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The Effect of the Inoculation with the Mycorrhizae and Spray with FeSO4 and Anti-Transpirant on Some Growth Characters and Yield of Okra Abelmoschus Esculentus L. Moench

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Abstract: **The present experiment was carried out at one field of the research station (B) belongs to Horticulture Department/College of Agriculture/ Baghdad University during the summer season of 2017 in order to study the effect of the inoculation with the mycorrhizae and spray with FeSO4 and Anti-Transpirant (Armurox) on some growth characters and yield of okra Abelmoschus esculentus L. Moench. The experiment was lay out as a factorial experiment (2x3x2) in randomized complete block design (RCBD) with three replications. The total number of treatments was twelve. The three factors of the experiment included; the inoculation with mycorrhizae (M) (0 and 10 g. plant-1), spray with FeSO4 (F) (0, 0.5, and 1g.L-1), and the Anti-Transpirant 'Armurox' (A) (0 and 5 ml.L-1). The results showed that the three factors and their interactions had significant effects on most of the growth characters measured. The inoculation with the mycorrhizae was superior in giving higher values of plant height, number of branches and total number of leaves per plant; 139.97 cm, 15.00 branch. plant-1 and 165.85 leaf. plant-1, respectively. The M1F0A0 combination treatment recorded the highest number of branches per plant (16.50) while the M1F2A1 treatment recorded the highest values of plant height (145.66 cm), total leaves number (170.33 leaf. plant-1), leaf area (731.36 dcm-2. plant-1), number of pods (19.20 pod. plant-1), and plant yield (809.40 g. plant-1).**

Keyword: **Okra, mycorrhizae, FeSO4, Anti-Transpirant, plant height, yield**

I. INTRODUCTION

Okra (Abelmoschus esculentus L. Moench) which belongs to the Malvaceae family, is considered as an important summer vegetable crop cultivated in most of tropical and subtropical regions of the world [1],[2] , [3]. It is known as a good source of some vitamins such as B1, B2, B3, C, E, and K in addition to some mineral nutrition and protein, carbohydrate and unsaturated fats. Each 100g of pod contains 88.6 g water, 8.20g carbohydrate, 2.10 g protein, 0.02 g fat, 1.70 g fibre, 90 mg phosphorus, 84 mg calcium, 1.2 mg iron, 0.60 mg nickel, 185 mg β-carotene, 0.02 mg B2 vitamin, 0.04 mg B3 vitamin, 47 mg ascorbic acid (vitamin C) in addition to 36 Kcal. Moreover, it was mentioned that mature okra seeds contain some of unsaturated fats [4].

Mycorrhizae is a symbiosis fungus that affect plant growth and productivity due to its large ability to habituate the rhizosphere of the plants and hinder the pathogens activities there, secreting number of vital compounds that contribute to promote plant growth, in addition to lower the soil pH that facilitates the absorption of some important mineral nutrition such as iron and manganese. Also, the biochemical compounds secreted by the fungi have a great importance in regulating and increasing plant growth [5]. It is known that infected roots secret some amount of carbon dioxide, therefore, the diffusion pressure will increase in the region surrounding the roots which considered as a normal result due to increase respiration rate. This increase leads to the formation of carboxylic acids H2CO3 and acidic radicals COOH on the surface of soil particles and to the release of ionic phosphorus, then absorption of phosphorus via the roots of host plant[6].[7] have found that using the mycorrhizae to inoculate the potato tubers led to increase yield by 20% compare to non-inoculated tubers.

Stress conditions that plants exposed to in Iraq such as high temperature, lack of irrigation in summer, increase of respiration, loss of water by the transpiration, all can cause adverse physiological changes that affect plant growth and development. In order to reduce that adverse effects, there is a need to use the Anti-Transpirant compounds by spraying them on plants to help in increasing plant water efficiency use and reduce transpiration which considered as the main source of water loss at the later stage of plant growth [8]. [9] found that spray with the Anti-Transpirant (Fulicoat) on potato plants caused a gradual increase in tubers yield as the concentration of the Anti-Transpirant increased from 0 to 15%.

