Asian Journal of Advances in Research

Volume 7, Issue 1, Page 600-613, 2024; Article no.AJOAIR.4193

Behavioral Study of Morphological Morphophysiological and Productivity Characteristics in (*Lathyrus sativus* L). under Salt Stress Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/4193

Original Research Article

Received: 14/08/2024
Accepted: 17/10/2024
Published: 31/10/2024

ABSTRACT

The experiment was conducted. in the greenhouse of the Faculty of Agricultural Engineering - Tishreen University - Latakia during the agricultural season 2022-2023 by planting seeds of four genetic – environmental genotypes of the *Lathyrus sativus* L. Jalapeno (Latakani, Tartousi, Homsi, and Shami) in plastic bags with a capacity of (5 kg) soil These bags were distributed according to Complete randomization design at a rate of three replicates for each treatment. The research aimed to evaluate the behavior of some morphological, morphysiological and productive traits of the studied Jalapeno genotypes under different levels of salinity of irrigation water with sodium chloride (0, 3, 6, 10 and 15 mmho/cm) in order to determine the most effective salinity levels and the most

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***Cite as:** Daher, Mais, Saleh Kubili, and Sawsan Haifa. 2024. "Behavioral Study of Morphological Morphophysiological and Productivity Characteristics in (Lathyrus Sativus L). Under Salt Stress Conditions". Asian Journal of Advances in Research 7 (1):600-613. https://jasianresearch.com/index.php/AJOAIR/article/view/487.*

tolerant genotype for future use in breeding programmes or cultivate it in lands affected by salinity. The results indicated a significant decrease ($P<0.05$) in the values of all studied traits, and increasingly proportional to the salt concentrations used (3, 6, 10, 15 mmho/cm). The Jalapeno Homsi genotype was superior in control conditions and under conditions of salt stress, especially high levels (10 and 15 mmho/cm), significantly ($P<0.05$) in most of the studied traits compared to the rest of the genotypes. The results also showed that the largest percentage decrease under the applied salinity levels was primarily noticeable in the characteristics of the leaf surface area of the plant in the Tartousi genotype (5.07) (cm^2/plant) at the concentration (15 mmho/cm), number of branches (branch/plant) In the Tartousi genotype (2.33 branches) at the concentration (15 mmho/cm), and the seed weight in the Tartousi and Shami genotypes (1 g) at the concentration (15 mmho/cm), which indicates the possibility of using it in screening the genotypess' tolerance to salt stress. The research concluded with the proposal to grow the Jalapeno Homsi genotype under control conditions, and under salinity conditions, whether low levels (3 mmho/cm) or high levels exceeding (10 mmho/cm), due to its superiority in most of the morphological, morphophysiological, and production traits studied.

Keywords: Lathyrus sativus L.; classify jalapeno, Morphysiological traits; productivity; salt stress.

1. INTRODUCTION

Lathyrus sativus L. is one of the crops of the legume family fabaceae with multiple uses: food, fodder and industrial. It is a good and cheap source of proteins, the percentage of which in seeds ranges between 18-34 [1].

It is an important leguminous crop used as food for humans and fodder for animals in dry areas. Its presence has been linked to several diseases, including neuritis, which is characterized by paralysis of the lower limbs of humans as a result of excessive consumption of cabbage in an unbalanced diet for a long time [2].

jalapeno is considered the most important nutritional component of legume seeds in terms of nutrition because of the proteins that participate in the most important functions of the body and cannot be replaced by other nutrients. In addition, the issue of expanding the cultivation area of drought-resistant leguminous crops arose, and one of the important crops was Jalapeno [3].

Jalapeno grows in different agricultural environmental conditions in the world for the purpose of nutrition, in addition to feeding agricultural animals, as grains and hay constitute an important food substance and can also be used as green fertilizer to increase soil fertility [4]. It is also a plant that is resistant to drought and diseases, has high feed values, and is a good stabilizer of atmospheric nitrogen [5].

Jalapeno is used as food for humans and fodder for animals. In the recent past, the crop has received great attention in both the scientific and agricultural community due to its climatic characteristics such as tolerance to drought, waterlogging, and heat [3]. It has a strong, penetrating root system suitable for a wide range of soil types, from low fertility to heavy clay [6]. It is added to some types of toothpaste and is used as a herbal medicine to avoid bleeding. It stimulates wound healing and can be considered a natural treatment for wounds [7]. Crop plants are often exposed to various stressors, both biotic (viruses, bacteria, and fungi) and abiotic (such as water shortages, salinity, etc.) which affect their growth and development and thus their productivity [8].

In fact, soil is considered saline, in general, when the concentration of salts, especially NaCl, rises to a level that inhibits the growth of most agricultural crops, and saline drylands have been classified into three levels, which are: light saline soils where conductivity Electricity of its saturated paste (ECe 2-4 dS/m), medium salinity soils (ECe 4-8 dS/m) and high salinity soils (ECe > 8 dS/m) [9].

