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Research Article

Effect of the Use of Arbuscular Mycorrhiza for Plant Growth Promotion on Morpho-physiological Properties of *Antirrhinum majus L.* Under Salinity Stress

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Abstract

The impact of arbuscular mycorrhizal (AM) fungi inoculation with mixed water irrigation on the vegetative and flowering growth, leaf mineral content, and chlorophyll (Chl) content of *Antirrhinum majus* L. (snapdragon) plants was studied through two seasons under two irrigation water sources. Five irrigation water treatments were applied as follows: T1 as a control (100% desalinized (DW)), T2 (75% DW + 25% well water, WW), T3 (50% DW + 50% WW), T4 (25% DW + 75% WW), and T5 (100% WW). The imposed salt stress conditions (T5) significantly reduced all vegetative and flowering growth, leaf mineral content (P, Na, K, Cl, and Ca), and chlorophyll content of the plants compared to those of the non-salted plants (T1). Inoculated snapdragon with AM fungi exhibited significantly higher values for most vegetative growth characters, flowering date, and spike length than those of non-mycorrhizal plants. With regard to interaction effects, the highest value of proline content of the leaves was detected with 100% WW (T5) and AM fungi treatments, which improved the salt stress tolerance compared to other treatments. Inoculated snapdragon plants with AM fungi showed both improved vegetative and flowering growth, mostly under salt stress conditions. With (T3) under mycorrhizal treatment, snapdragon plants showed the best results with earlier flowering dates, greater number of spikes, and longer spike length.

Keywords: *Annual Plant; Desalinized Water; Flower Yield; Proline; Well Water*

Abbreviations

AM: Arbuscular Mycorrhiza; DW: Desalinized Water; WW: Well Water; RCBD: Randomized Complete Block Design

Introduction

Antirrhinum majus L. (snapdragon) is major ornamental bedding and cut flower plant that is used worldwide in landscaping of gardens, streets, borders, and parks. It is also a valuable medicinal plant, with its leaves and flowers being widely used in the pharmaceutical industry [1]. Increasing growth rate and productivity of the ornamental plants, such as snapdragon per unit area and expanding its cultivated area, particularly in soils subjected to water stress, are major concerns for makers.

In semi-arid and arid climates, most crop water requirements are supplied through irrigation, with water that normally contains large amounts of dissolved salts. Consequently, salinity control frequently represents a major target of irrigation management [2]. In addition to affecting crop yield and soil physical conditions, quality irrigation water affects the performance of the irrigation system and soil fertility. Hence, irrigation water quality status is critical in understanding the necessary management changes for long-term crop productivity [3]. In cases when water resources are limited and the price of non-saline water becomes high, crops with moderate to high salt tolerance can be irrigated with saline water [4]. Currently, there are two strategies of water management to utilize saline water for crops irrigation: cyclic (alternative irrigation with saline and non-saline water) and blending (mixture of saline with non-saline water at different ratios). It is worthwhile to note that cumulative crop salt tolerance through plant breeding could enhance the sustainability of irrigation with low quality water [5].

Mycologists and botanists have realized that most terrestrial plants have a symbiotic relationship with soil fungi [6], which shows the symbiotic association between plant roots and fungi. Among the types of mycorrhizae in nature, arbuscular mycorrhiza fungi (AMF) share a symbiotic relationship with approximately 85% of herbaceous plants. Therefore, mycorrhizal symbiosis is a rule rather than an exception [6].

AMF are microscopic soil fungi that simultaneously colonize roots and their rhizosphere and spread out over several in the form of ramified filaments. This filamentous network dispersed inside and outside the roots allows the plant to have access to a greater quantity of water and soil minerals required for its nutrition [7]. The colonized plant is better nourished, better adapted to its environment, and has increased protection against environmental stresses [8], including salinity, pollution [9] and drought [10,11]. Furthermore, symbiosis tends to reduce the incidence of root diseases and minimize the harmful effects of certain pathogenic agents [12]. AMF plants have a greater osmotic adjustment than non-AMF plants [13,14]. The application of AM inoculation mitigates the adverse effect of water stress on flower yield, growth, and quality of ornamental plants is still under research.

