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MYCORRHIZA AND SALSALIC ACID IMPROVING DROUGHT TOLERANCE IN CARNATION *DIANTHUS CARYOPHYLLUS*

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Abstract

An experiment was conducted in a green house at the Department of Horticulture and Gardens Engineering, College of Agriculture, University of Baghdad in Jadriya district for the period from 15-8-2017 to 15-8-2018. Plant roots were inoculated with two levels of mycorrhiza (20.0g) subjected to three irrigation intervals (2 days, 4 days, and 6 days) and salicylic acid was sprayed on the vegetative part in three concentrations (150, 100, 50.0 mg l^{-1}. The results showed that the inoculation of carnation roots with mycorrhiza reduced the effectiveness of SOD (Superoxide dismutase) leaves content of proline, which amounted to 168.2 unit mol/12.72 mg l^{-1} dry weight. The results also indicated a significant increase in the vegetative growth traits in response to salicylic acid spraying at a concentration of 50 mg l^{-1} by interacting with mycorrhiza and D2 irrigation interval, namely plant height, dry matter, flower diameter, increasing leaf content of nitrogen, phosphorus, potassium, zinc, iron and the mycorrhiza infection percentage and roots surface area that reached 94.3 cm, 62.11% 10.79, 4.69%, 0.570%, 6.143%, 87.06%, 179.26%, 77.79% and 146.4g, respectively.

Key words: *Carnation, mycorrhiza, salsalic acid, irrigation intervals, Dianthus caryophyllus.*

Introduction

Plant growth under certain stress condition like water and salinity is mainly related to the norm of roots response against such stress, which in turn will reflect on the plant growth and yield. Plant production is subjected to different types of biological and non-biological stresses represented by the water, salt, temperature, oxidation, heavy metals and toxicity (Elsahookie, 2013). Water stress is the lack of available water necessary for absorption by the plant at any stage of growth, hence the less available water, may exposed the plant to the state of drought, and therefore the water stress has begun to affect and play key role in the plant normal development. In general, water stress is not only resulted from water deficiency, several stresses like salinity, high temperature, low heat, toxic elements can interact with each other to create higher level of complicated stressful environment (Alvares, 2015).

As a result of the scientific and technical development in addition to the growing need to find sound scientific means that may rationalize the irrigation water consumption. Recently, different techniques have been introduced in rationing water use that have depleted significantly and decreased in a wide range of the glob in general and in Iraq in particular in terms of the sharp decline in the received water from both Tigris and Euphrates rivers which highly fluctuated across the successive seasons.

The using of mycorrhiza as bio-fertilizer have been suggested to minimize the harmful effects of water scarcity by establishing a symbiotic relationship with the plant root system to ensure a higher rate of nutrients uptake, furthermore improving the plant capability to cope with inappropriate growing conditions.

Mycorrhiza has become a well known fungi involving in symbiotic relationship with about 95% of plants root (Read and Smith, 2008). This fungi have a crucial role during water stress (dehydration, salinity, etc.) via hyphae that acted as an open channels supplying soil with additional sources of ventilation and moisture preservation in these soils. Thus, soil will obtain hydroscopic water, which is firmly attached to the soil grains and supplied gradually to the roots. Furthermore, such channels can also extend to several meters in search of water and nutrients (Siddiqui *et al.*, 2008).

Mycorrhiza contributes efficiently in improving the enzymatic activity of a wide range of enzymes such as SOD (Superoxide dismutase), Catalase (CAT), Peroxidase, Phosphatase and Phosphatase dehydrolase, which in part of it will make phosphorus more available for the plants (Abohatem and others, 2011, Doley and Jite, 2013).

Salicylic acid (SA) is a phenolic plant growth regulator that acts as a non-enzymatic antioxidant and co-regulates a number of physiological processes in the plant. This acid plays a crucial role in drawing plant's response to the divergent environmental stresses such as heat stress, osmotic stress and salt stress. This regulation occurred via different mechanisms like organizing the cell membrane permeability (Purcarea and Cosma-Cachita, 2010), as well as the activity of antioxidant enzymes (Ghoohistani *et al.*, 2012).

Materials and methods

The experiment was carried out in the green house at the Department of Horticulture and Gardens Engineering - College of Agriculture/ University of Baghdad in Jadiriya for the period from 15-8-2017 to 15-8-2018. Polyethylene bags (10 kg) filled bottom with gravel then completed with the growing mixture of 1:3 soil and peatmoss. The rooted plants of five nodes developmental stage were inoculated with two levels of mycorrhiza fungi (0, 20 g) named (M0 and M1), then planted and sprayed with four concentrations of salicylic acid (50, 100, 150 mg l^{-1} named SA, SA50, SA100 and SA150, respectively. Concurrently, plants were subjected

Table 1: Irrigation level (ml) and times for the 2 days irrigation interval.

