

EFFECTS OF DIFFERENT CHEMICAL AND ORGANIC FERTILIZERS ON PLANT PROPERTIES OF COTTON (*GOSSYPIUM HIRSUTUM* L.) UNDER NON-SALINE AND SALINE SOIL CONDITIONS

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Abstract. This study was conducted to investigate the effects of organic and chemical fertilizers (diammonium phosphate, DAP) on by physiological development of two cotton (*Gossypium hirsutum* L.) varieties grown under non-saline and saline soil conditions. It was carried out in 2019 at plant research laboratory of Vocational School Technical Sciences in Harran University, Turkey. Chlorophyll content, plant height (cm), root length (cm), fresh root weight (g), dry plant weight (g) and dry root weight (g) of Candia and Lima cotton varieties were determined to evaluate the effects of fertilizers. The layout of the pot experiment was randomized block with three replications. In non-saline soil; the lowest chlorophyll value (17.83) was recorded for the control, while the highest chlorophyll value (32.64) was obtained under the chemical fertilizer (DAP) treatment. In saline soil; the lowest chlorophyll value (20.33) was obtained in chemical fertilizer treatment, and the highest chlorophyll value (24.11) was determined from vermicompost treatment. The lowest plant height (27.83 cm) in non-saline soil was measured in chemical fertilizer application, while the highest plant height (33.00 cm) was recorded in cattle manure application. The shortest root length (13.66 cm) in non-saline soil was obtained from the control, and the highest root length (16.00 cm) was measured in chemical fertilizer.

Keywords: *cotton (Gossypium hirsutum L.), non-saline and saline soil condition, organic and chemical fertilizer, physiological properties*

Introduction

Cotton (*Gossypium hirsutum* L.) is a very important raw material for the textile industry in Turkey and the world. Cotton sector report published by the National Cotton Council in 2019 revealed that 2.57 million tons of seed cotton was produced during 2018/2019 growing seasons in Turkey, and 38% of the seed cotton composed of fiber cotton, which was equal to 976 thousand tons of fiber cotton. Cotton fiber sufficiency ratio of Turkey is around 50% (Anonymous, 2020). Cotton is an industrial plant produced under non-saline soil conditions in semi-arid regions. Cotton plant needs plenty of water and fertilizer during vegetative and generative periods. However, excessive use of fertilizers and irrigation water may lead to an increased soil salinity, which inhibits germination, retards root and stem growth and the development of vegetative parts. Approximately, 20% of arable agricultural lands and 50% of the irrigated lands were affected by salinity (Zhu, 2001). Reclamation and eliminate the harmful effects of saline soils are very difficult and costly. Salt stress is one of the most hazardous abiotic stress factors that limit plant growth. Therefore, efforts should be focused on obtaining salinity tolerant plant varieties.

Salinity in agricultural lands due to the different irrigation systems adversely affects plant growth by osmotic, ionic and oxidative stresses (Munns et al., 2008; Flowers and Colmer, 2008). Cultivation of high yielding varieties in addition to optimizing the growing conditions is another important factor in increasing the cotton production in

Turkey. The optimum germination of seeds, ensuring optimum plant density per unit area and adequate are needed to obtain high yield and quality in cotton (Fujikura et al., 1993; De Villiers et al., 1994). Soil salinity decreases the vegetative development of cotton (Qadir and Shams, 1997), while low salt concentrations can increase growth (Pessaraki and Tucker, 1985; Gorham, 1996). Reclamation of soil salinity by conventional leaching is cost intensive and dependent on the availability of water (Laudicina et al., 2009). Therefore, varieties that are resistant to salt stress should be cultivated. Salt stress reduces the leaf area and the development of root and above-ground parts in cotton (Saghir et al., 2002). Salt concentration reaching 12 EC decreased the germination rate and plant height of cotton plants (Phogat et al., 2001). Similarly, germination rate decreased at 252 meq L⁻¹ NaCl level and seedling growth was prevented even at lower concentrations (Casenave et al., 1999). Salinity is one of the most important problems of the agricultural lands in the world and threatens the cotton production areas (Saghir et al., 2002). Degradation of 10 million ha land in the world every year due to the salinity reveals the extend of the problem (Kwiatowski, 1998). Excess level of salts in soils affects around 95 million ha agricultural land in the world (Szabolcs, 1994). In agricultural production; rational and efficient management of plant, soil and water increases the yield per unit area. Excess use of irrigation water will cause rising the groundwater, consequently salt concentration which will restrict plant growth. High salt concentration of soil adversely affects the physiological development of cotton plant.