The purpose of this study was to determine the effects of mixed irrigation treatments DW or WW and fungal inoculation to evaluate the effects of AMF (*Glomus mosseae*) on the growth, flower yield, and mineral content of snapdragon plants grown under greenhouse conditions. This study will helpful that AMF colonization can mitigate the deleterious effects of salinity stress on growth and flower yield of snapdragon plants.

Materials and Methods

Irrigation water

Two sources of irrigation water were used: I: desalinized water (DW, non-saline water) and II: well-water (WW, saline water). The chemical analysis of both irrigation sources is shown in table 1.

Characteristics	Well-water (saline)	Desalinized water (non-saline)
EC ($dS \cdot m^{-1}$)	4.07	0.54
pH	7.6	7.2
Ca^{++} (meq l^{-1})	13.3	0.74
Mg^{++} (meq l^{-1})	10.6	0.16
Na^{+} (meq l^{-1})	14.55	3.6
K^{+} (meq l^{-1})	0.58	0.1
HCO_3^{---} (meq l^{-1})	4.4	0.323
Cl^{-} (meq l^{-1})	12.6	1.84
No_3^{-} (ppm)	7.5	2.68
SO_4^{-}(meq l^{-1})	14.59	0.9

Table 1: Chemical analysis of the two irrigation water sources used.

Plant material and growth conditions

Antirrhinum majus L. was grown in a greenhouse at the Experimental Station of Floriculture and Ornamental plants landscape Grading Department, College of Agriculture, Alexandria University, Alex. A.R.E, during 2018/2019 and 2019/2020 growing seasons. The seeds were sterilized by soaking in 70% alcohol for 5 min and rinsed three times with distilled water. Then, the seeds were sown on November 17th inside plastic trays. Four-week-old seedlings, healthy and uniform in size, were transplanted into 20-cm-diameter plastic pots (one seedling per pot) containing 3.25 kg/ pot of autoclaved sandy soil. Soil chemical parameters were: pH = 7.46, EC (1.58 dS m^{-1}), available nitrogen (28.4 mg kg^{-1}), potassium (87 mg kg^{-1}), available phosphorus (8.04 mg kg^{-1}) and organic matter content (0.29%). One week after transplanting, plants were carefully watered as needed with tap water to maintain soil moisture near field capacity (67 - 74% v/w) to develop root growth. Then, plants were subjected to four well-water treatments as described previously. Greenhouse temperature was maintained at 18 ± 2°C day/ night, relative humidity at 65 - 75%, and photoperiod averaged 14 h day^{-1} throughout growth stages.

Experimental layout

The experimental layout selected was split-plot, using a randomized complete block design (RCBD). Five irrigation treatments were randomly allocated to the main plots, while two AMF treatments were arranged in the sub-plots, with three replications each. Each plot contained six pots in each replicate, for a total of 270 pots.

Inoculation of mycorrhizal fungus

At transplanting, the mycorrhizal fungus was added to the soil. Soil structure was 82.6% sand, 9.0% silt, and 8.4% clay. The mycorrhizal fungi inoculum involved soil, hyphae, spores, and infected root fragments of Sudan-grass plants (*Sorghum halepense* L.) from a stock culture of *Glomus mosseae*. The mycorrhizal soil injection followed the method of [15].

Mixed irrigation treatments

Mixed irrigation was done using a mixed water management strategy. Five irrigation treatments were applied as follows: irrigation with 100% DW for the whole growth period, i.e., control treatment (T1, EC 0.5 dS m^{-1}); irrigation with 75% DW + 25% WW (T2, EC 1 dS m^{-1}); irrigation with 50% DW + 50% WW (T3, EC 2 dS m^{-1}); irrigation with DW 25% + WW 75% (T4, EC 3 dS m^{-1}); and irrigation with 100% WW for the whole growth period (T5, EC 4 dS m^{-1}). The irrigation treatments were applied three times per week with the same amount of water for each treatment applied.

Data collection

Snapdragon plants were grown until their flowers matured, and then the plants were harvested. At harvest, the plant height, diameter, and root length were measured using scale with tape and Vernier caliper (mm). Leaf number per plant was counted. Leaf area was measured using a leaf area meter (LI-Cor, Lincoln, NE, USA). The number of branches, number of spikes, flowers per plant, and inflorescence length were also recorded. Flowering date (days from seed sowing), and flower fresh and dry weights in each treatment were determined. Fresh and dry weights of shoots and roots were also recorded. Dry weights were recorded after fresh shoots and roots were oven-dried at 70ºC for 48h until the weight became constant.