	Treatment	Irrigation number	Water amount	November	December	January	February	March	April	Mays	June	July
T1	M0+SA0+2Day	15	←	340	300	250	270	350	380	390	410	450
T2	M0+SA50+2Day	15	←	300	280	230	260	330	340	360	390	420
T3	M0+SA100+2Day	15	←	320	280	240	260	330	340	360	390	420
T4	M0+SA150+2Day	15	←	320	300	240	270	340	370	380	400	440
T13	M1+SA0+2Day	15	←	310	290	220	250	310	360	360	380	430
T14	M1+SA50+2Day	15	←	290	270	200	230	290	320	340	360	400
T15	M1+SA100+2Day	15	←	290	270	200	240	290	330	340	370	410
T16	M1+SA150+2Day	15	←	310	290	220	250	310	360	360	390	430

Table 2: Irrigation level (ml) and times for the 4 days irrigation interval.

	Treatment	Irrigation number	Water amount	November	December	January	February	March	April	Mays	June	July
T5	M0+SA0+4Day	7	←	400	360	340	320	380	420	460	490	570
T6	M0+SA50+4Day	7	←	380	330	310	300	360	390	420	440	540
T7	M0+SA100+4Day	7	←	380	330	320	300	370	390	420	450	550
T8	M0+SA150+4Day	7	←	400	340	340	310	380	410	460	470	570
T17	M1+SA0+4Day	7	←	330	280	260	300	350	390	430	470	550
T18	M1+SA50+4Day	7	←	290	240	220	260	310	340	390	440	510
T19	M1+SA100+4Day	7	←	300	240	230	270	310	350	390	450	520
T20	M1+SA150+4Day	7	←	320	270	250	300	340	380	420	470	540

Table 3: Irrigation level (ml) and times for the 6 days irrigation interval.

	Treatment	Irrigation number	Water amount	November	December	January	February	March	April	Mays	June	July
T9	M0+SA0+6Day	5	←	500	490	440	490	510	540	590	640	700
T10	M0+SA50+6Day	5	←	460	440	410	450	480	500	540	600	640
T11	M0+SA100+6Day	5	←	460	440	420	460	480	510	540	610	640
T12	M0+SA150+6Day	5	←	490	480	440	480	500	540	570	630	690
T21	M1+SA0+6Day	5	←	470	460	400	440	470	500	540	600	670
T22	M1+SA50+6Day	5	←	440	430	360	400	450	450	510	550	630
T23	M1+SA100+6Day	5	←	450	430	370	410	450	460	510	560	640
T24	M1+SA150+6Day	5	←	470	450	390	440	470	490	530	580	670

Table 4: Effect of mycorrhiza, irrigation interval and salicylic acid (SA) in the SOD.

MXD	Salicylic acid SA				intervals Irrigation(D)day	Mycorrhiza M
D	**SA-150**	**SA-100**	**SA-50**	**SA0**	**Day**	
189.2	180.3	174.7	165.3	236.7	D2	M0
292.8	287.0	285.0	273.3	326.0	D4	
332.2	310.7	294.0	251.3	472.7	D6	
119.2	117.3	115.7	96.3	147.7	D2	M1
183.2	201.7	163.7	158.0	209.3	D4	
202.2	197.3	189.0	112.0	310.3	D6	
12.9	25.7				LSD	
	215.7	203.7	176.1	283.8	Salicylic averages	
	10.5				LSD	
Salicylic X Mycorrhiza						
Average Mycorrhiza	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
271.4	259.3	251.2	230.0	345.1	M0	
168.2	172.1	156.1	122.1	222.4	M1	
7.4	14.9				LSD	
Salicylic X intervals irrigation						
Average intervals Irrigation	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
154.2	148.8	145.2	130.8	192.2	D2	
238.0	244.3	224.3	215.7	267.7	D4	
267.2	254.0	241.5	181.7	391.5	D6	
9.1	18.2				LSD	

Table 5: Effect of mycorrhiza, irrigation interval and salicylic acid (SA) in the leaves content of proline (mg g^{-1} dry weight) in *Dianthus caryyophyllus*.