Salt stress is classified as one of the factors that determine and threaten the performance of high-yielding field crops [10] as it causes an imbalance and a decrease in the leaves' content of photosynthetic pigments and thus a decrease in the activity of the photosynthetic rate in the plant [11].

It can also inhibit the action of the Rubisco enzyme (Ribulose1,5-biphosphates carboxylase/ oxygenase) in the plant [12]. Thus, weak photosynthetic activity can hinder the growth of crop plants, as this was noticeable through the decrease in plant height and the number and area of leaves in the plant [13]. Salt stress can also affect the morphology and anatomical structure of leaves and reduce their area [14].

Mahdavi and Sanavy [15] showed the effect of salinity at high levels exceeding 10 mmho/cm in reducing root length, reducing the dry and fresh weight of seedlings, increasing proline and reducing the seed germination rate of seedlings.

The results of a study conducted to compare the effect of salinity on the germination and growth of seedlings of pisum and Jalapeno crops indicated that high levels of salinity in the growing medium led to a reduction in the overall germination rate, and a decrease in stem length and root length was observed for both crops with increasing levels of salinity used [16].

Salinity also emerges as one of the most important environmental threats that threaten the cultivation of many field crops, especially those grown under rainfed conditions in arid and semi-arid regions [17] and especially under salinity conditions, and Jalapeno as one of the crops grown under rainfed conditions that requires... Working to improve plant growth and development to obtain high seed production, especially in unfavorable environmental conditions.

Hence, the research aimed to evaluate the behavior of a group of genotypess of Jalapeno for the most important morphological, physiological and production characteristics under different levels of salinity to determine the concentration and the best genotype and the interaction between them for future use in breeding programs and the possibility of cultivation in lands affected by salinity.

2. MATERIALS AND METHODS

The experiment was carried out in the greenhouse of the Faculty of Agricultural Engineering - Tishreen University - Latakia during the 2022-2023 agricultural season. The required studies were also conducted in the laboratories of the Field Crops Department and the Soil and Water Sciences Department at the college. Four genotypes of Jalapeno were used in the research, The seeds were obtained from the local market of the governorates in which they are grown. They are: (Latakani, whose seeds are smooth, gray in color, spherical in shape; Tartousi, whose seeds are slightly wrinkled, white in color, and spherical in shape; Homsi, whose seeds are wrinkled, gray-green in color, elliptical in shape; Shami, whose seeds are wrinkled, gray in color, and spherical in shape These genotypes are also characterized by their abundance of tolerance to the prevailing environmental conditions, their productivity is good, and they are desired by farmersThe experiment was conducted using two factors. The first factor included four models of Jalapeno (Latakani, Tartousi, Homsi, and Shami), and the second factor included concentrations of saline irrigation water (S1, S2, S3 , S4) used with NaCl (3, 6, 10, 15 mmho/cm^3). The concentrations of salt water intended for use were prepared as follows:

Add (2.5 - 5 - 8.3 - 12.5 g) of pure salt NaCl (obtained from agricultural pharmacies) per liter of water to obtain concentrations (3 - 6 - 10 - 15 mmho/cm^3). The plants of the control treatment (S0) were irrigated with tap water, where three seeds of Jalapeno were planted in plastic bags with a capacity of 5 kg of air-dry soil, perforated at the bottom. The bags were distributed within the house according to a completely randomized design at a rate of three replicates for each treatment, and individualization was done by leaving one plant in the bag. At a rate of three replicates for each treatment. The necessary physical and chemical analyzes of the experimental soil were also conducted before planting, and the results were as shown in Table 1.

Number of bags used = 60 bags (5 treatments: 4 salinity concentrations and control) (4 genotypes of Jalapeno) (3 replicate).

Table 1. Physical and chemical analyzes of the experimental soil before planting

	Soil
Clay %	17
Silt %	12
Sand %	71
soil	(Silty)
Organic matter %	0.98
Total calcium carbonate %	50
Cation exchange capacity $\boldsymbol{\mu}$.m\100 g.soil	20
Nitrogen	0.3
Phosphorus pentoxide	20
Potassium oxide	120
pH	7.6
EC	0.32

The soil was characterized by being light in texture (sandy), poor in nitrogen and organic matter, with a good content of potash, and rich in phosphorus. Its exchange capacity was low due to its richness in sand, and it was suitable for growing Jalapeno in the research, knowing that the lands for growing Jalapeno in Syria (Al-Ghab, Hama, and Homs) Heavy clay.

A set of morphological indicators were measured: number of leaves (leaf/plant): This is done by counting the leaves on the plant as it enters the flowering stage. Number of roots (root/plant) and their length (cm): The plants were removed from the bags and then their roots were washed well with water, so that their roots could be counted and their lengths (cm) measured. Root volume (cm^3): Root volume was measured by the volumetric method using a graduated cylinder of known volume filled with water. Root weight (g/plant): The root system was separated from the shoot of each plant and then its weight (g/plant) was determined.

The morphological aspect is: leaf surface area (cm^2/plant): The maximum length and maximum width of the leaf were measured, and then from the equation, the area of one leaf = maximum length plant leaves.