Therefore, and due to the economic importance of okra, we use the inoculation with mycorrhizae and spray with FeSO4 and Anti-Transpirant (Armurox) in order to investigate their role in increasing plant growth and yield per unit area.

II. Materials and Methods

The present experiment was carried out at one field of the research station belongs to Horticulture Department/College of Agriculture/Baghdad University/Al-Jadria, during 2017 summer growing season in order to study the effect of inoculation with mycorrhizae and spray with FeSO4 and anti-Transpirant (Armurox) on growth and yield of okra cv. Petra. Seeds were sown at 1/3/2017 in containers filled with a mixture of peat moss and the mycorrhizae. The mycorrhizae inoculum contains an infected roots and spores and hypha of the fungi which was obtained from the Agricultural Research Office in Al-Zafarania district/ Baghdad/ Ministry of Science and Technology. The density of the inoculum was 51 spore. g-1 soil. A 100 gram of sterilized peat moss was placed in the transplant bed for mycorrhizae inoculation treatment, and 10 g of the inoculum was added in a way that the inoculum be in touch with the plant roots. The experiment field was divided into three blocks, each block consists of 12 treatments with a distance of 40 cm between plants and 70 cm between rows. Plants were irrigated using drip irrigation system. FeSO4 solution was prepared at three concentrations; 0, 0.5 and 1 g. L-1 and spray was done twice; first after 45 days of planting and the other after 15 days of the first spray. The Anti-Transpirant (Armurox) was prepared at two concentrations; 0 and ml. L-1 and spray was done after one week of the spray with FeSO4. Chemical and physical properties of soil of the field were analyzed at the graduate student laboratory /College of Agriculture/Baghdad University (table 1). Flods Harvest was done for 35 times started from 9/5/2017 and continue till 29/8/2017.

Table 1: Physical and chemical properties of the soil of the experiment.

Analysis		**Unit**	**Value**	**g.kg-1**			
EC		ds.m -1	2.10	Sand	Silt	Clay	Texture
pH			7.23	892	60	48	Loamy sand
Dissolved Cations	**Ca+2**	mg.L-1	10.22				
	Mg+2		7.27				
	Na+		4.45				
Anion	**HCO3-**		Nil				
	CO3-2		Nil				
	Cl-		17.13				
	SO4-2		4.83				
NPK Available	**N**	%	0.004				
	P	mg.Kg-1 soil	10.13				
	K		104.3				
		%	0.73				
Bacterial and fungi number		Bacteria	25X10 -6				
		Fungus	24X10 -3				

At the end of the experiment, five plants were randomly chosen from each experimental unit after 155 days of planting to measure the following:

1. Plant height (cm): was measured for all the five plants from soil level to the top of the plant using metric tape.
2. Total number of branches per plant: was calculated for each plant of the five plants chosen above.
3. Total number of leaves per plant: was calculated for the five plants chosen above also.
4. Leaf area (dcm-2. plant-1): was measured using light scanner and Digimizer program according to [10] procedure.
5. Number of pods per plant: was calculated as a total number of pods per experimental unit divided by the number of plants per the experimental unit.

6. Total plant yield (g): was calculated according to the following ;
   Yield of plant (gm) = yield of the experimental unit (g)/number of plants per experimental unit
   Treatments were arranged in randomized complete block design (RCBD) as a factorial experiment (2x3x2) with three replications. Treatments means were compared using LSD at 0.05 level.

Plant height (cm)

It was clear from table 2 that there was a significant increase in plant height due to the inoculation with the mycorrhizae. Inoculation (M1) recorded higher values for plant height (139.97 cm) than that for non-inoculated plants (129.92 cm). Also, treatment with FeSO4 resulted in significant increase in plant height especially at 0.05 g. L-1 (F1), 137.33cm compare to 131.41 cm for the control. Treatment with the anti-transpiration (A1) recorded plant height of 137.47 cm while in control treatment the plant height was 132.41 cm.