MXD	Salicylic acid SA				intervals Irrigation(D)day	Mycorrhiza M
D	**SA-150**	**SA-100**	**SA-50**	**SA0**	**Day**	
8.68	11.32	7.11	6.50	9.79	D2	M0
10.31	10.73	10.08	6.68	13.77	D4	
34.15	34.80	33.26	29.31	39.25	D6	
4.28	6.49	6.54	2.09	6.00	D2	M1
5.02	4.88	6.04	2.72	9.46	D4	
28.88	31.19	29.03	25.74	29.55	D6	
1.17	2.34				LSD	
	16.57	14.18	12.17	17.97	Average Salicylic acid	
	0.96				LSD	
Salicylic acid X Mycorrhiza						
Average Mycorrhiza	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
17.72	18.95	16.82	14.16	20.94	M0	
12.73	14.19	11.54	10.18	15.00	M1	
0.68	1.35	LSD				
Salicylic acid X Irrigation intervals						
Average intervals Irrigation	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
6.48	8.91	4.83	4.30	7.89	D2	
7.67	7.80	6.56	4.70	11.61	D4	
31.51	32.99	31.14	27.52	34.40	D6	
0.83	1.66	LSD				

to three irrigation intervals (D2 irrigation after 2 days, D4 irrigation after four days, D6 irrigation after six days, respectively). The field experiment was carried out according to the RCBD design with three replicates for

Table 6: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the leaves dry matter (%) in *Dianthus caryyophyllus*.

MXD	Salicylic acid SA				intervals Irriga-tion(D)day	Mycor-rhiza M
D	**SA-150**	**SA-100**	**SA-50**	**SA0**	**Day**	
13.90	11.61	14.71	16.18	13.11	D2	M0
12.20	8.83	13.66	16.00	10.31	D4	
5.53	6.24	5.39	6.06	4.45	D6	
20.44	18.39	20.39	26.11	16.87	D2	M1
15.09	10.42	11.25	25.85	12.84	D4	
6.64	6.50	6.80	7.57	5.71	D6	
0.97	1.95				LSD	
	10.33	12.03	16.30	10.55	Average salicylic acid	
	0.80				LSD	
salicylic acid X Mycorrhiza						
Average Mycorrhiza	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
10.55	8.89	11.25	12.75	9.29	M0	
14.06	11.77	12.82	19.84	11.80	M1	
0.56	1.13	LSD				
salicylic acid X Irrigation intervals						
Average Irriga-tion intervals	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
17.17	15.00	17.55	21.15	14.99	D2	
13.64	9.63	12.45	20.93	11.57	D4	
6.09	6.37	6.10	6.81	5.08	D6	
0.69	1.38	LSD				

Table 7: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the nitrogen content (%) in *Dianthus caryyophyllus*.

MXD	Salicylic acid SA				intervals Irriga-tion(D)day	Mycor-rhiza M
D	**SA-150**	**SA-100**	**SA-50**	**SA0**	**Day**	
2.98	2.45	3.23	3.41	2.84	D2	M0
2.59	2.09	2.90	3.18	2.19	D4	
1.48	1.07	1.71	1.90	1.22	D6	
3.92	3.36	4.09	4.69	3.53	D2	M1
3.80	3.00	4.43	4.63	3.13	D4	
2.15	1.90	2.33	2.37	1.99	D6	
0.15	0.29				LSD	
	2.31	3.12	3.36	2.49	Average salicylic acid	
	0.12				LSD	
salicylic acid X Mycorrhiza						
Average Mycorrhiza	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
2.35	1.87	2.61	2.83	2.09	M0	
3.29	2.75	3.62	3.90	2.88	M1	
0.08	0.17				LSD	
salicylic acid X irrigation interval						
Average irriga-tion interval	**SA-150**	**SA-100**	**SA-50**	**SA 0**		
3.45	2.91	3.66	4.05	3.19	D2	
3.20	2.55	3.67	3.91	2.66	D4	
1.81	1.49	2.02	2.13	1.60	D6	
0.10	0.21				LSD	

the three studied factors, respectively. Least significance differences of 0.05 was adopted to compare between the treatments means.

Study Indicators:

Leaves content of proline: Proline is estimated according to Bates et al. (1973). SOD (Superoxide dismutase) activity was estimated following Nitrotetrazolium (NBT) and riboflavin method (yang *et al.,* 2006). Leaves dry matter (%): The percentage of dry matter was calculated for the vegetative part in each experimental unit. Ten grams of fresh leaves weight was sampled and dried in the oven at 70°C till it reached the constant weight, then weighted with sensitive balance to find out the percentage of dry matter as follows; dry weight / fresh weight × 100. Flower diameter (cm): Nine flowers were randomly taken in the full bloom phase and the maximum width between two petals of each flower was adopted to estimate this trait. Length of flower stem (cm): represented by the total plant height from the soil surface to the highest peak of the four plant branches (Abdali, 2002). Nitrogen (%): The percentage of nitrogen content was estimated according to Micro-Kejldahl method (Jones, 1970). Phosphorus (%): The leaves content of phosphorus at the beginning of flowering stage was estimated by adding ascorbic acid and ammonium sulphides, then estimated by Spectrophotometer (Olsen and Sommers, 1982). Potassium (%): The leaves content of potassium was estimated with aid of Flame photometer at 766 nm. Zinc (%) and Iron (%): Spectrophoto Atomic Absorption was used to estimate the percentage of Zinc and Iron elements. Root infection percentage (%): The percentage of root infection with mycorrhiza was estimated at the end of the experiment in the Labs of the Agricultural Researches Board-Ministry of Science and Technology. Three plants were randomly selected to cut their roots and the round soil was taken too to estimate the infection percentage according to Kormanik *et al.,* (1982).

Results and discussion

SOD activity (u ml^{-1}): The results listed in table 4 clearly indicated the significant effect of mycorrhiza fungi in decreasing the SOD activity to reach 168.2 (unit ml^{-1}), whereas, D2 interval has a decreased SOD activity which was about 154.2 unit ml^{-1}.

For SA levels, the enzymatic activity was significantly increased against the control treatment reached 283.8 u ml^{-1} (Table 4). Meanwhile, the same table showed a significant effect of interaction between the mycorrhizal inoculation and irrigation intervals revealing a significant decrease in SOD activity in the treatment of M1D2 (mycorrhiza and 2 days interval), while the enzyme activity decreased in the M1D2 treatment scored 122.1 u ml^{-1}. At the same time, the results confirmed the interaction of irrigation interval and salsalic acid. The treatment of the D6SA0 has an increased enzymatic activity up to 391.5 u ml^{-1}. The three studied factors interacted significantly in both directions, increasing and decreasing the SOD activity that reached 472.7 u ml^{-1} for M0D6SA0 treatment and 96.3 u ml^{-1} for M1D2SA50 treatment.

Proline content (mg g^{-1} dry weight): The mycorrhiza had the ability to reduce the leaves content of proline in M1 treatment (12.72 mg g^{-1} dry weight). For the irrigation intervals, D2 interval had the lowest leaves content of proline (6.48 mg g^{-1} dry weight). As for the SA levels, leaves content of proline showed a significant reduction to be 12.17 mg g^{-1} dry weight at the concentration of 50 mg l^{-1}. The interaction between the mycorrhiza and irrigation intervals resulted in a significant decrease in the leaves content of proline reaching 4.28 mg kg^{-1} dry weight in M1D2 treatment. SA and irrigation intervals significantly affected the leaves content of proline that reduced in the D2SA50 treatment to be 4.30 mg g^{-1} dry weight. Both, M1D2SA50 and M1D4SA50 treatments had a reduced content of proline (2.09 and 2.27 mg g^{-1} dry weight, respectively), on the other hand proline content was increased in M0D6SA0 treatment to be 39.25 mg g^{-1} dry weight.

Leaves dry matter (%): Mycorrhiza resulted in a significantly higher percentage of leaves dry matter (14.60%). Table 6 cleared that the D2 interval achieved the maximum mean (17.17%) which was significantly higher than the rest of the treatments that D6 scored its minimal vale (9.06%). Also, salicylic acid levels, particularly 50 mg l^{-1} affected significantly trait mean (1630%). The interaction between mycorrhiza and the irrigation intervals showed significant effects as M1D2 was superior (20.44%). D2SA50 and D4SA50 treatments were significantly different compared with other treatments scoring 21.15% and 20.93%, respectively. D6SA0 treatment revealed the lowest percentage of leaves dry matter (5.08%). Although, M1D2SA50 and M1D4SA50 had no significant difference against each other in context leaves dry matter, both were significantly higher than the other treatments with 26.11% and 25.28%.

Nitrogen: The results of table (6) showed that the mycorrhizal treatment of M1 was significantly higher than other biofertilizer treatments (3.29%). Salicylic acid (SA) treatment of 50 mg l^{-1} was in the lead achieving the highest mean of nitrogen content (3.36%). M1D2 and M1D4 were in significantly higher interaction means between mycorrhiza fungi and irrigation intervals (3.92% and 3.80%, respectively). From the same table, SA found to interact significantly with the irrigation intervals especially D2SA50 and D4SA50 treatments, which were significantly higher than the other treatments by reaching 4.05% and 3.91%, respectively. The triple interaction indicated that M1D2SA50 and M1D4SA50 treatments increased the nitrogen content up to 4.69% and 4.63%.