Chemical composition

Chlorophyll content

Chlorophyll content (a, b and total chl.) were determined in the sample solution using the method of [16].

Proline content

Proline was extracted by the method of [17]. Leaf samples (0.1g) were homogenized in 10 ml of 3% aqueous sulfosalicylic acid and the homogenate was filtered through filter paper. Two of the filtered extract was reacted with 2 ml acid ninhydrin and 2 ml of glacial acetic acid in a test tube for 1h at 100°C, and the reaction was terminated by placing the reaction mixture on ice. The reaction mixture was extracted with 4 ml toluene and vortexed. The chromophore containing toluene was aspirated from the aqueous phase and warmed to room temperature 24 ± 2°C and the absorbance was read by a spectrophotometer (Shimadzu, UV-160, Kyoto, Japan) at 520 nm using toluene as the blank. Proline concentration was determined against a standard curve with L-proline (Sigma-Aldrich Chemie, Steinheim, Germany).

Mineral content

Leaf samples from the three randomly selected plants (fifth leaf from the apex) were detached, washed, dried to a constant mass, ashed at 550°C, acid extracted, and then the extract volume was made constant [18]. All chemical elements were determined in the sample solution. Phosphorus (P) content was determined by the vanadate-molybdate method [19]. Sodium (Na) and Potassium (K) content was determined using a flame photometer (Corning 400, UK). Calcium (Ca) content was determined using atomic absorption (PerkinElmer, Model 2380, USA) according to the method described by [20].

Statistical analysis

The collected data were statistically analyzed using Statistical Analysis System (SAS version 9.1, Institute, NC, USA) software. Differences among means were tested using a revised least significant difference (LSD) test at 0.05 levels according to a method described by [21].

Results

Interaction effects between mixed irrigation treatments and AMF inoculation

Vegetative growth

Interaction effects between mixing of irrigation water and AMF inoculation treatments both AMF and salinity level in the substrate affected snapdragon growth characteristics (Table 2 and 3). Plant height, number of branch, stem diameter, number of leaf, leaf area, shoot fresh and dry weights, and root fresh and dry weights of both mycorrhizal (AMF) and non-mycorrhizal (non-AMF) snapdragon plants grown under saline water conditions were significantly lower than those of plants grown under non-saline water conditions. However, the decreases in most growth characteristics were more distinct in non-mycorrhizal than in mycorrhizal Antirrhinum plants.

Irrigation treatment	Mycorrhizal	Plant height (cm)		No. of branches/ plant		Stem diameter/ plant (mm)		No. of leaf/plant		Leaf area/plant (cm^2)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1 (100% DW)	-AMF	43.37c	42.53f	2.96de	3.07de	3.53bc	3.46c	60.71bc	57.01a	188.26b	193.25c
	+AMF	49.93bc	51.27bcd	6.01a	6.73a	4.69a	4.89a	86.01a	88.67a	291.98ab	305.31a
T2 (25% WW and 75% DW)	-AMF	43.01c	42.13f	4.67abc	4.83b	4.35a	4.19b	54.68cd	53.32a	236.70ab	230.37b
	+AMF	59.03a	61.77a	4.33bcd	5.03b	4.32a	4.46ab	73.67ab	76.33a	286.21ab	296.20a
T3 (50% WW and 50% DW)	-AMF	49.80bc	48.77cde	2.65e	2.71e	4.13ab	4.02b	54.58cd	53.31a	196.57b	203.24bc
	+AMF	60.71a	62.67a	6.03a	6.76a	4.55a	4.75a	77.69a	79.66a	341.51a	349.84a
T4 (75% WW and 25% DW)	-AMF	46.91bc	45.90def	3.36cde	3.73cd	3.54bc	3.43c	44.28de	45.02a	243.02ab	231.69b
	+AMF	52.90b	54.93bc	5.33ab	6.03a	4.23a	4.16b	62.59bc	62.30a	321.34ab	324.01a
T5 (100% WW)	-AMF	44.67c	43.31ef	2.04e	1.77f	2.54d	2.34d	34.66e	35.67a	210.83ab	206.50b
	+AMF	50.47bc	51.43bc	3.29cde	4.03c	3.34c	3.39c	60.31bc	60.35a	320.84ab	337.51a

Table 2: Influence of mixing irrigation water and mycorrhizal treatments on vegetative growth of snapdragon plants.