For the interaction between the inoculation with the mycorrhizae and the spray with the FeSO4, M1F2 combination treatment was superior in its effect. Plant height at this treatment was 141.91 cm, which was not significantly differing from the M1F1 combination treatment, while in control treatment the plant height was (125.33 cm). In the same way, for interaction between the inoculation with the mycorrhizae and the spray with the Anti-Transpirant, M1A1 combination treatment resulted in higher plants with an average plant height of 143.00 cm in compare to that for the control (127.88 cm). Also, the F2A1 combination treatment, interaction between FeSO4 and the Anti-Transpirant, gave the highest plant height (138.60 cm), while the control treatment gave the lowest plant height (127.58cm). Interaction among the three factors has also significant effect. The M1F2A1 combination treatment resulted in higher plants with an average of 145.66 cm compare to 119.83 cm for the control treatment (M0F0A0).

Number of total branches (branch. plant-1)

Results of table 3 clearly showed that the inoculation with the mycorrhizae had significant effect. Branches number per plant increased from 12.36 for the non- Inoculated plants to 15.00 for the inoculated ones (M1 treatment). Also, with spray with FeSO4, the branches number increased from 12.16 for F0 treatment to 14.91 for F2 treatment. The Anti-Transpirant treatment had no effect. interaction between the inoculation with the mycorrhizae and FeSO4 had significant effect. The highest number of total branches was obtained at the M1F2 combination treatment (15.25 branch. plant-1) while the lowest number was recorded at the control (9.25 branch. plant-1) (M0F0). In the same way, interaction between inoculation with mycorrhizae and the spray with the Anti-Transpirant had significant effect. The highest number of branches per plant (15.88) was obtained at the A0M1 combination treatment while the lowest number was at the control (11.44 branches. Plant-1).

Spray with FeSO4 along with the Anti-Transpirant resulted in larger number of branches per plant at all combination treatments. The F1A0 combination treatment was superior in its effect which resulted in the prefect number of branches (15.41). Control treatment (F0A0) gave the lowest number (10.66 branches. Plant-1). For the combination of the three factors studied, the M1F0A0 treatment was more effective in giving the largest number of branches per plant (16.50) which did not differ significantly from other combination treatments except the M0F2A1 treatment. The control treatment (M0F0A0) gave the least number of branches per plant (4.83).

Table 2: Effect of the inoculation with the mycorrhizae (M) and the spray with the FeSO4 (F) and the Anti-Transpirant (A) and their interaction on plant height (cm) of okra cv. Ptera

A	F	M0	M1	A×F	Average
A0	F0	119.83	135.33	127.58	132.41
	F1	134.83	137.33	136.08	
	F2	129.00	138.16	133.58	
A1	F0	130.83	139.66	135.25	137.47
	F1	133.50	143.66	138.58	
	F2	131.53	145.66	138.60	
LSD		2.153		1.522	0.879
A x M					
A0		127.88	136.94	LSD= 1.243	
A1		131.95	143.00		
F x M					

F0	125.33	137.50	131.41
F1	134.16	140.50	137.33
F2	130.26	141.91	136.09
LSD	1.522		1.076
	129.92	139.97	
LSD	0.879		

Table 3: Effect of the inoculation with the mycorrhizae (M) and the spray with the FeSO4 (F) and the Anti-Transpirant (A) and their interaction in total number of branches per plant (branches. Plant-1) of okra cv. Ptera

A	F	M0	M1	A×F	Average
A0	F0	4.83	16.50	10.66	13.67
	F1	15.16	15.66	15.41	
	F2	14.33	15.50	14.91	
A1	F0	13.66	13.66	13.66	13.69
	F1	15.16	13.66	14.41	
	F2	11.00	15.00	13.00	
LSD		3.803		2.689	N.S
A x M					
A0		11.44	15.88	LSD= 2.195	
A1		13.27	14.11		
F x M					
F0		9.25	15.08	12.16	
F1		15.16	14.66	14.91	
F2		12.66	15.25	13.95	
LSD		2.689		1.901	
		12.36	15.00		
LSD		1.552			

