf. Fruit is smooth and has 15 to 25 cm long. Pulpit is sweet.

Baklouti: is a vigorous plant with a very hot chair.

2.2 Experimental Conditions

Seeds of two pepper varieties were germinated in germination trays using peat moss as a substrate in automatic growth chamber under 28°C of temperature and 80% of humidity. After thirty day, seedling were transferred to 5 l containers filled with 1/3 manure, 1/3 sand and 1/3 clay and grown in unheated greenhouse. A nutrient solution (13-5-30) + 2MgO was applied directly in the irrigation water.

2.3 Treatments

Treatments were applied 10 days after transplanting (DAT). Plants were divided into six groups subjected to the following irrigation treatments.

Control (T_0) = The control plants were irrigated with tap water only with maintained field capacity.

Water shortage (T_1) = irrigation with 50% depletion of available soil water when wilting sign developed

$T_2 = T_0$ + 30 mM NaCl

$T_3 = T_0$ + 60 mM NaCl

$T_4 = T_1$ + 30 mM NaCl

$T_5 = T_1$+ 60 mM NaCl

The experiment was arranged in two factors Completely Randomized Design (CRD) with 3 replications.

2.4 Parameters Measured

- Plant height (cm) measured at harvest by graduated ruler
- Total leaf surface (cm²) measured at harvest by leaf area meter (Model no. Li-3100C, USA).
- Yield (g)/plant (precision balance)
- Average fruit weight (g) (precision balance)
- % necrotic fruit

2.5 Statistical Analysis

Data were analyzed by STATISTICA program and the treatments means were compared by using Least Significant Difference (LSD).

3 RESULTATS

3.1 PLANT HEIGHT

Plant height of two varieties of pepper was significantly affected by salinity and water stress treatments and it ranged from 18 to 40 cm (fig.1). Under only water stress condition (T_1), Doux de Teboulba produced the highest plant height (35 cm) and Baklouti had the least one. The reduction of height was between 13 and 15 % under water shortage and was not significant.

Moderate salinity (T_2) had significantly the same effect as moderate water stress (T_1).

Plant height was drastically diminished in combined salt and water stress conditions than only in salt stress in both the salinity levels (30 and 60 mM NaCl) but decrease was more important at 60 mM NaCl combined with water stress (T_5). For this treatment, height decreased by 51% for Baklouti and by 40 % for Doux de Teboulba.

3.2 TOTAL LEAF SURFACE

The two pepper varieties are genetically different for leaf area. In fact, Doux de Teboulba is leafier than Baklouti. Under the salinity and water stress treatments, leaf area of each pepper variety was significantly affected (fig. 2).

Under only water stress condition, the highest leaf area recorded in Doux de Teboulba pepper (400 cm²) and the lowest recorded in Baklouti pepper (346 cm²).

Leaf area reduced in 60 mM NaCl salinity combined with water stress condition. But there was no significant difference among the genotypes at this treatment.

Moderate salinity (T_2) had significantly the same effect as moderate water stress (T_1).

3.3 YIELD PER PLANT

From Table 1, analysis of variance of the various treatment means at 5% probability level showed that significant difference existed among the treatments for the various varieties. However T_0 produced the largest mean yield of 287.5 g per plant while T_5 produced the lowest mean yield of 3 g/plant. Moderate salinity (T_2) produced more fruit than moderate water stress (T_1) and T_4 is more productive than T_3.

The yield per plant drastically reduced in combined salt and water stress conditions in both the salinity levels (30 and 60 mM NaCl) but decrease was more severe for T_5. Significantly, the lowest yield weight was observed in Doux de Teboulba (3g), but the genotypes were not differed at this treatment.

The yield per plant was decreased to 97 and 99% of the control in Baklouti and Toux de Teboulba, respectively.