Values in each column followed by the different letter(s) are significantly different at $P \leq 0.05$.

* Desalinized water (DW); well-water (WW).

** -AMF: Without mycorrhizal inoculation, +AMF: With mycorrhizal inoculation.

Irrigation treatment	Mycorrhizal	Shoot fresh weight per plant (g)		Shoot dry weight per plant (g)		Root length per plant (cm)		Root fresh weight per plant (g)		Root dry weight Per plant (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1 (100% DW)	-AMF	10.98d	11.27e	2.10c	2.20c	37.57a	38.23a	5.13a-d	5.47a	1.11bc	1.17b-e
	+AMF	16.09a	16.49b	3.03ab	3.16a	38.01a	39.67a	7.35a	6.91a	1.97a	2.03a
T2 (25% WW and 75% DW)	-AMF	17.19a	16.46b	3.07ab	3.12a	43.83a	43.17a	6.05abc	5.39a	1.49ab	1.36bcd
	+AMF	15.42abc	15.85bc	3.01ab	3.08a	33.90a	34.91a	4.40bcd	4.72a	1.15bc	1.22b-e
T3 (50% WW and 50% DW)	-AMF	13.18bcd	12.45de	2.09c	2.17c	40.77a	39.80a	6.12abc	6.22a	1.51ab	1.46bc
	+AMF	17.22a	17.89ab	3.06ab	3.18a	45.56a	45.89a	4.22bcd	4.91a	0.96bc	1.06cde
T4 (75% WW and 25% DW)	-AMF	15.29abc	14.26cd	2.59bc	2.45bc	38.23a	37.90a	6.54ab	6.45a	1.84a	1.67ab
	+AMF	17.80a	18.83a	3.37a	3.21a	43.30a	44.37a	3.89cd	4.46a	0.86c	0.94de
T5 (100% WW)	-AMF	12.45cd	12.38de	2.07c	2.02c	30.30a	29.61a	3.32d	3.02a	0.82c	0.79e
	+AMF	16.87a	16.87ab	2.78abc	2.96ab	40.02a	41.65a	3.58cd	4.08a	0.91c	0.97cde

Table 3: Influence of mixing irrigation water and mycorrhizal treatments on vegetative growth of snapdragon plants.

Values in each column followed by the different letter(s) are significantly different at $P \leq 0.05$.

* Desalinized water (DW); well-water (WW).

** -AMF: Without mycorrhizal inoculation, +AMF: With mycorrhizal inoculation.

In both seasons, the results obtained indicate that T3 +AMF treatment (50% WW and 50% DW) considerably affect plant height and branch number per plant (60.71 and 62.67 cm and 6.03 and 6.67, respectively).

Under T1 treatment (100% DW at +AMF), stem diameter per plant was significantly high in both seasons (4.69 and 4.89 mm). The maximum average leaf number per plant was observed in a few numbers of plants under 100% DW at +AMF treatment (86.01) for the 1st season; however, this number was insignificant in the 2nd season. The minimum average leaf number per plant was observed under T5 (100% WW at -AMF treatment) (34.66 for the 1st season). The interactions between salinity level and +AMF had significant effects on the mean values of leaf area per plant in both seasons. The largest leaf area per plant was observed under T3 (50% WW and 50% DW at +AMF treatment), while the smallest leaf area per plant was recorded under T1 (100% DW at -AMF treatment) (Table 2).

The interactions between irrigation water level and +AMF did show significant differences in the mean values of plant fresh and dry weights during the two seasons (Table 3). Regarding the interaction effect in both seasons, the highest plant fresh and dry weights were recorded under T4 (75% WW and 25% DW at +AMF treatment) (17.80 and 18.83g, 1st season and 3.37 and 3.21g, 2nd season, respectively), whereas the lowest plant fresh and dry weights (12.45 and 12.38g, 1st season and 2.07 and 2.02g, 2nd season, respectively), were detected at under T5 (100% WW at -AMF treatment).

The interactions between the level of irrigation water and +AMF did not show any significant differences in the mean values of root length in both seasons (Table 3).