Number of leaves (leaf. plant-1)

Table 4 demonstrates the significant effect of the inoculation with the mycorrhizae on the total number of leaves. The inoculation treatment (M1) resulted in higher number of leaves per plant (165.85) than that for the control (147.86). Also, for the FeSO4 treatments effects, 1 g. L-1 (F2) treatment recorded the highest number of leaves (164.83) which did not differ from F1 treatment. Spraying the Anti-Transpirant on plants have also promoting effect on total leaves number. Higher number of leaves per plant was recorded at A1 treatment (162.55) in compare to 151.17 leaves. Plant-1 for the control. It was obvious from the same table that the interaction between the mycorrhizae and spray with the FeSO4 significantly increased number of leaves. At the M1F2 combination treatment, the total number of leaves per plant was 170.25 while the number at the control was much lower (117.08 leaf. plant-1). However, no significant differences were noted among the M1F2, M0F1, M1F0 and M1F1 combination treatments. With regard to the effect of the combination between the mycorrhizae and the Anti-Transpirant, significant effect was also noticed. The M1A1 combination treatment recorded the highest number of leaves (167.04) which did not differ from the M1A0 combination treatment, while the control treatment recorded the lower number of leaves per plant (137.67). For the combination between FeSO4 and the Anti-Transpirant, all treatments increased significantly leaves number.

Table 4: Effect of the inoculation with the mycorrhizae (M) and the spray with the FeSO4 (F) and the Anti-Transpirant (A) and their interaction on total number of leaves per plant (leaves. plant-1) of okra cv. Ptera

A	F	M0	M1	A×F	Average
A0	F0	79.66	170.66	125.17	151.17
	F1	167.33	161.16	164.25	
	F2	166.00	162.16	164.08	
A1	F0	154.50	162.66	158.58	162.55
	F1	166.83	160.13	163.48	
	F2	152.83	178.33	165.58	
LSD		14.42		10.20	5.88
A x M					
A0		137.67	164.67	LSD= ٨.٣٣	
A1		158.06	167.04		
F x M					
F0		117.08	166.67	141.88	
F1		167.08	160.65	163.86	
F2		159.42	170.25	164.83	
LSD		10.20		7.21	
		147.86	165.85		
LSD		5.88			

As for other parameters measured, the total number of leaves was affected by the combination among the three factors. The M1F2A1 combination treatment was superior in giving the highest number of leaves (178.33) which did not differ from M1F0A0, M0F1A0, M0F2A0 and M0F1A1 combination treatments. The least number of leaves was at the control treatment (79.66).

Leaf area (dcm-2. plant-1)

The inoculation with the mycorrhizae (F1) was superior in giving larger leaf area (591.42 dcm-2. plant-1) (table 5). Spray with the FeSO4 resulted also in the higher leaf area than the control, amounted of 634.66 dcm-2. plant-1 at F2 treatment which was much more than that for the control (471.72 dcm-2. plant-1). The Anti-Transpirant had no effect.

Combination between the mycorrhizae and FeSO4 or between mycorrhizae and the Anti-Transpirant resulted in higher leaf area. M1F2 combination treatment recorded the highest leaf area (660.20 dcm-2. plant-1). However, the M1F2 treatment did not differ significantly from M0F1, M1F0 and M0F2 combination treatments. Also, M1A0 treatment recorded the highest leaf area (599.58 dcm-2. plant -1) although this treatment did not differ significantly from other treatments. From the same table,and for the interaction on beween FeSo4 and anti-transpiration, F2A1 treatment gave the highest leaf area (661.36) which not differ from other combination treatments. The F0A0 treatment recorded the lowest area (428.59 dcm-2. plant-1). When the three factors interact, the highest leave area was obtained at the M1F2A1 combination treatment (731.36 dcm-2. plant-1) which did not differ from M0F1A1, M1F0A0, M0F2A0 and M1F2A0 treatments.