Phenology: Number of flowers (flower/plant): The flowers formed on the plant were counted as it entered the flowering stage (i.e. 70% of the plants were flowering.

Productivity: Number of branches/plant: This is the number of branches formed as the plant enters the maturity stage. Number of pods (pod/plant) and their weight (g/plant): The pods formed on the plant were counted and then their weight was measured, and seed weight (g/pod): The seed weight of each pod on the plant was measured.

Data analysis was conducted using the GenStat12 statistical analysis program, by estimating the value of (F) and then comparing the differences between the means based on the results of the (F) test and using the least significant difference (LSD) test at the probability level (95%), when the (F) test indicates that are significant differences between the transactions.

3. RESULTS AND DISCUSSION

1- The effect of salt stress with sodium chloride on the number of roots:

The results in Table (2) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease ($P<0.05$) in the number of roots, which amounted to (5.16 - 4.66 - 3.66 - 3.49 roots/plant) on respectively, compared to the control (5.58 roots/plant).

The results indicated that there were no significant differences ($P>0.05$) between the used genotypes of Jalapeno in terms of the number of roots/plant, as the largest number, reaching 5.39 roots/plant, was recorded for the Jalapeno Homsi genotype, followed by the Latakani, Shami, and Tartousi genotypes, which reached 4.66, 4.04, and 3.92 roots/ Plant.

The use of increased salt concentrations (3, 6, 10, and 15 mmho/cm) led to a significant decrease ($P<0.05$) among the treatments in the number of roots/plant, especially at high salt concentrations (10 and 15 mmho/cm), where the number of roots reached (4- 2.66- 5- 3 roots/plant) when treated (10 mmho/cm) and (4- 2.66- 5- 2.33 roots/plant) when treated (15 mmho/cm) when embroidering the Jalapeno (Latakani-Tartusi- Homsi-Shami) respectively. We find a comparison between the four genotypes of Jalapeno.The Homsi Jalapeno showed the least decrease in the number of roots when the applied salt concentration increased, followed by the Latakani, Tartousi and Shami genotypes, with a percentage decrease in the number of roots reaching (6-17%, 29%, 50% and 44-56%) respectively, at high salt concentrations (10 and 15). mmho/cm) compared to control plants for each genotype. The results showed a decrease in the number of roots. This decrease in the number of roots is explained by the fact that increased salinity in the soil negatively affects the growth and development of the root system by reducing its ability to absorb water and nutrients due to the high osmotic pressure of the soil solution, which leads to a significant decrease in the number of roots formed. This decrease increases directly with increasing salt concentration. This result is consistent with the results of Alam and Azmi, [18].

2-The effect of salt stress with sodium chloride on root length (cm):

The results (Table 3) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease ($P<0.05$) in root length, reaching (24.55 - 22.86 - 20.77 - 19.45 cm) respectively compared with the control, which gave the highest root length (25.27 cm).

The results showed that there were no significant differences (P>0.05) between the used genotypes of Jalapeno in terms of root length (cm/plant). The highest root length reached 23.07 cm for both the Tartousi and Shami genotypes of Jalapeno, followed by the Homsi and Latakani genotypes, which reached 22.56 and 21.63 cm, respectively.

Treatment with increased salt concentrations (3, 6, 10, and 15 mmho/cm) caused a significant (P<0.05) decrease in root length (cm), especially at high salt concentrations of 10 and 15 mmho/cm, where root length reached (19.77- 21.90 - 19.00 - 22.43 cm) when treated with 10 mmho/cm and (18.33 - 20.57 - 18.30 - 20.60 cm) when treated with 15 mm/cm for the Jalapeno genotypes (Latakani - Tartousi - Homsi - Shami), respectively. In comparison between the four Jalapeno genotypes, we find that the Shami Jalapeno showed the least decrease in root length when the applied salt concentration increased, followed by the Tartousi, Latakani, and Homsi genotypes, with a percentage of decrease in root length reaching 9-16%, 13-18%, 21-27%, and 27-30% respectively at high salt concentrations (10 and 15 mmho/cm), compared to the control plants for each genotype.

The results showed a decrease in root length, and the decrease in root length could be due to exposure to stress using sodium chloride at high concentrations can lead to a defect in all metabolic processes and thus the synthesis of biochemical compounds within the plant that are necessary for cell division activity and cell elongation, which leads to a reduction in the length of the roots of the stems. It was noticed that increasing the salt concentration of 10 mmho/cm caused a decrease in the integrity of the cellular membranes in the root tissues and thus their ability to absorb and transfer the nutrients necessary for biosynthesis processes within the plant, and this result is consistent with the results of Piwowarczyk et al., [19].

3-Effect of salt stress with sodium chloride on root weight (g):

The results in Table (4) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in root weight, reaching (1.72 - 1.48 - 1.35 - 1.24 g) respectively, compared to the control that gave the highest root weight (1.75 g).