Insufficient precipitation and high evaporation are the major causes of salinity in arid and semi-arid regions. In addition, improper irrigation can cause soil salinity especially in bad drainage conditions (Ergene, 1982). Limited land used in agricultural production and the continuous increase in food demand necessitates more efficient use of existing arable lands. Therefore, the improvement and productive use saline soils is extremely important (Woods, 1996). The aim of this study was to investigate the responses of different cotton varieties grown in non-saline and saline conditions to chemical and organic fertilizers and to observe different growth parameters of cotton plants starting from the germination of cotton seeds. In this study, salinity tolerance of some cotton varieties in non-saline and saline conditions were determined. This study was also aimed to determine salt-resistant cotton varieties and fertilizer combinations and to recommend varieties and treatments that show high performance to chemical and organic fertilizer applications in both non-saline and saline conditions.

Materials and methods

Materials

Delineated seeds of Candia and Lima cotton cultivars were used as plant material of the study. Solid farm fertilizer (Biofarm Fertilizer) and vermicompost (Ecosolfarm) was used as organic fertilizer, and di ammonium phosphate (DAP; 18N-46P₂O₅-0K₂O) was used as chemical fertilizer. Fertilizer doses applied were 2000 kg ha⁻¹ solid farm manure, 1500 kg ha⁻¹ vermicompost, and 300 kg ha⁻¹ DAP. No fertilizer applied to the control plots.

Methods

The lay out of the pot experiment was randomized plots with three replications. This study was carried out in Şanlıurfa, Turkey. The study consisted of the germination test

and characterization of vegetative growth parameters. Candia and Lima cotton varieties were used for salinity tolerance test in non-saline and saline soils. The study was carried out in the plant laboratory of Sanliurfa Technical Sciences Vocational School of Harran University twice, the first one was in April and the second one was in September 2019. Germination test was conducted under laboratory conditions according to guidelines of ISTA. The surfaces of seeds were sterilized with 70% ethanol for 30 s to prevent contamination of cotton seeds, and kept in pure water for surface sterilization. The seeds were then kept in 2% sodium hypochlorite solution for 3-5 min, and surface sterilization was completed by washing 2-3 times in deionized distilled water. Surface sterilized seeds were sown in pots containing the fertilizers (Fig. 1).



Figure 1. Pots in which the research was conducted (A) saline soil (B) non-saline soil

Fertilizers were applied at the doses specified by the manufacturers given on the packages. The soils used in the study were taken from a non-saline agricultural field and a saline area. non-saline soils had a pH of 7.82, electrical conductivity (EC) was 3.03 ms cm^{-1} and lime and organic matter contents were 10.96 and value is 0.88%, respectively. Saline soils had a pH of 7.20, EC was 3.74 ms cm^{-1} , lime and organic matter contents were 26.62 and 3.74%, respectively. The pots consist of a radius of 12.5 cm and a height of 20 cm. The soils were passed through a 2 mm sieve and filled into free draining plastic pots with 5 kg soil. The pots were irrigated after sowing to ensure germination of seeds. Water requirement of the plants was observed and the pots were irrigated twice a week with distilled water (pH close to 7). The temperature of the growing environment was set to $27 \pm 1 \text{ }^\circ\text{C}$ per day (Reddy et al., 2004; Salvucci and Crafts-Brandner, 2004). The lighting of the growing environment was set to 14 h light and 10 h dark. Sunlight and fluorescent light were used for the luminous phase. Plant growth was monitored from seed sowing to the squaring period. Plants whose cotyledon leaves completely reached the soil surface were counted. Plants were harvested 12 weeks after the emergence.

Total chlorophyll content (%), plant height (cm), plant root length (cm), overall fresh weight (g), fresh root weight (g), general dry weight (g) and root dry weight (g) of cotton plants were determined. The chlorophyll content (SPAD values) was measured on the leaves of selected plants using a SPAD meter (CCM 200 Plus).