In the 1st season, significant effects were observed only on the weight per plant. At the same time, mixed irrigation water and AMF treatments had significant effects on root dry weight/plant in both seasons (Table 3). The root fresh and dry weights per plant were 7.35g and 1.97 and 2.03g, respectively, due to the lowest irrigation level T1 (100% DW at +AMF treatment) and were 3.32g and 0.82 and 0.79g, respectively, due to T5 (100% WW at -AMF treatment).

Inflorescences characters

In general, the flower yield (flowering date, spike number, and spike length) of mycorrhizal snapdragon plants was significantly higher than that of non-mycorrhizal plants grown using saline water (Table 4). Differences in flower yield parameters were more pronounced in non-mycorrhizal than in mycorrhizal plants grown using well water. The inflorescence number and fresh weight per plant were not affected by either the saline water level or presence of mycorrhizal fungi. AMF plants had higher spike number and length than non-AMF plants regardless of the type of water treatment. The interaction effect of T5 (100% WW at -AMF treatment) delayed flowering in snapdragon plants in both 1st and 2nd seasons by 87.11 and 88.30 days, respectively.

In the 1st and 2nd seasons, medium treatment of T3 (50% WW and 50% DW at +AMF treatment) appeared to result in a higher number of inflorescence (8.83 and 9.50, respectively) and increase in spike length/plant (11.70 and 13.03 cm, respectively).

The differences in weight were not significant between non-AMF plants with saline water treatment and +AMF plants treated with non-saline water. In the 1st season, significant effects were observed only on the inflorescence dry weight per plant (Table 4). The mycorrhizal dependency values (inflorescence dry weight per plant) of snapdragon plants in response to AMF inoculation were significantly higher under saline water conditions than those under non-saline water conditions. A low irrigation level T2 (25% WW and 75% DW at +AMF treatment) appeared to result in a higher weight inflorescences dry weight per plant (1.39g).

Chemical content

Chlorophyll contents

Well-water significantly decreased the Chlorophyll (Chl) a and b contents in leaves of snapdragon mycorrhizal and non-mycorrhizal plants (Figure 1). The total Chl content in leaves of AMF plants was significantly higher than that in leaves of non-AMF plants, irrespective of the type of water treatment. Significant differences were observed in Chl a/Chl b ratios between mycorrhizal and non-mycorrhizal plants under well-water conditions. However, there were no constant trends in these ratios between the mycorrhizal and non-mycorrhizal plants grown under four different well-water treatments. AMF significantly enhanced the chlorophyll concentration in plants grown under saline conditions and those grown under non-saline conditions.

Proline content

The proline content in mycorrhizal and non-mycorrhizal Antirrhinums leaves was increased by increasing the WW level (Figure

Irrigation treatment	Mycorrhizal	Flowering date (days)		inflorescences number/plant		Spike number/ plant		Spike length/ plant (cm)		inflorescences fresh weight/ plant (g)		inflorescences dry weight/ plant (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1 (100% DW)	-AMF	79.05b	79.65c	3.01a	3.13a	4.67c	5.37c	7.45cde	7.82de	4.44a	4.31a	0.89bc	0.93a
	+AMF	62.33e	63.64h	3.33a	3.67a	5.45bc	5.78bc	9.15b-e	9.45cd	4.47a	4.83a	0.88c	0.92a
T2 (25% WW and 75% DW)	-AMF	79.07b	78.31cd	3.02a	2.97a	4.09c	4.47c	7.03de	6.63e	5.39a	5.09a	0.95abc	0.98a
	+AMF	68.01d	69.01g	2.31a	2.50a	6.76abc	7.63ab	10.43abc	11.10abc	6.63a	7.01a	1.39a	1.44a
T3 (50% WW and 50% DW)	-AMF	79.68b	78.67cd	2.67a	2.17a	8.33ab	9.01a	9.65a-d	9.33cd	5.83a	5.48a	1.09abc	1.06a
	+AMF	70.04cd	71.03fg	2.29a	3.16a	8.83a	9.50a	11.70a	13.03a	6.40a	7.07a	1.27abc	1.35a
T4 (75% WW and 25% DW)	-AMF	82.63b	84.33b	2.33a	2.10a	4.34c	4.97c	7.48cde	8.42de	7.86a	7.52a	1.37ab	1.43a
	+AMF	71.66cd	73.35ef	1.65a	2.27a	8.67a	9.21a	11.59ab	12.06ab	6.99a	7.39a	1.32abc	1.37a
T5 (100% WW)	-AMF	87.11a	88.30a	1.67a	1.32a	5.51bc	5.23c	6.43e	5.07e	6.01a	5.87a	1.05abc	0.99a
	+AMF	74.05c	76.00de	2.30a	2.26a	6.78abc	8.07a	9.62a-d	10.02bcd	6.64a	6.31a	1.31abc	1.38a