Table 9: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the potassium content (%) in *Dianthus caryyophyllus*.

MXD	Salicylic acid SA				intervals Irriga-tion(D)day	Mycor-rhiza M
D	SA-150	SA-100	SA-50	SA0	Day	
3.279	2.857	3.157	4.440	2.663	D2	M0
2.690	1.837	2.357	4.300	2.267	D4	
1.673	1.430	1.900	2.253	1.110	D6	
5.060	4.253	5.310	6.143	4.533	D2	M1
4.589	3.970	4.013	6.103	4.270	D4	
2.926	2.350	3.153	3.633	2.567	D6	
0.286	0.572				LSD	
	2.783	3.315	4.479	2.902	Average salicylic acid	
	0.234				LSD	
salicylic acid X Mycorrhiza						
Average Mycorrhiza	SA-150	SA-100	SA-50	SA 0		
2.548	2.041	2.471	3.664	2.013	M0	
4.192	3.524	4.159	5.293	3.790	M1	
0.165	0.330				LSD	
salicylic acid X irrigation interval						
Average irriga-tion interval	SA-150	SA-100	SA-50	SA 0		
4.170	3.555	4.233	5.292	3.598	D2	
3.640	2.903	3.185	5.202	3.268	D4	
2.300	1.890	2.527	2.943	1.838	D6	
0.202	0.405				LSD	

Table 8: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the phosphorus content (%) in *Dianthus caryyophyllus*.

MXD	Salicylic acid SA				intervals Irriga-tion(D)day	Mycor-rhiza M
D	SA-150	SA-100	SA-50	SA0	Day	
0.318	0.293	0.323	0.360	0.293	D2	M0
0.291	0.267	0.293	0.320	0.283	D4	
0.203	0.187	0.210	0.220	0.193	D6	
0.436	0.333	0.497	0.570	0.343	D2	M1
0.413	0.293	0.473	0.560	0.323	D4	
0.226	0.207	0.230	0.243	0.223	D6	
0.014	0.028				LSD	
	0.263	0.338	0.379	0.277	Average salicylic acid	
	0.011				LSD	
salicylic acid X Mycorrhiza						
Average Mycorrhiza	SA-150	SA-100	SA-50	SA 0		
0.270	0.249	0.276	0.300	0.257	M0	
0.358	0.278	0.400	0.458	0.297	M1	
0.008	0.016				LSD	
salicylic acid X irrigation interval						
Average irriga-tion interval	SA-150	SA-100	SA-50	SA 0		
0.377	0.313	0.410	0.465	0.318	D2	
0.352	0.280	0.383	0.440	0.303	D4	
0.214	0.197	0.220	0.232	0.208	D6	
0.010	0.020				LSD	

Phosphorus (%): The results presented in table 7 showed that the percentage of phosphorus was significantly increased by 0.358% in response to the mycorrhizal biofertilizer compared to 0.270% in the control. In addition, D2 treatment has significantly higher phosphorus content than the other irrigation interval

Table 11: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the flower diameter (cm) in *Dianthus caryyophyllus.*

MXD	Salicylic acid SA				intervals Irriga-tion(D)day	Mycor-rhiza M
D	SA-150	SA-100	SA-50	SA0	Day	
6.53	6.17	6.72	6.93	6.28	D2	M0
5.99	5.45	6.15	6.80	5.55	D4	
4.37	4.24	4.38	4.86	4.00	D6	
8.29	7.08	7.62	10.79	7.67	D2	M1
8.09	7.29	7.48	10.76	6.83	D4	
6.01	5.96	5.94	6.35	5.78	D6	
0.25	0.51				LSD	
	6.03	6.38	7.75	6.02	Average salicylic acid	
	0.21				LSD	
	salicylic acid X Mycorrhiza					
Average Mycorrhiza	SA-150	SA-100	SA-50	SA 0		
5.63	5.29	5.75	6.20	5.28	M0	
7.46	6.78	7.01	9.30	6.76	M1	
0.15	0.29				LSD	
	salicylic acid X irrigation interval					
Average irriga-tion interval	SA-150	SA-100	SA-50	SA 0		
7.41	6.63	7.17	8.86	6.98	D2	
7.04	6.37	6.82	8.78	6.19	D4	
5.19	5.10	5.16	5.61	4.89	D6	
0.18	0.36				LSD	

Table 10: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the zinc content (%) in *Dianthus caryyophyllus.*