Table 5: Effect of the inoculation with the mycorrhizae (M) and the spray with the FeSO4 (F) and the Anti-Transpirant (A) and their interaction on leaf area (dcm-2. plant-1) of okra cv. Ptera

A	F	M0	M1	A×F	Average
A0	F0	192.08	665.10	428.59	528.48
	F1	565.17	532.61	548.89	
	F2	614.86	601.04	607.95	
A1	F0	474.83	554.85	514.84	580.89
	F1	669.36	463.55	566.45	

	F2	591.37	731.36	661.36	
LSD		131.56		93.00	N.S
A x M					
A0		457.37	599.58	LSD= 76.00	
A1		578.52	583.25		
F x M					
F0		333.46	609.98	471.72	
F1		617.27	498.06	557.67	
F2		603.11	666.20	634.66	
LSD		93.00		65.78	
		517.95	591.42		
LSD		53.70			

Number of pods (pod. plant-1)

Number of pods increased significantly due to the inoculation with mycorrhizae or foliar spray with FeSO4 with values of 112.87, 99.28 and 98.63 pod. plant-1, for M1, F1 and F2 treatments, respectively, in compare to 81.04 and 92.95 pod. plant-1 for M0 and F0, respectively. However, spray with the Anti-Transpirant did not show any significant effect (table 6).

For the combination of inoculation with the mycorrhizae and foliar application of FeSO4, the M1F0 treatment recorded the highest number of pods per plant amounted of 118.60 pods which did not differ significantly from F1M1 combination treatment. The control treatment recorded the lowest number of pods (67.30). For the combination of inoculation with the mycorrhizae and the Anti-Transpirant, M1A1 combination treatment resulted in the highest number of pods (114.60) which did not differ significantly from M1A0 treatment while the control treatment recorded the lowest number of pods. The spray with FeSO4 along with the Anti-Transpirant had no significant effect.

Combination of the three factors had also significant effect. The M1F2A1 treatment recorded the highest number of pods per plant (119.20 pod. plant-1) which did not differ from M1F0A0, M1F1A1, or M1F1A0 combination treatments. The least number of pods was at M0F0A0 treatment (66.07 pod. plant-1).

Table 6:Effect of the inoculation with the mycorrhizae (M) and the spray with the FeSO4 (A) and the Anti-Transpirant (A) and their interaction on number of pods per plant (pod-1. plant-1) of okra cv. Ptera

A	**F**	**M0**	**M1**	**A×F**	**Average**
A0	**F0**	66.07	129.47	97.77	97.65
	F1	86.77	111.03	98.90	
	F2	99.67	92.93	96.30	
A1	**F0**	68.53	107.73	88.13	96.25
	F1	82.47	116.87	99.67	
	F2	82.73	119.20	100.97	
LSD		8.522		N.S	N.S
A x M					
A0		84.17	111.60	LSD= ٤.٩٢٠	
A1		77.91	114.60		
F x M					
F0		67.30	118.60	92.95	
F1		84.61	113.95	99.28	
F2		91.20	106.06	98.63	

LSD	6.026		4.261
	81.04	112.87	
LSD	3.479		

Plant yield (g)

Table 7 clearly shows the significant superiority of the inoculation with the mycorrhizae (F1) in giving higher plant yield (701.75 g. plant-1) than that for the control (522.17 g. plant-1). Also, spray with FeSO4 resulted in higher plant yield while there was no effect due to the use of the Anti-Transpirant. The combination between mycorrhizae and FeSO4 shows that M1F0 treatment was superior in giving the highest plant yield amounted of 730.53 g. plant-1 which did not differ from M1F1 combination treatment. Combination between mycorrhizae and the Anti-Transpirant also shows that the M1A1 combination treatment gave the highest plant yield of 736.57 g. plant-1 while the control treatment gave the lowest plant yield (536.93). On the other hand, combination between FeSO4 and the Anti-Transpirant had no effect.