The results of the analysis of variance showed that there were significant differences (P<0.05) between the used genotypes of Jalapeno in terms of root weight (g/plant). The highest root weight was 1.69 g/plant for the Jalapeno Homsi genotype, followed by the Latakani and Shami-Tartosi genotypes, and the weight of the roots reached 1.48. 1.47 and 1.40 g/plant, respectively. Treatment with increased salt concentrations (3, 6, 10, and 15 mmho/cm) led to a significant decrease (P<0.05) in root weight, especially at high salt concentrations of 10 and 15 mmho/cm, where root weight reached (1.30 - 1.30 - 1.46- 1.36 g/plant) when treated with 10 mmho/cm and (1.20 - 1.23 - 1.33 - 1.23 g/plant) when treated with 15 mmho/cm for the Jalapeno embroidery (Latakani - Tartousi - Homsi - Shami), respectively. In comparison between the four Jalapeno genotypes, the Tartousi Jalapeno showed the least decrease in root weight when the applied salt concentration increased, followed by the Shami, Latakani and Homsi genotypes, with a percentage decrease in root weight of 13-18%, 21-29%, 26-32% and 28-34%, respectively. At high salt concentrations of 10 and 15 mmho/cm, compared to control plants for each genotype, given the effect of salinity in reducing the number and length of the roots formed, this explains the decrease in the weight of the roots. In this context, the results of a study showed a decrease in all growth characteristics, such as the weights of green and dry branches, stem length, length and weight of the root, and a decrease in the production of the biological mass of stems, with an increase in salinity levels of more than 10 mmho/cm [20].

4-The effect of salt stress with sodium chloride on root volume (cm3):

The results (Table 5) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in root volume, reaching (30.41 - 28.28 - 23.99 - 23.15 cm3) respectively, compared to the control that gave the largest root volume (30.75 cm3).

The results of the analysis of variance showed that there were significant differences (P<0.05) between the used genotypes of Jalapeno in terms of root volume (cm3). The highest root volume reached 31.15 cm3 for the Jalapeno Homsi genotype, followed by the Latakani and Tartousi and Shami genotypes, which reached 28.45, 25.38 and 24.28 cm straight, treatment with increased salt concentrations (3, 6, 10, 15 mmho/cm) caused a significant (P<0.05) decrease in root volume (cm3), especially at high salt concentrations of 10 and 15 mmho/cm, where root volume reached (25.56-22.23 - 27.23 - 20.96 cm3) when treated with 10 mmho/cm and (24.66 - 21.80 - 26.20 - 19.96 cm3) when treated with 15 mmho/cm when embroidering the Jalapeno (Lattakani - Tartous - Homsi - Shami) respectively. In comparison between the four Jalapeno genotypes, the Tartousi Jalapeno showed the least decrease in root size when the applied salt concentration increased, followed by the Latakani and Homsi and Shami genotypes, with a decrease in root length of 21-23%, 22-24%, 22-25% and 23-27% respectively. At high salt concentrations of 10 and 15 mmho/cm compared to control plants for each genotype, The results showed a decrease in the size of the roots, as the roots of the wedge plants appear facing downward, while the control plants are facing horizontally direct measurements conducted on the roots of wheat plants also showed that they are a model for studying the effect of salinity on sensitive plants [21] as local stress is reduced or water stress reduces the efficiency and ability of the roots to produce cytokinins, and increases the production of growth-inhibiting hormones such as abscisic acid and ethylene, causing an imbalance in the hormonal balance, which reflects the important role that the roots play in regulating the plant’s vital metabolism [22].

Table 2. Number of roots of the studied types of Jalapeno (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (0, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	5.66	5.33	6.00	5.33	5.58
S1	5.33	4.66	5.66	5.00	5.16
S2	4.33	4.33	5.33	4.66	4.66
S3	4.00	2.66	5.00	3.00	3.66
S4	4.00	2.66	5.00	2.33	3.49
Average genotype	4.66	3.92	5.39	4.04	
LSD 5%	LSDG= 0.33	LSDS= 0.37	LSDG.S= 1.3		

Table 3. Root length (cm) of the studied genotypestypes of Jalapeno (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (0, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	25.17	25.20	26.20	24.53	25.27
S1	23.70	25.27	25.03	24.22	24.55
S2	21.20	22.43	24.27	23.57	22.86
S3	19.77	21.90	19.00	22.43	20.77
S4	18.33	20.57	18.30	20.60	19.45
Average style	21.63	23.07	22.56	23.07	
LSD 5%	LSDG= 2.33	LSDS= 2.60	LSDG.S= 5.21		

Table 4. Root weight (g/plant) of the studied Jalapeno genotypes (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (0, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	1.76	1.50	2.03	1.73	1.75
S1	1.66	1.56	2.00	1.66	1.72
S2	1.43	1.43	1.63	1.46	1.48
S3	1.30	1.30	1.46	1.36	1.35
S4	1.20	1.23	1.33	1.23	1.24
Average genotype	1.47	1.40	1.69	1.48	
LSD 5%	LSDG= 0.04	LSDS=0.05	LSDG.S= 0.10		