Table 4: Influence of mixing irrigation water and mycorrhizal treatments on flowering of snapdragon plants.
Values in each column followed by the different letter(s) are significantly different at P ≤ 0.05.
* Desalinized water (DW); well-water (WW).
** -AMF: Without mycorrhizal inoculation, +AMF: With mycorrhizal inoculation.

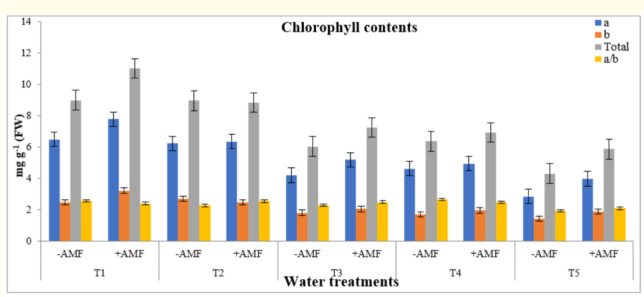

Figure 1: The leaf chlorophyll (Chl) contents of mycorrhizal (AMF) and non-mycorrhizal (non-AMF) Snapdragon plants grown under either well-watered (WW) or desalinized water (DW) conditions. T1, T2, T3, T4 and T5 are WW treatments at 100% DW, (25% WW and 75% DW), (50% WW and 50% DW), (75% WW and 25% DW), and 100% WW soil water content, respectively.

2A). The proline content in leaves was increased by increasing the level of well-water used. The increase in proline content was related to the degree of mycorrhizal infection. However, +AMF plants had relatively lower proline content than non-AMF plants irrespective of the type of water treatment used, and this effect was clearly pronounced under well-water conditions.

Mineral content

Leaves of AMF snapdragon plants had higher Na, P, K, Ca, and Cl contents than those of non-AMF plants (Figure 2). However, both mycorrhizal and non-mycorrhizal WW plants had lower P and K contents than the DW plants. Reduction in the nutrient content of plants as a result of WW treatment was more pronounced in non-mycorrhizal plants as compared to mycorrhizal plants. Overall, the P concentration significantly decreased when the salinity increased. The concentration of Na increased with increasing levels of salinity. As expected, the K and P concentrations in plants exposed to saline water were decreased as compared to the control.

Discussion

Salt stress can inhibit plant growth through root-to-shoot non-hydraulic signaling mechanisms before leaf dehydration occurs [22].