3.4 AVERAGE FRUIT WEIGHT

The highest fruit weight was obtained from Doux de Teboulba (50g). Average fruit weight of different varieties of pepper was significantly affected by salinity and water stress treatments (Table 2). However, T_1 and T_2 produced significantly the same average fruit weight (table 2). T_5 and T_3 recorded the lowest mean weight of fruits as 3.5g and 9g, respectively. In fact, when water requirements are satisfied, salinity has less prejudice but when water irrigation is reduced, the effect of salt becomes important: 60 mM NaCl combined with water stress caused a greater reduction in the average fruit weight.

3.5 % NECROTIC FRUIT

Doux de Teboulba appeared more necrotic than Baklouti (fig.3). Under moderate or severe salinity conditions, increasing water shortage increase necrotic fruit proportion but at 60 mM NaCl combined with water stress almost all fruits become necrotic.

4 DISCUSSION

Pepper (*Capsicum annuum* L.) is very susceptible to salt stress, and salt-affected pepper shows severe decreases in growth and in production ([22], [27]), particularly at highest salinity level (60 mM NaCl).

4.1 GROWTH AND LEAF SURFACE

Plant height and leaf area per plant decreased significantly under water stress and saline conditions separately but decrease was more severe under combined salt and water stress conditions, particularly under higher saline concentration.

Decreased biomass production was observed in pepper culture under salinity [28]. Reduced growth was attributed to reduced water content in leaves caused by poor osmotic adjustment [29], osmotic effect and increased Na^+ and Cl^- in the leaves [30] and decreased transpiration [28].

Exposure to high salinity leads to leaf senescence [31]caused probably by salt compartmentation inefficient in the vacuole causing salt to build up in the cytoplasm to toxic levels [32]. Death of leaves reduce total photosynthetic leaf area. Consecutively, supply of photosynthate to the plant diminishes and growth was affecting and impeding [33].

The leaf area reduction is a common phenomenon of glycophytes grown under salt stress conditions [34]. The reduction in leaf area due to salinity was reported earlier by [35] in pepper plant.

Drought stress reduces cell and leaf expansion, stem elongation, and leaf area index ([36],[37],[38]). The reduction in leaf area was attributed to the increasing in leaf senescence and reduced size of leaves developed due to low turgor under saline and water stress conditions. This result confirm the findings of previous investigators, which indicated that pepper is a salt sensitive plant species ([29], [39]).

For varieties susceptibility, Baklouti appeared more vulnerable than Doux de Teboulba. Several authors have indicated existence of substantial genotypic variation in tolerance to NaCl stress in pepper ([40], [41]). It seems very likely that exclusion of Na from roots into growth medium plays a critical role in expression of high Na tolerance in pepper [42].

4.2 YIELD PER PLANT AND AVERAGE FRUIT WEIGHT

The yield per plant and average fruit weight drastically reduced in combined salt and water stress conditions in both the salinity levels (30 and 60 mM NaCl) but decrease was more severe for high salinity level. This result was corroborated by [30].

In fact, when water requirements are satisfied, salinity has less prejudice. The higher salinity associated with deficit irrigation treatments were sufficient to cause reduction in pepper yield, through a reduction in fruits number and weight.

The decrease in total yield by salinity was mainly due to a decrease in the fruit fresh weight [43]. Johnson et al. [44] mentioned that the sap flow into the fruit and therefore the fruit expansion rate is highly dependent on the phloem turgor, which is immediately reduced by an increase of the osmotic potential in the root medium.

Fruit weight reduction was caused by a decrease in the water accumulation rate during the cell expansion phase [9]. Fruits are more sensitive to salinity than leaves and stems in pepper plants [25]. In pepper plants, Na^+ is more highly accumulated in fruits than leaves or stems. Consequently Na^+ caused salt toxicity inducing water deficits, and ionic imbalance in the fruits tissue [45].

Under salt stress, severe disturbance in root uptake of mineral nutrients and imbalances between Na, K and Ca at cellular level are commonly observed, and these impairments play a critical role in the extent of salt tolerance of plants ([46], [47], [48], [49]). When absorbed and accumulated at large amounts in plants, Na becomes highly toxic at different physiological levels. Physiological impairments caused by Na toxicity include disruption of K and Ca nutrition, development of water stress and induction of oxidative cell damage.