Table 5. Root volume (cm3) of the studied Jalapeno genotypes (Latakian, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (control, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	32.66	28.23	34.86	27.26	30.75
S1	31.50	28.20	34.56	27.40	30.41
S2	27.90	26.46	32.93	25.83	28.28
S3	25.56	22.23	27.23	20.96	23.99
S4	24.66	21.80	26.20	19.96	23.15
Average genotype	28.45	25.38	31.15	24.28	
LSD 5%	LSDG=0.30	LSDS=0.34	LSDG.S= 0.68		

5-Effect of salt stress with sodium chloride on the number of branches (branch/plant):

The results in Table (6) indicated that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in the number of branches, as it reached (7.57 - 6.49 - 5.07 - 4.16 branches/plant) respectively, compared to the control that gave the highest number of branches (8.32 branches/plant).

The results of the analysis of variance showed that there were significant differences (P<0.05) between the genotypes of Jalapeno used in terms of the number of branches (branch/plant). The highest number of branches was 10.52 branches/plant for the Jalapeno Homsi genotype, followed by the Latakani and Shami and Tartousi genotypes, and the number of branches reached 5.59. 4.86 and 4.32 branches/plant.

Treatment with increased salt concentrations (3, 6, 10, and 15 mmho/cm) caused a significant decrease (P<0.05) in the number of branches, especially at high salt concentrations of 10 and 15 mmho/cm, where the number of plant branches reached (4.66 - 3.66 - 8.33 - 3.66 shoots/plant) when treated with 10 mmho/cm and (3.66 - 2.33 - 7.33 - 3.33 shoots/plant) when treated with 15 mmho/cm when embroidering the Jalapeno (Latakani - Tartousi - Homsi - Shami), respectively. In comparison between the four genotypes of Jalapeno, The Homsi Jalapeno showed the least decrease in the number of branches when the applied salt concentration increased, followed by the Latakani and Shami and Taratousi genotypes, with a percentage decrease in the number of branches amounting to 39-46%, 36-50%, 45-50% and 39-59%, respectively, at high salt concentrations of 10 and 15 mmho/cm compared to control plants for each genotype. The results showed a decrease in the number of branches is due to the fact that increased salinity concentrations cause a decrease in the activity of cambium cell division in the stem and root and a failure to increase the thickness of each, which is accompanied by a decrease in the formation of new meristematic cells and the prevention of their transformation into adult cells, which is reflected in the weakness of the formation of plant branches [23].

6-Effect of sodium chloride salt stress on the number of leaves (leaf/plant):

The results in Table (7) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in the number of leaves, which amounted to (102.25 - 94.37 - 89.04 - 81.37 leaves/plant) on respectively, compared to the control, which had the highest number of leaves (108.75 leaves/plant).

The results indicated that there were significant differences (P<0.05) between the genotypes of Jalapeno used in terms of the number of leaves (leaf/plant). The highest number of leaves reached 108.1 leaves/plant for the Jalapeno Homsi genotype, followed by the Latakani and Tartousi and Shami genotypes, and the number of leaves reached 98.83, 88.9, and 84. 8 leaves/plant respectively.

Treatment with increased salt concentrations (3, 6, 10, and 15 mmho/cm) led to a significant decrease (P<0.05) in the number of leaves, especially at high salt concentrations of 10 and 15 mmho/cm, where the number of leaves reached (93.16 - 85.50 - 100.50- 77 leaves/plant) when treated with 10 mmho/cm and (82 - 72.50 - 97 - 74 leaves/plant) when treated with 15 mmho/cm for the Jalapeno genotypes (Latakani - Tartousi - Homsi - Shami) respectively. In comparison between the four genotypes of

Jalapeno, the Homsi Jalapeno showed the least decrease in the number of leaves on the plant when the applied salt concentration increased, followed by the Shami, Latakani and Tartousi genotypes, with a percentage decrease in the number of leaves amounting to 20-23%, 21-24%, 17-27% and 15-28%, respectively, at high salt concentrations 10 and 15 mmho/cm compared to control plants for each genotype. This decrease in the number of leaves formed under conditions of high levels of salinity may be due to the lack of branches formed on the plant, and this was confirmed by the results of Al Rabiah and Abbas [24] who found that irrigation salinity at levels exceeding (6 mmho/cm) led to a significant decrease in number and area of leaves compared to the control.

7-Effect of salt stress with sodium chloride on plant leaf surface area (cm2/plant):

The results of the analysis of variance (Table 8) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease ($P<0.05$) in the area of leaves per plant, which amounted to (131.31 - 78.41 - 38.66 - 21.19 cm2) respectively compared to the control, which gave the highest leaf area per plant 155.07 cm2).)

The results showed that there were significant differences ($P<0.05$) between the used genotypes of Jalapeno in terms of the leaf area of the plant (cm2/plant). The largest leaf area was 190.57 cm2/plant for the Jalapeno Homsi and the Shami genotype, followed by the Latakani and Tartousi genotypes, and the leaf area reached 57.70. 53.43 and 38.01 cm2/plant respectively. Treatment with increased salt concentrations (3, 6, 10, and 15 mmho/cm) caused a significant decrease ($P<0.05$) in leaf surface area, especially at high salt concentrations of 10 and 15 mmho/cm.