MXD	Salicylic acid SA				intervals Irriga-tion(D)day	Mycor-rhiza M
D	SA-150	SA-100	SA-50	SA0	Day	
49.78	39.51	53.76	62.41	43.43	D2	M0
44.39	33.03	49.59	58.18	36.76	D4	
24.50	21.41	26.09	28.58	21.91	D6	
68.98	54.07	73.12	87.06	61.67	D2	M1
63.98	46.20	71.39	85.36	52.99	D4	
33.23	27.39	35.83	38.67	31.03	D6	
1.76	3.53				LSD	
	36.94	51.63	60.04	41.30	Average salicylic acid	
	1.44				LSD	
	salicylic acid X Mycorrhiza					
Average Mycorrhiza	SA-150	SA-100	SA-50	SA 0		
39.56	31.32	43.15	49.72	34.03	M0	
55.40	42.56	60.11	70.37	48.56	M1	
1.02	2.04				LSD	
	salicylic acid X irrigation interval					
Average irriga-tion interval	SA-150	SA-100	SA-50	SA 0		
59.38	46.79	63.44	74.74	52.55	D2	
54.19	39.61	60.49	71.77	44.87	D4	
28.86	24.40	30.96	33.62	26.47	D6	
1.25	2.49				LSD	

treatments being 0.270%. Using of salicylic acid at a concentration of 50 mg l^{-1}, phosphorus percentage reached a significant level (0.379%). Data of table 7 indicated a significant increase in the phosphorus percentage in response to the interacted effect of mycorrhiza and D2 irrigation interval (M1D2), hence the leaves content of phosphorus was 0.436%. From the same table, it can be noticed that the higher interaction between the irrigation interval and salicylic acid (0.465%) was recorded by D2SA50 followed by D4SA50 treatment (0.440%). The three practiced factors interact in a significant way when M1D2SA50 and M1D4SA50 achieved the highest values (0.570% and 0.560%, respectively).

Potassium (%): Results of the statistical analysis presented in table 8 showed that the mycorrhizal fungi (M1) was beyond the significant level with 4.192% potassium content. Furthermore, the second irrigation interval (D2) was significantly higher than the other intervals scoring 4.170% for potassium content. Salicylic acid had a clear effect in the percentage of potassium especially the concentration of 50 mg l^{-1} 4.479%. The interaction between the M1 mycorrhizal treatment and the D2 irrigation interval increased the percentage of potassium in a significant way reaching 5.060% followed by D4SA50 treatment with 4.589% potassium content. Irrigation intervals and SA has derived the potassium content in both, D2SA50 and D4SA50 treatments to significantly increased up to 5.292% and 5.202%, respectively. In the case of triple interaction between all studied factors, M1D2SA50 and M1D4SA50 were in the lead reaching the maximal values of 6.143% and 6.103%, respectively.

Zinc (%): Significant differences in the zinc content (Table 9) were detected between the subjected bio-concentrations of mycorrhiza. The M1 mycorrhizal treatment was significantly higher than other treatments reaching 55.40% of zinc percentage. For the irrigation interval treatments, the D2 increased significantly in the percentage of zinc content (59.38%). The different concentrations of salicylic acid had a significant effect in respect of zinc percentage, thus the concentration of 50 mg l^{-1} achieved the highest value (60.04%). The M1D2 treatment was 68.98%, followed by M1D4 treatment (63.98%). Irrigation intervals interacted significantly with the different levels of salicylic acid, so, D2SA50 was superior as it scored 74.74% followed by D4SA50 treatment with 71.74%. In the same table, M1D2SA50 and M1D4SA50 indicated significant interaction between the three studied factors acheiving 87.06% and 85.36% of zinc content, respectively.

This may be due to the exceptional ability of these fungi to produce a variety of nutritional compounds that have a significant role in improving physiological activities and increasing plants ability to the absorb water and macro- and/or micro-nutrients, which in turn improves plant growth and productivity (Kaschuk *et al.*, 2010). The significant reduction in the vegetative growth of carnation plants subjected to different intervals of irrigation may have been due to the direct effects of water stress inhibiting the enzymatic activity of several enzymes like SOD and resulting in imbalance nutritional system disrupting the cellular membranes function and plant metabolism in general. Such effects will negatively reflect on the photosynthetic process, and electron transfer in the energy production (Cha-Um and Kirdmanee, 2009). The previously stated results showed that salicylic acid spraying improved the vegetative traits by reducing the absorption of Na^+ and Cl ions. It has a crucial role in facilitating the absorption of nitrates, magnesium, iron, manganese and copper. Salicylic acid has a significant effect in increasing photosynthesis rate and increasing nutrients absorption that in total will reflect on plant growth (Liu *et al.*, 2017).