For the effect of the three factors together, the M1F2A1 combination treatment was superior in increasing plant yield. However, no significant differences were found between M1F2A1 and M1F0A0 treatments. The M0F0A0 recorded the least plant yield (408.63 g. plant-1).

Table 7: Effect of the inoculation with the mycorrhizae (M) and the spray with the FeSO4 (F) and the Anti-Transpirant (A) and their interaction on total plant yield (g-1. plant-1) of okra cv. Ptera

A	F	M0	M1	A×F	Average
A0	**F0**	408.63	789.17	598.90	602.13
	F1	588.43	682.23	635.33	
	F2	613.73	530.60	572.17	
A1	**F0**	448.50	671.90	560.20	621.79
	F1	549.73	727.20	638.47	
	F2	524.00	809.40	666.70	
LSD		60.25		N.S	N.S
A x M					
A0		536.93	667.33	LSD= 34.79	
A1		507.41	736.17		
F x M					
F0		428.57	730.53	579.55	
F1		569.08	704.72	636.90	
F2		568.87	670.00	619.43	
LSD		42.60		30.12	
		522.17	701.75		
LSD		24.59			

It was clear that the obvious increase in values of the measured characters was due to positive effect of the inoculation with mycorrhizae and spray with both FeSO4 and the Anti-Transpirant on plant growth and development. It is known that inoculation with mycorrhizae at the primary stage of plant growth leads to improve plant performance after transfer to the field [11] . The inoculation with VAM increases the efficiency of photosynthesis. Symbiosis fungi promote phosphorus absorption and increase the growth of the host plant that supply the fungi with the carbonic compounds[12], therefore, the photosynthesis activity will increase as a result of symbiosis fungus activity [13]. Also, the mycorrhizae have an important role in increasing solubility and availability of mineral nutrition which reflected in increasing the biosynthesis and translocation of foods to the pods as an ultimate sink. Therefore, weight of pods and chemical composition would be improved, and in turn, plant yield increase. The current results agree with previous ones of [14], [15], [16], [17].

The positive effect of FeSO4 in increasing values of parameters measured may be due to the vital role of iron as an important component of cytochromes and ferredoxin which are important in increasing the rate of photosynthesis, and in turn, rate of whole plant growth. In addition, the increase in chlorophyll content due to

high levels of iron would be reflected in increasing rate of photosynthesis also [18], [19]. Also, it wsas noted that the spray with FeSO4 at the early stage of plant growth increases the biological processes and leads to promote the whole plant growth and development. Iron has a role in nucleic acids and plastids assimilation which increase the chlorophyll content and protein of the plastids and then photosynthesis efficiency and growth in general [20]. The increase in chlorophyll synthesis and then increase photosynthesis efficiency would enhance vigorous of plant promote components of vegetative growth such as plant height, number of branches, leaves number anid leaf area (tables 2- 6). Also, a balanced levels of iron at favorite environment condition enhances the physiological processes and activate cell division and elongation and increase number of branches [21].

Use of Armurox leads to increase plant biological yield and this may be due to the fact that the Anti-Transpirant contains some free amino acids that have an important role in increase plant yield, in addition to availability of silicon and its promoting role in enhancing cells activity [22]. It was mentioned that silicon has a role in increasing plant heat tolerance in open field and increase the plant water use efficiency under water stress. Silicon increase absorption of calcium and potassium ions and the anti-oxidants, and in turn maintains the chlorophyll content and cell turgidity. These results come in agreement with results of [23], [24].

It can be concluded that the interaction among the mycorrhizae, FeSO4 and the Anti-Transpirant Armurox significantly affect vegetative growth and yield of okra plant.

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