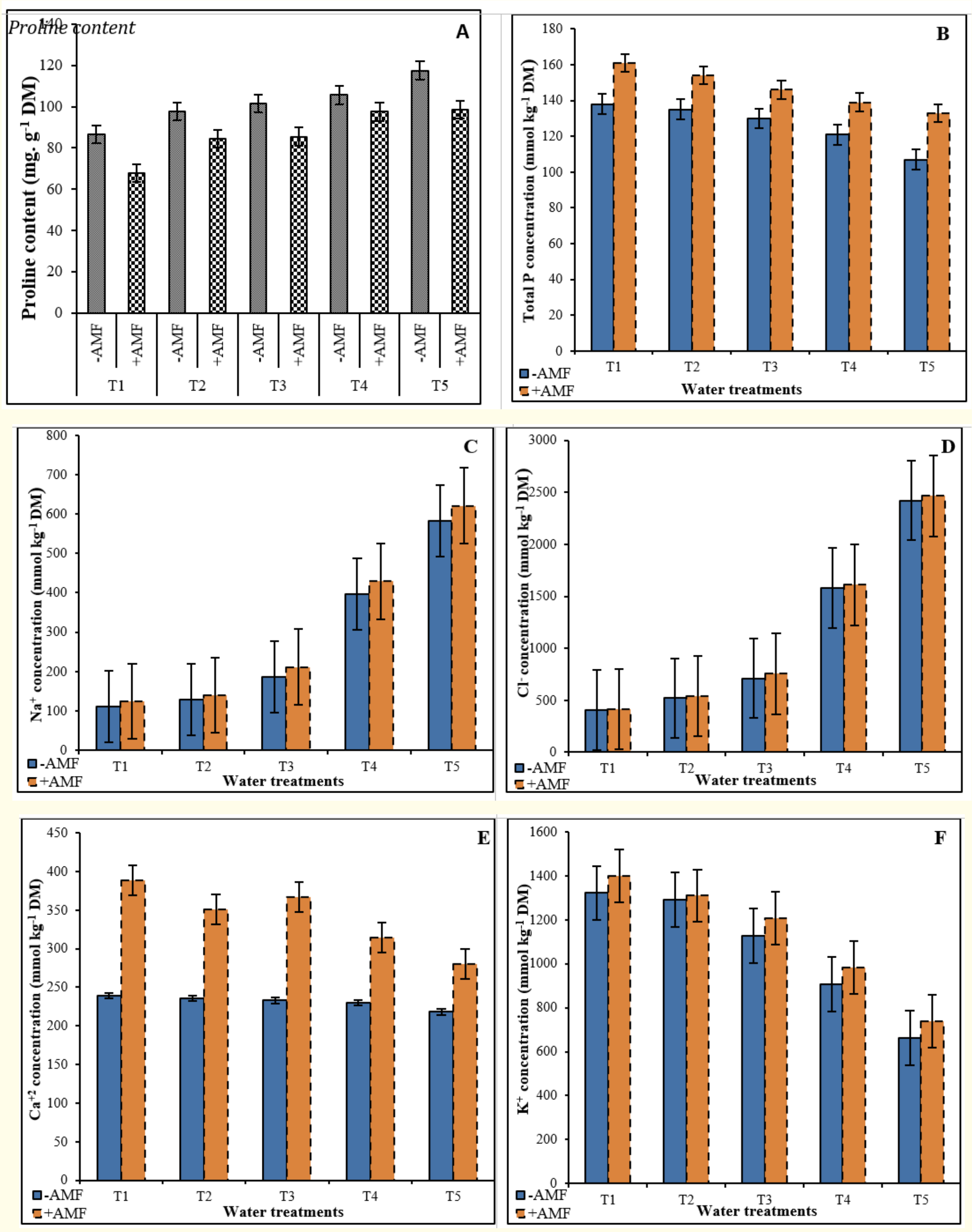

Figure 2: Proline (A) and nutrients content such as: Total P (B), Na^+ (C), Cl^- (D), Ca^{++} (E) and K^+ (F), of mycorrhizal (AMF) and non-mycorrhizal (non-AMF) snapdragon plants grown under either well-watered (WW) or desalinized water (DW) conditions. T1, T2, T3, T4 and T5 are WW treatments at 100% DW, (25% WW and 75% DW), (50% WW and 50% DW), (75% WW and 25% DW), and 100% WW soil water content, respectively.

Colonization with AMF significantly enhanced the fresh and dry weight and also increased the leaf area in salt-stressed plants. This effect of AMF on dry matter was more pronounced in aerial biomass than in root biomass. This may be caused by the greater localization of carbohydrates in the shoot than the root, due to arbuscular mycorrhizal colonization [23]. Improved growth of mycorrhizal tomato plants in saline environments has partly been attributed to mycorrhiza-mediated enhancement of P levels in host plants [24,25]. Reported that AMF promoted matter in *Cenostigma pyramidale* under saline conditions [26]. Reported that, in *Chrysanthemum morifolium*, root and shoot dry weight and root length were higher in mycorrhizal plants than in non-mycorrhizal plants under conditions of moderate salinity. In our study, arbuscular mycorrhizal inoculation enhanced the growth of snapdragon plants in the control group as well as the plants exposed to saline conditions.

Exposure to saline water caused reductions in the values of flowering parameters in both mycorrhizal and non-mycorrhizal snapdragon plants as compared to the control. Plants in T3, EC 2.2 dSm^{-1} and (50% WW + 50% DW) + AMF had greater flower yield and also had better flower number, spike number, spike length, and flower weight better than the control. These results are in agreement with what has been reported for other ornamental plants [27-29], Additionally, [15] also reported that mycorrhizal plants had a better flower yield than non-mycorrhizal plants.