Data obtained in the study was subjected to variance analysis (ANOVA) using JMP 13.0 software to compute the differences of measured variables between the treatments. Analysis of variance was performed by using the averages of the growth parameters

obtained during the carding period, which is the 60th day of cotton plant development. Following the ANOVA, means were grouped by using least significant difference test (LSD) at 95% probability level.

Results and discussion

The result of variance analysis indicated statistically significant differences among the characteristics of cotton varieties grown in non-saline and saline soils (*Table 1*). Germination under non-saline soil conditions was achieved in all fertilizer applications and plant characteristics were determined when plants reached a certain physiological development. The results recorded under saline soil conditions showed that germination could not be achieved in all fertilizer applications. Germination and physiological development in saline soil were obtained only in chemical fertilizer and vermicompost treatments.

Total chlorophyll content

Total chlorophyll content of plants grown in pot conditions was measured using SPAD device. The SPAD values measured in cotton development stages were significantly different. High chlorophyll content during the squaring period when the plant has the highest physiological development is an expected situation for cotton plants. Chlorophyll values of cotton cultivars grown under non-saline soil conditions were not significantly different (*Table 1*). The chlorophyll content between fertilizer applications was significantly different ($P < 0.01$). The lowest mean chlorophyll value (17.83) was obtained in control and the highest total chlorophyll value (32.64) was recorded in DAP application. The effects of cultivar \times fertilizer interaction on total chlorophyll content was statistically significant ($P < 0.01$). The lowest total chlorophyll value (17.44) in variety \times fertilizer interaction was obtained in Candia variety \times control treatment, while the highest chlorophyll value (37.90) was measured in Candia variety \times DAP interaction. Total chlorophyll value in saline soil condition was not significantly different between cotton varieties grown with different fertilizer applications. Total chlorophyll value recorded in different fertilizer treatment was significantly different ($P < 0.01$). The lowest total chlorophyll value (20.33) was obtained in DAP fertilizer application and the highest total chlorophyll value (24.11) in vermicompost treatment. The difference in total chlorophyll content in cultivar \times fertilizer interaction was statistically significant ($P < 0.01$). The lowest total chlorophyll value (18.60) was obtained in Candia variety \times DAP interaction, while the highest total chlorophyll value (24.63) was recorded in Candia variety \times vermicompost treatment. The results indicated no significant difference in total chlorophyll content between the varieties. The differences in chlorophyll values among the fertilizer applications is meaningful. In addition, the chlorophyll content of cotton plants grown in non-saline soils is higher than that measured in saline conditions. High SPAD values obtained in applications with high nitrogen doses indicate higher photosynthesis rate and organic material production. Plants tend to photosynthesize more in non-saline soil conditions and in optimum available nutrition content. Shankar et al. (2020) reported that SPAD values ranged between 41 and 45 with nitrogen application at 60, 90, 120 and 150 kg ha⁻¹ doses. The increase in SPAD values with the increase nitrogen doses is in accordance with our findings. Similarly, Dođru and Canavar (2019) stated that soil salinity reduced the pigment content and photosynthetic activity of plants and consequently plant growth

was adversely affected. In addition, studies using the electron microscope showed that salt stress causes some changes in the chloroplast structure and reduces photosynthetic activity (Mitsuya et al., 2000). Our findings are in agreement with the decrease in total chlorophyll and protochlorophyllide of *Greviela arenaria* compared to control under saline conditions reported by Kennedy and Filippis (1999), decrease in total chlorophyll and chlorophyll content of tomato reported by Khavari-Nejat and Mostofi (1998), and decrease in chlorophyll a and b and total chlorophyll content of *Bruguiera parviflora* reported by Alamgir and Ali (1999). Maxwell and Johnson (2000) also revealed that change in photosynthetic pigment biosynthesis is the most obvious effect of salt stress on plants. Bhagwat et al. (2020) carried out a study using different cotton varieties under severe saline conditions, and reported poor germination and subsequent abnormal plant development indicated by low membrane stability (%), leaf relative water content (%), chlorophyll content and photosynthesis. Their findings stating the decreases in carotenoid content, perspiration rate and stomatal conductivity are substantially consistent with our findings. In addition, the findings of Castilo (2011) who reported that stomatal conductance, photosynthesis and carbohydrate formation decreased under excessive salt concentration are also agreement with our findings. Fertilizer applications in saline soil conditions and the cotton varieties used in the experiment did not provide full physiological development. These results are contradicting with the findings of Hemphill et al. (2006) who reported that cotton plant is a relatively resistant to salt tolerance, has the potential to perform physiological development in saline conditions.