It reached (13.05 - 22.25 - 93.96 - 25.41 cm2/plant) when treated with 10 mmho/cm and (5.32 - 5.07 - 61.11 - 13.28 cm2/plant) when treated with 15 mmho/cm. That is when the Jalapeno embroidery (Latakani - Tartousi - Homsi - Shami) respectively. In comparison between the four genotypes of Jalapeno, the Humsi Jalapeno showed the least decrease in leaf area when the applied salt concentration increased, followed by Shami and Tartousi and Latakani with a percentage of decrease in leaf area amounting to 73-83%, 71-85%, 69-93% and 88-95%, respectively. At high salt concentrations of 10 and 15 mmho/cm, compared to control plants for each genotype.

Table 6. Number of branches (branch/plant) of the studied genotypes of Jalapeno (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (0, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	7.33	5.66	13.66	6.66	8.32
S1	6.66	5.33	12.66	5.66	7.57
S2	5.66	4.66	10.66	5.00	6.49
S3	4.66	3.66	8.33	3.66	5.07
S4	3.66	2.33	7.33	3.33	4.16
Average genotype	5.59	4.32	10.52	4.86	
LSD 5%	.LSDG=0.38	LSDS=0.42	LSDG.S= 0.84		

Table 7. Number of leaves (leaf/plant) of the studied genotypes of Jalapeno (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (0, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	112.00	100.50	125.50	97.00	108.75
S1	110.50	99.00	110.50	89.00	102.25
S2	96.50	87.00	107.00	87.00	94.37
S3	93.16	85.50	100.50	77.00	89.04
S4	82.00	72.50	97.00	74.00	81.37
Average genotypes	98.83	88.9	108.1	84.8	
LSD 5%	LSDG= 1.09	LSDS= 1.22	LSDG.S= 2.45		

Table 8. Leaf surface area (cm2/plant) of the studied genotypes of Jalapeno (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (control, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	108.60	71.37	353.96	86.36	155.07
S1	105.00	54.87	279.68	85.71	131.31
S2	35.21	36.49	164.18	77.77	78.41
S3	13.05	22.25	93.96	25.41	38.66
S4	5.32	5.07	61.11	13.28	21.19
Average genotypes	53.43	38.01	190.57	57.70	
LSD 5%	LSDG=4.8	LSDS=5.75	LSDG.S= 7.86		

The results showed a decrease in the leaf surface area. The reason for this noticeable decrease in the morphological indicators of the plant may be due to the high concentration of salinity causing a decrease in the growth of the plant and its leaf area as a result of a decrease in meristematic activity and a decrease in cell elongation in the growing tips, which results in dwarfing of the plant [25].

8-Effect of sodium chloride salt stress on the number of flowers (flower/plant):

The results (Table 9) showed that the use of increased salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease ($P>0.05$) in the number of flowers, reaching (38.58 - 36.50 - 25.83 - 14.50 flowers/plant) respectively, compared to the control that gave the highest number of flowers (40.83 flowers/plant).

The results of the analysis of variance showed that there were no significant differences ($P>0.05$) between the used genotypes of Jalapeno in terms of the number of flowers formed on the plant (flower/plant). The largest number of 36.06 flowers/plant was recorded for the Jalapeno Homsi genotype, followed by the Tartousi and Shami and Latakani genotypes, which amounted to 33.20, 30.73 and 25 flowers/plant respectively. Treatment with increased salt concentrations (3, 6, 10, and 15 mmho/cm) led to a significant decrease ($P<0.05$) in the number of flowers/plant, especially at high salt concentrations of 10 and 15 mmho/cm. It reached (16.33- 31.33- 30.33- 25.33 flowers/plant) when treated with 10 mmho/cm and (10.67- 14.67- 18- 14.67 flowers/plant) when treated with 15 mmho/cm. This was when embroidering the Jalapeno (Lattakani - Tartousi - Homsi - Shami) respectively. In comparison between the four Jalapeno genotypes, the Homsi Jalapeno showed the least decrease in the number of flowers/plant when increasing the applied salt concentration, Shami and Tartousi and Latakani, with a decrease rate of 28-57%, 37-64%, 24-65% and 59-73%, respectively. At high salt concentrations of 10 and 15 mmho/cm, compared to control plants for each model. The results showed a decrease in the number of flowers, and this could be explained by the fact that the high level of salinity in the medium leads to the accumulation of sodium ions in the plant, which toxically affects various vital functions of the plant, including the processes of pollination and fertilization of flowers [26].