Some authors [50] reported that water stress significantly reduced fresh fruit yield in pepper culture. Others ([51],[52]) mentioned also that water deficit affect fruit number and weight. In fact, pepper is among the most susceptible horticultural plants to drought stress ([53], [54]). The water deficit, particularly during the period between flowering and fruit development, reduced final fruit production ([51],[55]).

4.3 NECROTIC FRUIT

Blossom-end rot is the most common physiological disorder found in pepper. Blossom-end rot is associated with a local calcium deficiency during the initial stage of fruit development [56]. Calcium is required in relatively large concentrations for normal cell growth. Among the possible causes of BER induced by fruit Ca^{2+} deficiency, saline stress and imbalance of nutrient solution caused primarily by high K^+/ Ca^{2+} ratios stand out ([57],[58]).

Blossom-end rot incidence was the major fruit physiological disorder observed in the present study which increased by salinity and water shortage combined. Under only water stress, rate of necrotic fruits was minor. Under salinity conditions, BER increased highly. This result is increasing as water is a limiting factor. The results obtained in this study are in close agreement with the report of [58] and [59] who indicate that blossom-end rot could be caused by a reduction of Ca^{2+} translocation to the fruit tip in the period of rapid fruit expansion. The contribution of salinity to the reduction of Ca^{2+} in the fruit tip could be due to the decrease in the xylem water import caused by a decrease in water uptake by the roots and the reduction of xylem development in fruits ([9],[60]). BER disease incidence under saline conditions in pepper are not clear, generation of oxygen free radicals in the apoplast ([61],[62]) and poor Ca^{2+} status during rapid fruit expansion [59] were suggested to be the contributing factors.

Susceptibility to blossom-end rot varies among pepper varieties. In fact, larger fruits and longer fruits are most susceptible [63]. This result was observed for Doux de Teboulba which appeared more necrotic than Baklouti. Dagnoko et al. [64] observed that peppers are usually considered a robust crop compared with tomatoes and chili pepper is more robust than sweet pepper.

Table 1. Yields (g) of two varieties under water and salinity treatments.

Treatment Variety	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**
Baklouti	225 b **A**	50 a **C**	100 a **B**	10 a **D**	42 a **C**	6 a **D**
Doux de Teboulba	350 a **A**	60 a **B**	70 b **B**	10 a **D**	40 a **C**	4 b **E**
Average Treatment	287.5 *A*	55 *C*	85 *B*	10 *E*	41 *D*	5 *F*

Capital letters indicate difference between treatments for each variety
Lower case letter indicate difference between varieties
Italic letters indicate difference between Treatments

Table 2. Average fruit weight (g) of two varieties under water and salinity treatments.

Treatment Variety	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**
Baklouti	40 b **A**	20 a **B**	22 a **B**	12 a **C**	15 a **C**	4 a **D**
Doux de Teboulba	50 a **A**	18 a **B**	22 a **B**	6 b **D**	12 b **C**	3 a **D**
Average Treatment	45 *A*	19 *B*	22 *B*	9 *D*	13.5 *C*	3.5 a *E*

Capital letters indicate difference between treatments for each variety
Lower case letters indicate difference between varieties
Italic letters indicate difference between Treatments