Table 1. Effects of fertilizers applied in non-saline and saline soil conditions on total chlorophyll content

Properties	Fertilizers	Non-saline soil			Saline soil		
		Varieties			Varieties		
		Candia	Lima	Mean	Candia	Lima	Mean
Chlorophyll	DAP	37.90a	27.40cd	32.64	18.60d	22.06c	20.33
	Cattle manure	29.73b	27.66c	28.70	-	-	-
	Vermicompost	25.50d	25.37d	25.43	24.63a	23.60b	24.11
	Control	17.44e	18.23e	17.83	-	-	-
	Means	27.64	24.66	26.15	21.61	22.83	22.22
	CV (%), LSD	CV (%), 4.39 LSD (Variety), ns LSD (Fertilizer), 1.44** LSD (Variety × Fertilizer), 2.04**			CV (%), 1.02 LSD (Variety), ns LSD (Fertilizer), 0.36** LSD (Variety × Fertilizer), 0.51**		

There is no significant difference between the mean values in the same letter group compared to LSD (5%). ns: not significant. *, **: Important at $P < 0.05$ and $P < 0.01$ level of significance

Plant height

Plant height was not significantly different between cotton varieties under non-saline soil conditions (Table 2). The effects of fertilizer treatments on plant height was statistically significant ($P < 0.01$). The lowest mean plant height (27.83 cm) in fertilizer applications was measured DAP application and the highest plant height (33.00 cm) was recorded in cattle manure application. The effects of variety × fertilizer interaction on plant height was not statistically significant. The difference in mean plant height between the variety and fertilizer applications was not significant in saline soil

conditions. The height of plants grown in saline soil conditions were shorter compared to the plant height in non-saline soil. Saline soil environments are not suitable for plant growth, therefore, the plants cannot grow as under optimum conditions. Castillo (2011) also indicated that salinity is an important abiotic stress factor that has a negative impact on plant growth. The highest plant height was recorded in cattle manure application in non-saline soils. Similarly, Jackson et al. (2003) reported that organic fertilizers improve physical and chemical properties of soils as well as increase the number, diversity and activity of microbial communities. Our results are in agreement with the findings of Khaliq et al. (2006) who stated that organic and microbial fertilizers increased the nutrient uptake of plants. Similar to our study, Barrick et al. (2015) investigated the effect of salinity on growth and some of characteristics of cotton lines grown under organic and conventional conditions. The results showed that cotton lines significantly affected by stress condition including the salinity, and salt applications reported to have negative effects on all properties examined, except chlorophyll content.

Table 2. Effects of fertilizers applied in non-saline and saline soil conditions on plant height

Properties	Fertilizers	Non-saline soil			Saline soil		
		Varieties			Varieties		
		Candia	Lima	Mean	Candia	Lima	Mean
Plant height (cm)	DAP	24.33	31.33	27.83c	24.00	27.00	25.50
	Cattle manure	32.33	33.66	33.00a	-	-	-
	Vermicompost	30.33	33.33	31.83ab	26.00	23.66	24.83
	Control	25.66	32.00	28.83bc	-	-	-
	Mean	28.16	32.58	30.37	25.00	25.33	24.16
	CV (%), LSD	CV (%), 9.40 LSD (Variety), ns LSD (Fertilizer), 3.55* LSD (Variety × Fertilizer), ns			CV (%), 16.18 LSD (Variety), ns LSD (Fertilizer), ns LSD (Variety × Fertilizer), ns		

There is no significant difference between the averages in the same letter group compared to LSD (5%). ns: not significant. *, **: Important at $P < 0.05$ and $P < 0.01$ level of significance