Flower diameter (cm): The results of table 10 indicated that there was a significant effect of mycorrhiza in the flower diameter, that M1 mycorrhiza treatment achieved the highest mean of 7.46 cm compared to the control treatment (M0) that achieved the lowest mean (5.63 cm).

Length of flower stem (cm): The results of table 12 indicated that the biological mycorrhizal fertilizer was had superior effect on plant height. The M1 treatment gave the highest value for plant height of 65.7 cm. The irrigation intervals included two days interval (D2) reached plant height of 70.8 cm, whereas, the effect of salicylic acid at the concentration of 50 mg l^{-1} was superior (73.1 cm) compared to the other spraying levels. Interaction found to be significant between the M1 mycorrhizal treatment and the D2 (2 days) irrigation interval, and higher than the other interaction effects, reaching 76.3 cm.

Interaction between irrigation intervals and the different salicylic acid levels showed a significant variation. Both, D2 and D4 treatments exceeded the significantly threshold at the concentration of 50 mg l^{-1} reaching 85.9 cm and 83.2 cm, respectively. While the lowest interaction value was achieved by the D6 treatment and 150 mg l^{-1} producing a plant height of 43.1 cm. The treatments M1D2SA50 and M1D4S50 recorded the highest values of plant height (94.3 cm and 91.2 cm, respectively), meanwhile M0D6SA150 was on the opposite direction as it gave the lowest plant height (41.0 cm). For the triple interaction, M1D2SA50 and M1D4SA50 recorded the lowest mean for the studied trait that was about 179.26% and 172.62%.

The iron content was sharply declined in M1D4SA50

Table 12: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the length of flower stem (cm) in *Dianthus caryyophyllus.*

Mycorrhiza M	intervals Irrigation(D)day	Salicylic acid SA				MXD
	Day	SA0	SA-50	SA-100	SA-150	D
M0	D2	60.1	77.5	70.3	53.2	65.3
	D4	53.0	75.1	62.7	49.7	60.1
	D6	41.6	46.4	43.4	41.0	43.1
M1	D2	70.6	94.3	80.4	59.9	76.3
	D4	62.0	91.2	69.8	58.4	70.4
	D6	50.7	54.2	51.9	45.3	50.5
	LSD				4.80	2.40
Average salicylic acid		56.3	73.1	63.1	51.2	
	LSD				1.958	
		salicylic acid X Mycorrhiza				
		SA 0	SA-50	SA-100	SA-150	Average Mycorrhiza
	M0	51.5	66.3	58.8	48.0	56.2
	M1	61.1	79.9	67.4	54.5	65.7
	LSD				2.77	1.39
		salicylic acid X irrigation interval				
		SA 0	SA-50	SA-100	SA-150	Average irrigation interval
	D2	65.3	85.9	75.4	56.6	70.8
	D4	57.5	83.2	66.3	54.1	65.2
	D6	46.1	50.3	47.6	43.1	46.8
	LSD				3.39	1.70

Table 13: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the mycorrhiza infection percentage (%) in *Dianthus caryyophyllus.*

Mycorrhiza M	intervals Irrigation(D)day	Salicylic acid SA				MXD
	Day	SA0	SA-50	SA-100	SA-150	D
M0	D2	10.88	15.34	12.06	9.12	11.85
	D4	10.46	11.78	10.40	8.72	10.34
	D6	0.00	7.51	6.75	1.73	4.00
M1	D2	41.05	77.79	57.48	41.08	54.35
	D4	35.47	67.44	47.26	27.80	44.49
	D6	18.50	33.18	29.80	14.45	23.98
	LSD				10.33	5.17
Average salicylic acid		19.39	35.51	27.29	17.15	
	LSD				4.22	
		salicylic acid X Mycorrhiza				
		SA 0	SA-50	SA-100	SA-150	Average Mycorrhiza
	M0	7.11	11.54	9.74	6.52	8.73
	M1	31.67	59.47	44.85	27.78	40.94
	LSD				5.97	2.98
		salicylic acid X irrigation interval				
		SA 0	SA-50	SA-100	SA-150	Average irrigation interval
	D2	25.96	46.56	34.77	25.10	33.10
	D4	22.96	39.61	28.83	18.26	27.42
	D6	9.25	20.35	18.27	8.09	13.99
	LSD				7.31	3.65

treatment reaching iron 112.70%. The results obtained from the tables of flower parameters indicated a clear effect of mycorrhiza in improving flowering traits. Vegetative and syphilis resulting in an increase in all floral traits (Bashan, 2010 and Elrys, 2018). The improved floral traits may be attributed to the active role of salicylic acid

Table 14: Effect of Mycorrhiza, irrigation interval and salicylic acid (SA) in the roots surface area (cm^2) in *Dianthus caryyophyllus*.