Table 9. Number of flowers (flower/plant) of the studied genotypes of Jalapeno (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (control, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	39.67	41.33	42.00	40.33	40.83
S1	30.33	39.67	45.67	38.67	38.58
S2	28.00	39.00	44.33	34.67	36.50
S3	16.33	31.33	30.33	25.33	25.83
S4	10.67	14.67	18.00	14.67	14.50
Average genotype	25.00	33.20	36.06	30.73	
LSD 5%	LSDG= 0.77	LSDS= 0.86	LSDG.S= 1.73		

9-Effect of salt stress with sodium chloride on the number of pods on the plant (pod/plant):

The results (Table 10) indicated that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in the number of pods formed on the plant, as it reached (38.91 - 31.25 - 23.66 - 15.83 pods/cm plant). respectively, compared to the control that gave the highest number of pods per plant (41.25 pods/plant).

The results of the analysis of variance indicated that there were significant differences (P<0.05) between the used types of Jalapeno in terms of the number of pods on the plant (pod/plant). The largest number of pods was 49.33 pods/plant for the Homsi Jalapeno genotype, followed by the Tartousi and Latakani genotypes, then the Shami, and it reached 27.33, 24.86 and 19.20 pods/plant respectively.

Treatment with increased salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in the number of pods/plant, especially at high salt concentrations of 10 and 15 mmho/cm, as it reached (14 - 19.67 - 46 - 15 pods/plant) when treated with 10 mmho/cm and (10 - 12.33 - 29 - 12 pods/plant) when treated with 15 mmho/cm for the Jalapeno embroidery (Latakani-Tartousi - Homsi - Shami), respectively. In comparison between the four Jalapeno genotypes, the Homsi Jalapeno showed the least decrease in the number of pods/plant when the applied salt concentration increased, followed by Shami, Tartousi, and Latakani.

A decrease of 25-52%, 42-54%, 50-68% and 64-74% respectively, at high salt concentrations (10 and 15 mmho/cm) compared to the control plants for each genotype. The results showed a decrease in the number of pods formed on the plant, and this can be explained in view of the toxic effect of the accumulation of sodium chloride salts in the plant on the process of pollination and fertilization of flowers, and thus the decrease in pod formation [27].

10-Effect of sodium chloride salt stress on pods weight (g/pod):

The results of the analysis of variance (11) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in the weight of the pods, reaching (0.800 - 0.641 - 0.425 - 0.191 g/horn) respectively, compared to the control that gave the highest pods weight (0.842 g/pod).

The results showed that there were significant differences (P<0.05) between the used genotypes of Jalapeno in terms of pods weight (g/plant). The highest weight of the pod was 0.786 g for the Homsi Jalapeno genotypes, followed by the Latakani, Tartousi, and Shami genotypes, which reached 0.593, 0.473, and 0. 466 g/pod, respectively.

Treatment with increased salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant (P<0.05) decrease in the weight of the pod, especially at high salt concentrations of 10 and 15 mmho/cm, as it reached (0.433 - 0.367 - 0.567 - 0.333 g /pod) when treated with10 mmho/cm and (0.167- 0.1- 0.367- 0.133 g/pod) when treated with 15 mmho/cm when embroidering the robes (Latakani-Tartousi-Homsi-Shami) respectively. In comparison between the four Jalapeno genotypes, the Shami Jalapeno showed the least decrease in pod weight (g/plant) when increasing the applied salt concentration in Tartousi and Latakani and Shami, with a decrease rate of 7-37%, 28-46%, 43-53% and 40-55%, respectively. At high salt concentrations of 10 and 15 mmho/cm, compared to control plants for each genotype. The results showed a decrease in the weight of the pods formed on the plant. This is because salinity affects the productive capacity of the plant, especially in the pre-flowering stage, which leads to a partial inability to produce fruits, causing their size, number, and weight to decrease. This was confirmed by the results of Khalid et al. [27].

11-Effect of NaCl salt stress on seed weight (g/pod):]

The results (Table 12) showed that the use of increasing salt concentrations (3, 6, 10, 15 mmho/cm) led to a significant decrease (P<0.05) in seed weight/pod, which reached (0.566 - 0.400 - 0.275 - 0.150 g/pod) respectively, compared to the control that gave the highest seed weight (0.558 g/pod).

The results indicated that there were significant differences (P<0.05) between the used genotypes of Jalapeno in terms of seed weight (g/pod), and the largest seed weight was 0.453 g/pod for the Jalapeno Homsi genotype, followed by the Latakani and Shami and Tartousi genotypes, which reached 0.433, 0.346 and 0.326 g/pod respectively.

Treatment with increased salt concentrations (3, 6, 10, and 15 mmho/cm) led to a significant decrease (P<0.05) in seed weight g/pod, especially at high salt concentrations of 10 and 15 mmho/cm, as it reached (0.367 - 0.2 - 0.3 - 0.233 g/pod) when treated with 10 mmho/cm and (0.167- 0.1- 0.233- 0.1 g/cm) when treated with 15 mmho/cm, for the Jalapeno genotypes (Latakani - Tartousi - Homsi – Shami) respectively. In comparison between the four Jalapeno genotypes, the Humsi Jalapeno showed the least decrease in seed weight in g/pod when the applied salt concentration increased, Latakani, Shami, and Tartousi, with a decrease rate of 55-65%, 35-71%, 53-80%, and 60-80% respectively, at high salt concentrations of 10 and 15 mmho/cm compared to the control plants for each genotype. The results showed a decrease in seed weight, and this is due to the high percentage of salinity in the medium due to the accumulation of sodium ions in the plant, and a slowdown in the activity of the photosynthesis process, so that the amount of dry matter accumulated in the plant decreases, thus resulting in less formation of pods and a decrease in its seed content, in addition to the decrease in The dry weight of pods and seeds [26].