Root length

Root length was not statistically different between the cotton varieties grown in non-saline soil conditions (Table 3). However, the difference in root length between fertilizers was statistically significant ($P < 0.05$). The lowest root length (13.66 cm) among fertilizer treatments was recorded in control and the longest root length (16.00 cm) was measured in DAP application. The effect of variety × fertilizer interaction on root length was statistically significant ($P < 0.01$). The lowest root length (13.00 cm) value was measured in Lima variety × control interaction, while the longest root length (18.00 cm) was recorded in Lima variety × control interaction. The mean root length recorded for cotton varieties and fertilizers was not significantly different in saline conditions. The result can be attributed to restriction of root and above ground plant part growth under saline conditions. Abdel-Aziz (2019) investigated the effects of humic acid and bacillus bacteria on some physiological and productivity characteristics of cotton plants and reported that fertilization methods had a significant effect on plant growth ratio ($\text{g/m}^2/\text{week}$). Similarly, the findings reported by Carter (1975), Munns (2002), Pitman and Läuchli (2002), and Sharma and Goyal (2003) are in accordance

with the harmful effects of salinity on germination and vegetative growth particularly in arid and semi-arid climates. Ashraf (2004), Mittler (2006), and Neumann (1997) also investigated the salt resistance of plants. The findings of aforementioned researchers are in agreement with our findings that soil salinity and local environmental conditions may cause a serious problem in cotton production. In contrast to our findings, Amjad et al. (2002) reported that root lengths were not affected by low salt density and the root length did not change with the increase in salt content. In addition, Jafri and Ahmet (1994) and Leidi (1994) stated that root length increased at low salt concentrations. The differences in response of plants to root growth can be attributed to the differences in soil and climatic conditions under which the experiments conducted, cotton varieties and management practices.

Table 3. Effects of fertilizers applied in non-saline and saline soil conditions on root length

Properties	Fertilizers	Non-saline soil			Saline soil		
		Varieties			Varieties		
		Candia	Lima	Mean	Candia	Lima	Mean
Root length (cm)	DAP	16.00ab	16.00ab	16.00	12.73	16.00	14.36
	Cattle manure	15.66abc	13.66cd	14.50	-	-	-
	Vermicompost	13.33cd	18.00a	15.66	17.33	15.33	16.33
	Control	14.33bcd	13.00d	13.66	-	-	-
	Mean	14.83	15.08	14.95	15.03	15.66	15.34
	CV (%), LSD	CV (%), 9.32 LSD (Variety), ns LSD (Fertilizer), 1.73* LSD (Variety × fertilizer), 2.45**			CV (%), 11.85 LSD (Variety), ns LSD (Fertilizer), ns LSD (Variety × Fertilizer), ns		

There is no significant difference between the averages in the same letter group compared to LSD (5%). ns: not significant. *, **, Important at $P < 0.05$ and $P < 0.01$ level of significance

Fresh weight (g)

The difference in fresh weight under non-saline soil conditions was not significant between the cotton varieties. Similarly, the effect of fertilizer treatments on fresh weight was not significant. Lack of significant difference in fresh weight between the cultivars and among the fertilizers used may be related to physiological and environmental effects.

The difference in fresh weight in saline conditions was not statistically significant between the cultivars. The effect of fertilizers on fresh weight under saline conditions was statistically significant ($P < 0.01$). The variety × fertilizer interaction in saline conditions had a statistically significant impact ($P < 0.01$) on fresh weight variety of cotton plants. The lowest fresh weight (13.68 g) in fertilizer treatments under saline conditions was recorded in vermicompost application and the highest fresh (16.81 g) weight was obtained in DAP application (Table 4). The lowest fresh weight (13.00 g) in variety × fertilizer interaction was obtained in Lima variety × vermicompost application, while the highest fresh weight (17.33 g) was recorded in Lima variety × DAP application. The fresh plant weight was at a certain level in non-saline soil conditions, however, plant could not grow under saline conditions as compared to non-saline soil conditions. Saline soils do not have optimal conditions for plant growth; thus, vegetative growth did not occur at a desired extent. Similar to the results reported in this

study, Taghipour and Salehi (2009) reported that application of calcium chloride and sodium chloride to 12 barley varieties significantly decreased fresh weight in all barley varieties. In contrast, some researchers stated that some plant varieties are resistant to high salt concentrations. In addition, Basal (2010) observed significant differences in several characteristics of 15 cotton genotypes grown under increased salt levels. Nirmala (2011) also reported vegetative development of cotton genotypes without showing salt stress. Fresh weights of cotton varieties under different salt concentrations decreased, while fresh weight increased in non-saline soil conditions (Avcı et al., 2020). The findings of Abdel-Aziz (2019) are compatible with our results. The researchers who investigated effects of humic acid and bacillus bacteria on some physiological and productivity properties of a cotton variety, indicated that fertilization methods increased the fresh weight. However, our findings were not in agreement with the results reported by Khenifi et al. (2011) who investigated the effects of salt stress on vegetative growth of cotton genotypes.