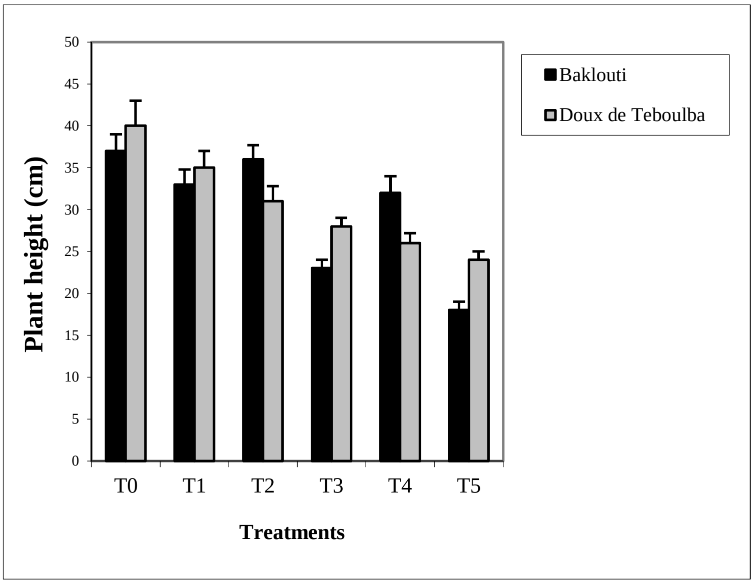

Figure 1. Plant height of pepper varieties as affected by salinity and water stress

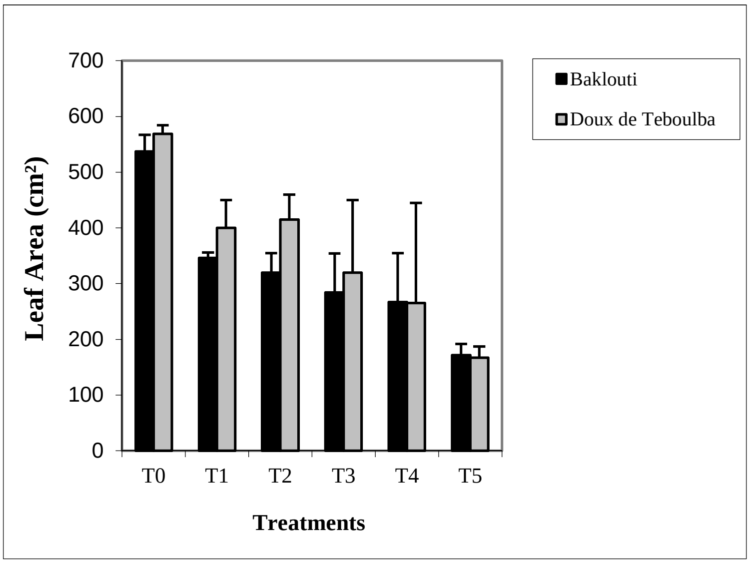

Figure 2. Total Leaf Surface of pepper varieties as affected by salinity and water stress

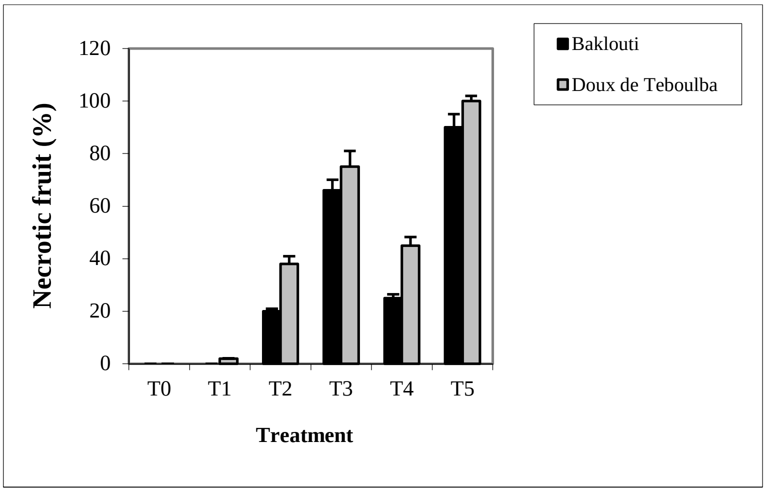

Figure 3. Necrotic fruit (%) of pepper varieties as affected by salinity water stress

5 CONCLUSION

The results of this study indicated that growth and production of pepper varieties drastically decreased with water stress, salt stress and, combined salt and water stress conditions. Moreover, we underlay that a moderately saline irrigation is better than no irrigation to optimize yield in the specific environment considered. Variation in salt and water stress tolerance of pepper genotypes was obvious and sweet pepper appears more sensitive to BER than chili pepper.

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