Chlorophyll concentrations were significantly reduced after salinity treatments because of the suppression of specific enzymes involved in the synthesis of photosynthetic pigments [30]. The contents of Chl in the leaves of mycorrhizal and non-mycorrhizal snapdragon plants were reduced when the salinity of water was increased. In this study, all treated snapdragon plants colonized by AMF had higher Chl contents than the non-mycorrhizal plants. The data presented in figure 1 indicate that reduction in Chl content with salt stress may be due to the reduction in the K concentration [31]. The levels of these elements have usually been found to be higher in mycorrhizal plants than in non-mycorrhizal avocado plants [26,32].

Compared to the control water, saline water caused increases in proline content in both mycorrhizal and non-mycorrhizal snapdragon plants. However, snapdragon plants colonized by AM fungi had lower proline content under all treatments compared to non-mycorrhizal plants. Osmotic adjustment is considered an important component of drought-and salt stress-tolerant mechanisms in higher plants. Under saline water conditions, plants accumulate some small molecules for example organic solutes such as soluble sugars and proline [15]. It is possible that a high level of proline accumulation might play a role in drought tolerance by helping plants survive short periods of drought and recover from stress [33]. These findings indicated that AM snapdragon leaves had lower amount of proline, suggesting that AM colonization improved host plant WW tolerance, and thus the plants were under lower stress compared to non-AMF plants [34].

Enhanced growth in mycorrhizal plants is often associated with improved total P and other nutrient (Na, Cl, Ca, K) acquisition; however, the availability of P in soils is reduced by soil drying [31]. In the present study, total P concentration was significantly lower in plants under saline water conditions compared with the control non-saline water plants. Reduction in P uptake in saline soils can be attributed to precipitation of $H_2PO_4^-$ with Ca^{2+} ions in soil, and K and Ca competition with Na ions [35]. A marked effect of AMF on the uptake of P was observed even in the control plants. The improvement in plant P [36] uptake caused by AMF has been reported and is considered to play a key role in amelioration of growth in salt-affected plants colonized by AMF [37,38]. Indicated that application of AMF improve nitrogen assimilation by host plants. Improved nitrogen uptake may help in reducing the toxic effects of Na ions by adaptable its uptake and by indirectly helping to maintain the chlorophyll content of the plant [26,38,39].

Na, K, Cl, and Ca levels were significantly higher in leaves of WW mycorrhizal than those in non-mycorrhizal snapdragon plants. Plants subjected to increased salinity have shown less accumulation of K [36]. Mycorrhizal *G. mosseae* plants had a higher concentration of K at both salinity levels. Higher K levels in mycorrhizal plants in saline soil could be beneficial for maintaining a high K/Na ratio and inducing the ionic balance of the cytoplasm or Na efflux from plants [36]. Na concentration was lower in mycorrhizal than non-mycorrhizal plants regardless of the salinity level. The lack of response of Na concentration to AMF treatment may be explained by the dilution effects of plant growth improvement caused by AMF colonization [25,36]. Demonstrated that under saline conditions, AMF caused low content of leaf and root Na^+ and Cl^- in *C. pyramidale*. Previous studies have shown that the protection of mycorrhizal plants against drought stress was related to mycorrhizal-induced leaf conductance [11,15] and transpiration [31] as well as P and K uptake. K plays a key role in plant salt stress tolerance and its cationic solute is responsible for stomatal movement as a result of change in bulk leaf status [40]. In the present study, the response of AMF to protect snapdragon plants from the damaging effect of salt stress and K content in plants were positively correlated.

Conclusion

The decrease in plant growth under salinity stress is caused to the osmotic stress resulted from decreasing of parameters growth and nutrient uptake. This search showed that AMF inoculation significantly alleviated the harmful effects of salinity stress on snapdragon plants (*Antirrhinum majus* L.) grown under different soil salinity stress through enhancing growth and flower yield, and increasing elements contents. These benefits in response to the mycorrhizal inoculation are usually accelerated when the extent of the salinity stress increases in soil. These studies conclude that AMF colonization can mitigate the deleterious effects of salinity stress on growth and flower yield of snapdragon plants.

Conflict of Interest

The authors can declare that they have no conflict of interest.

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