Table 4. Effects of fertilizers applied in non-saline and saline soils on fresh weight (g)

Properties	Fertilizers	Non-saline soil			Saline soil		
		Varieties			Varieties		
		Candia	Lima	Mean	Candia	Lima	Mean
Fresh weight (g)	DAP	15.53	17.63	16.58	16.30b	17.33a	16.81
	Cattle manure	18.44	15.86	17.15	-	-	-
	Vermicompost	18.60	17.46	18.03	14.36c	13.00d	13.68
	Control	21.80	14.36	18.08	-	-	-
	Mean	18.59	16.33	17.46	15.33	15.16	15.24
	CV (%), LSD	CV (%), 15.40 LSD (Variety), ns LSD (Fertilizer), ns LSD (Variety × Fertilizer), ns			CV (%), 1.33 LSD (Variety), ns LSD (Fertilizer), 0.32** LSD (Variety × Fertilizer), 0.44**		

There is no significant difference between the averages in the same letter group compared to LSD (5%). ns: not significant. *, **: Important at $P < 0.05$ and $P < 0.01$ level of significance

Fresh root weight (g)

The increase in soil content of soils adversely affects the root growth and fresh and dry root weights (Munns, 2002). Fresh root weight under non-saline soil conditions was significantly different ($P < 0.01$) between the cotton cultivars. The difference in fresh root weight between the fertilizer treatments was statistically significant ($P < 0.01$). In addition, a statistically significant difference ($P < 0.01$) was found in variety × fertilizer interaction. Fresh root weight of Candia variety was higher than that of the Lima variety. The difference in fresh root weight between the cotton varieties may be attributed to the genetic structure, environment and environment × genotype interaction. The lowest mean fresh root weight (0.92 g) in different fertilizer treatments was recorded in cattle manure application and the highest fresh root weight (1.10 g) was obtained in vermicompost applications. The lowest fresh root weight (0.71 g) in variety × fertilizer interaction was obtained in Lima variety × control treatment, while the highest fresh root weight (1.25 g) was recorded in Lima variety × vermicompost treatment. The differences in fresh root weight under saline soil conditions was not statistically significant between the cotton varieties, but a statistical difference

($P < 0.01$) was found among the fertilizers used. In addition, the effect of variety \times fertilizer interaction on fresh root weight was statistically significant ($P < 0.01$). The lowest fresh root weight (0.70 g) among different fertilizer treatments was obtained in vermicompost application, while the highest fresh root weight (0.83 g) was recorded in DAP application. The lowest mean fresh root weight (0.68 g) in variety \times fertilizer interaction was obtained from Lima variety \times vermicompost interaction and the highest mean fresh root weight (0.86 g) was recorded in Lima variety \times DAP interaction (Table 5). Fresh root weight of cotton varieties decreased with the increase in salinity. The root development of cotton plants increased in parallel to the progress in vegetative development period of the cotton plants. The roots are the first plant parts to interact with salt due to contact with the soil, and are therefore directly affected by the salt concentration of soils. The highest fresh root weight in this study was obtained in vermicompost application. The results are in agreement with the findings of Jackson et al. (2003) who stated that organic fertilizers improved physical and chemical properties of the soil, and also increased the number, diversity and activity of microbial communities in the soil. Our results are in agreement with the findings of Khaliq et al. (2006) who indicated that organic and microbial fertilizers increased the nutrient uptake of plants. The results of Reinhardt and Rost (1995a, b), Raia and Azimov (1988), Meloni et al. (2001), and Ashraf and Ahmad (2000) were in accordance with our results.