MXD	Salicylic acid SA				intervals Irriga-tion(D)day	Mycor-rhiza M
D	SA-150	SA-100	SA-50	SA0	Day	
115.8	109.0	118.6	120.2	115.5	D2	M0
110.1	96.2	116.6	119.1	108.5	D4	
68.2	60.5	72.2	74.8	65.4	D6	
131.4	120.0	133.7	146.4	125.6	D2	M1
125.6	111.0	128.4	144.1	119.0	D4	
83.9	75.8	87.3	91.4	81.1	D6	
2.4	4.8				LSD	
	95.4	109.5	116.0	102.5	Average salicylic acid	
	2.0				LSD	
salicylic acid X Mycorrhiza						
Average Mycorrhiza	SA-150	SA-100	SA-50	SA 0		
98.0	88.6	102.5	104.7	96.4	M0	
113.6	102.2	116.5	127.3	108.5	M1	
1.4	2.8				LSD	
salicylic acid X irrigation interval						
Average irriga-tion interval	SA-150	SA-100	SA-50	SA 0		
123.6	114.5	126.2	133.3	120.5	D2	
117.9	103.6	122.5	131.6	113.7	D4	
76.0	68.2	79.7	83.1	73.2	D6	
1.7	3.4				LSD	

in the production of internal auxins. The acid also shares some enzymes to form proteins and preserve the genetic material to synthesize more DNA, in addition to its effect on the transfer of crude and elaborated sap. The increase in the number of flowers, which may be due to the induction role of salicylic acid that may accelerate the photosynthesis process (Hayat and Ahmed, 2010).

The results of table 13 showed an increase in the percentage of infected roots in response to the mycorrhiza inoculation. The M1 treatment of fungi recorded a percentage of 40.94%. The D2 irrigation interval resulted in the highest percentage of infected roots reaching 33.10%, as well as the salicylic acid spraying was significantly differentiated at 50 mg l^{-1} scoring a percentage of infected roots about 35.15%. Also, the interaction between the mycorrhizal biofertilizer and the irrigation intervals was superior in M1D2 treatment achieving 54.35%. The interaction between the irrigation intervals and the salicylic acid levels showed a significant effect in this trait, thus both D2SA50 and D4SA50 treatments increasing the trait mean up to 46.56% and 39.16%, respectively. The three studied factors affected the trait mean significantly as M1D2SA50 treatment had the highest percentage of infected roots (77.79%) followed by M1D4SA50 treatment (67.44%).

Roots surface area (cm^2): The roots surface area increased significantly in response to the mycorrhizal infection and M1 treatment was superior recording 113.6 cm^2, also, the roots surface area achieving significant increase at the D2 irrigation interval giving 123.6 cm^2. Salicylic acid spraying at the concentration of 50 mg l^{-1} achieved a significant increase about 116.0 cm^2. The roots surface area at M1D2 treatment was significantly increased reaching 131.4 cm^2. The interaction between mycorrhiza and salicylic acid at the M1SA50 treatment was significantly higher than the other treatments scoring 127.3 cm^2. Irrigation intervals interacted significantly with the salicylic acid levels resulting in the superiority of both M1D2SA50 and M1D4SA50 treatments which had a higher roots surface area reached 146.4 cm^2 and 144.1 cm^2.

Interaction between the irrigation intervals and salicylic acid levels, increased the length of lateral roots which was significantly increased at D2SA50 and D4SA50 treatments reaching 32.58 cm and 32.02 cm, respectively. The studied factors showed significant interaction values and both M1D2SA50 and M1D4SA50 treatments were significantly higher than the other interacted treatments giving 39.10 cm and 38.40 cm, respectively. This may be due to the ability of these fungi to synthesize and/or release a group of active compounds that have a considerable function in improving physiological processes and increasing plants capability to absorb water, micro- and macronutrients, which in turn improves plant growth (Kaschuk *et al.*, 2010, Lopez *et al.*, 2010). In addition, mycorrhiza participate effectively in secreting Acc-Deminase, which enters the pathway of ethylene and inhibits plants aging via conserving chlorophyll and improving photosynthesis rate (Lalitha, 2017). All the previously mentioned effects will in turn contributes to the production of many plant hormones, including auxins and gibberellins, which in turn activate the cell division and extension, thus increasing plant height, leaf area and stem diameter, in addition to crucial role of increasing absorption of other nutrients such as potassium, which contributes to the building of carbohydrates and proteins (Richardson *et al.*, 2009).

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