Table 10. Number of pods (pod/plant) of the studied genotypes of Jalapeno (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (control, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	39.00	39.00	61.00	26.00	41.25
S1	36.00	36.67	59.00	24.00	38.91
S2	25.33	29.00	51.67	19.00	31.25
S3	14.00	19.67	46.00	15.00	23.66
S4	10.00	12.33	29.00	12.00	15.83
Average genotype	24.86	27.33	49.33	19.20	
LSD 5%	LSDG= 0.97	LSDS= 1.09	LSDG.S= 2.19		

Table 11. Weight of pods (g/plant) of the studied types of Jalapeno (Latakani, Tartousi, Homs, and Shami) under the influence of salt stress with sodium chloride (control, 3, 6, 10, and 15 mmho/cm

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	19.73	14.73	21.97	13.27	17.42
S1	19.60	13.83	15.00	13.63	15.52
S2	15.30	13.17	17.83	12.80	14.77
S3	11.80	10.57	12.53	12.33	11.81
S4	8.90	8.00	10.33	8.33	8.89
Average genotype	15.06	12.06	15.53	12.07	
LSD 5%	LSDG= 1.86	LSDS= 2.08	LSDG.S= 4.17		

Table 12. Seed weight (g/pod) of the studied Jalapeno genotypes (Latakani, Tartousi, Homsi, and Shami) under the influence of salt stress with sodium chloride (control, 3, 6, 10, and 15 mmho/cm)

Salinity concentrations	Latakani	Tartousi	Homsi	Shami	Average salinity
S0	0.567	0.500	0.667	0.500	0.558
S1	0.600	0.533	0.600	0.533	0.566
S2	0.467	0.300	0.467	0.367	0.400
S3	0.367	0.200	0.300	0.233	0.275
S4	0.167	0.100	0.233	0.100	0.150
Average genotype	0.433	0.326	0.453	0.346	
LSD 5%	LSDG= 0.032	LSDS= 0.036	LSDGS= 0.072		

4. CONCLUSION

1-The use of increasing salt concentrations (3, 6, 10, and 15 mmho/cm) led to a significant gradual decrease ($P<0.05$) in most of the morphysiological, morphological, and productivity indicators measured in all the studied genotypes. This decrease was more noticeable at higher salt concentrations of 10 and 15 mmho / cm.

2-The Al- Jalapeno Homsi genotype was superior to the rest of the genotypes in all the studied traits under control conditions. This genotype also showed, under conditions of salt stress, especially the high levels of 10 and 15 mmho/cm, a significant ($P<0.05$) superiority over the rest of the genotypes in most of the studied traits, including : Number of roots/plant, Number of branches/plant, Number of leaves/plant, Leaf surface area (cm2/plant), Number of flowers/plant, Number of pods/plant, Seed weight (g/pod), as this model recorded the lowest percentage. The value of the characteristic decreases under stress conditions.

3-The interference values of the Jalapeno Homsi genotype were the highest in most traits at the salt stress level of 3 mmho/cm compared to the rest of the studied genotypes, with no significant difference ($P>0.05$) compared to the control, as it was in the number of roots (5.66). Volume of roots (34.56 cm3), weight of roots (2 g), number of branches (12.66), number of leaves (110.50), area of leaves per plant (279.68 cm2), number of flowers (45.67), number of pods in the plant (59 pods), seed weight per pod (0.6 g).

5. RECOMMENDATIONS

4-An experiment in planting the Jalapeno Homsi genotype in saline lands to verify the compatibility of the results of this experiment under natural conditions and in the areas where the Jalapeno is grown.

5-Using the Jalapeno Homsi genotype in control conditions, due to its superiority in most of the morphysiological, morphological and production traits studied, and the possibility of growing it under salinity conditions, whether at low levels (3 mmho/cm) or high levels of more than 10 mmho/cm, given the low sensitivity of its studied traits to salinity.

6-The possibility of using a number of morphological and physiological traits: such as the area of the plant’s leaf surface (cm2/plant) and the number of branches (branch/plant), and productivity: the weight of seeds (g/pod) is at the forefront of important indicators in screening the models’ tolerance to salt stress, followed by the characteristics of the number of flowers. (flower/plant) and number of pods (pod/plant), while plant root system traits showed a lesser response in terms of being affected by the salinity levels used.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Developers should have a background in mathematics and be comfortable with algorithms.
2. Artificial intelligence can use machine learning to analyze large amounts of data faster than any human.
3. AI platforms can identify trends, analyze data, and provide guidance. By predicting data

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/4193