Table 5. Effects of fertilizers applied in non-saline and saline soils on fresh root weight (g)

Properties	Fertilizers	Non-saline soil			Saline soil		
		Varieties			Varieties		
		Candia	Lima	Mean	Candia	Lima	Mean
Fresh root weight (g)	DAP	0.97c	0.94c	0.96	0.81b	0.86a	0.83
	Cattle manure	1.07b	0.78d	0.92	-	-	-
	Vermicompost	1.09b	1.25a	1.10	0.72c	0.68d	0.70
	Control	1.25a	0.71d	0.98	-	-	-
	Mean	1.09	0.89	0.99	0.77	0.77	0.70
	CV (%), LSD	CV (%), 4.06 LSD (Variety), 0.07** LSD (Fertilizer), 0.05** LSD (Variety \times Fertilizer), 0.07**			CV (%), 1.90 LSD (Variety), ns LSD (Fertilizer), 0.02** LSD (Variety \times Fertilizer), 0.02**		

There is no significant difference between the averages in the same letter group compared to LSD (5%). ns: not significant. *, **: Important at $P < 0.05$ and $P < 0.01$ level of significance

Dry plant weight (g)

Dry plant weight under non-saline soil conditions was significantly different ($P < 0.05$) between the cotton varieties (Table 6). The difference in dry plant weight among fertilizer treatments was statistically significant ($P < 0.01$). In addition, the difference in dry plant weight for variety \times fertilizer interaction was also statistically significant ($P < 0.01$). The lowest dry plant weight (2.44 g) in cotton varieties grown under non-saline soil conditions was recorded in Lima variety and the highest dry plant weight (3.11 g) was obtained from Candia variety. Mean dry plant weight of Candia variety was higher compared to dry plant weight of Lima variety. The differences in dry plant weight between the varieties is a genetic feature. The lowest mean dry plant weight (2.48 g) fertilizer treatments was obtained in cattle manure application, while the

highest mean dry plant weight (3.13 g) was recorded in vermicompost application. The lowest mean dry plant weight (1.90 g) in variety × fertilizer interaction was obtained in Lima variety × cattle manure interaction and the highest mean dry plant weight (3.55 g) was recorded in Candia variety × control interaction. The difference in dry plant weight under saline conditions was not statistically significant between the cotton varieties. The effects of fertilizer treatment and variety × fertilizer interaction on dry plant weight were statistically significant ($P < 0.01$). The lowest mean dry plant weight (1.93 g) among the fertilizer treatments was recorded in vermicompost application and the highest mean dry plant weight (2.38 g) was obtained in DAP application. The lowest mean dry plant weight (1.83 g) in variety × fertilizer interaction was obtained from Lima variety × vermicompost interaction, while the highest mean dry plant weight (2.46 g) was recorded from Lima variety × DAP fertilizer interaction. The results reported by Turan (2000), Revathi and Arumugam (2015), and Soares et al. (2018) revealed that dry plant weight decreased with the increase in salt content of the soils. Our results are similar to the findings of Soyergin (2003) who indicated that manure application affected the net mineralization (C/N) rate and organic fertilizers provide a suitable environment for soil fertility by increasing the soil organic matter in long-term as well as available plant nutrients in short and medium terms. Our findings are consistent with the finding of Abdel-Aziz (2019) who investigated the effects of humic acid and bacillus bacteria on some physiological and productivity characteristics of a cotton variety and stated that fertilization methods significantly affected the dry plant weight. Avcı et al. (2020) studied the effects of salt applications on dry plant weight and reported a decrease in dry plant weight with the increasing salt content of soils.

Table 6. Effects of fertilizers applied in non-saline and saline soils on dry plant weight (g)

Properties	Fertilizers	Non-saline soil			Saline soil		
		Varieties			Varieties		
		Candia	Lima	means	Candia	Lima	Means
Dry Plant weight (g)	DAP	2.76c	2.67c	2.71	2.30b	2.46a	2.38
	Cattle manure	3.07b	1.90d	2.48	-	-	-
	Vermicompost	3.09b	3.17b	3.13	2.02c	1.83d	1.93
	Control	3.55a	2.02d	2.78	-	-	-
	Mean	3.11	2.44	2.77	2.16	2.15	2.15
	CV (%), LSD	CV (%), 4.92 LSD (Variety), 0.38* LSD (Fertilizer), 0.17** LSD (Variety × Fertilizer), 0.24**			CV (%), 1.92 LSD (Variety), ns LSD (Fertilizer), 0.05** LSD (Variety × Fertilizer), 0.05**		

There is no significant difference between the averages in the same letter group compared to LSD (5%). ns: not significant. *, **: Important at $P < 0.05$ and $P < 0.01$ level of significance

Dry root weight (g)

Dry root weight under non-saline soil conditions was significantly different ($P < 0.05$) between the cotton cultivars. The dry root weight of cotton varieties was significantly different ($P < 0.01$) between the fertilizers used. In addition, the effects of variety × fertilizer interaction was statistically significant ($P < 0.01$). The lowest root dry weight (0.46 g) was recorded in Lima variety and the highest root dry weight (0.59 g) was recorded in Candia variety. The dry root weight in Candia variety was

higher than that of the Lima variety. The difference in dry root weight between the varieties is related to genetic properties of the cotton varieties. In addition, environmental and cultural factors may have an effect on the difference in dry root weight. The lowest root dry weight (0.47 g) among the fertilizers use, was obtained from cattle manure application and the highest dry weight (0.59 g) was obtained in vermicompost application. The lowest dry root weight (0.36 g) in variety × fertilizer interaction was recorded in Lima variety × cattle manure interaction and the highest dry root weight (0.67 g) was obtained in Candia × control treatment. In terms of variety × fertilizer interaction, the lowest root dry weight (0.36 g) was obtained from Lima variety × cattle manure interaction and the highest root dry weight (0.67 g) was obtained from Candia × control interaction. The dry root weight of cotton varieties under saline conditions was not significantly different. In contrast, the dry root weight among the fertilizers used was significantly different ($P < 0.01$). In addition, a statistically significant difference ($P < 0.05$) was found in variety × fertilizer interaction. The lowest dry root weight (0.37 g) in the fertilizers used was recorded in DAP application, while the highest dry root weight (0.45 g) was obtained from vermicompost application. The lowest dry root weight (0.35 g) in variety × fertilizer interaction was recorded in Lima variety × vermicompost interaction and the highest root dry weight (0.46 g) was obtained from Candia variety × DAP interaction (Table 7). Adverse effects of soil salinity on root growth and dry root weight have also been reported by Reinhardt and Rost (1995a, b), Raia and Azimov (1988), Meloni et al. (2001), Ashraf and Ahmad (2000) and Munns (2002).

Table 7. Effects of fertilizers applied in non-saline and saline soils on dry root weight (g)

Properties	Fertilizers	Non-saline soil			Saline soil		
		Varieties			Varieties		
		Candia	Lima	Mean	Candia	Lima	Mean
Dry root weight (g)	DAP	0.52c	0.50c	0.51	0.46a	0.45b	0.45
	Cattle manure	0.58b	0.36d	0.47	-	-	-
	Vermicompost	0.58b	0.60b	0.59	0.39c	0.35d	0.37
	Control	0.67a	0.38d	0.53	-	-	-
	Mean	0.59	0.46	0.52	0.42	0.40	0.41
	CV (%), LSD	CV (%), 5.01 LSD (Variety), 0.043* LSD (Fertilizer), 0.02** LSD (Variety × Fertilizer), 0.04**			CV (%), 0.98 LSD (Variety), ns LSD (Fertilizer), 0.22** LSD (Variety × Fertilizer), 0.19*		

There is no significant difference between the averages in the same letter group compared to LSD (5%). ns: not significant. *, **: Important at $P < 0.05$ and $P < 0.01$ level of significance

Conclusion

The results of the study revealed that the highest total chlorophyll content and plant root length was recorded in chemical (DAP) fertilizer application, and the highest plant height was measured in cattle manure application. The fertilizers used had no significant effect on the fresh plant weight. The highest fresh and dry root weight values were recorded in Candia variety and vermicompost application. The results showed that the highest values of plant properties in general under non-saline soil condition were recorded in Candia variety × vermicompost interaction. In saline soil conditions; plant

germination and development occurred only in DAP DAP and vermicompost applications, and all observations and measurements were carried out in these treatments. The highest total chlorophyll content was obtained in vermicompost application. The highest plant height value was recorded in cattle manure application. Plant root length was not significantly different between the fertilizers used. The highest fresh plant weight, fresh root weight, and dry plant weight values were recorded in the DAP application. The highest dry root weight was obtained in vermicompost application. The highest values of plant properties examines in saline soil conditions were mostly recorded in DAP application. The values of plant properties examined in saline soil conditions were lower compared to those in non-saline soil conditions. The results concluded that saline soil conditions have adverse impact on germination, physiological development and yield of the cotton varieties. The use of organic fertilizers in saline soils positively affected the development of the root part of the plant. For this reason, the use of organic fertilizers in saline soils should be encouraged and more comprehensive studies should be carried out in this area.

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