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EFFECT OF DUAL INOCULATION (VA-MYCORRHIZAE AND *RHIZOBIUM*) AND ZINC FOLIAR APPLICATION ON GROWTH AND YIELD OF MUNGBEAN

[32]

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ABSTRACT

Two field experiments were carried out during 2000 and 2001 seasons at the Experimental Farm, Fac. of Agric. Moshtohor to study the effect of dual inoculation with *Rhizobium* sp (Mungbean strain) and VA-mycorrhizae (VAM) *Glomus aggregatum* in presence of zinc application on nodulation, N_2-ase activity, mycorrhizal root infection, growth and yield of mungbean plants. Results of this study showed that dual inoculation with *Rhizobium* and mycorrhizae gave higher records of mungbean nodulation, N_2-ase activity and mycorrhizal root infection percentage compared to individual inoculation with either *Rhizobium* or mycorrhizae. All tested parameters were increased with zinc foliar application especially when zinc was sprayed in a concentration of 20 ppm. Ammoniacal and nitrate nitrogen in rhizosphere were higher in rhizobial inoculated treatments than mycorrhizal inoculated ones. Whereas, available phosphorus and CO_2 evolution were higher in mycorrhizal inoculated treatments than rhizobial inoculated ones. Mungbean growth characters were significnatly increased in case of dual inoculation compared to individual inoculation and this was true in the two growing seasons. Also, mungbean growth characters were improved with zinc application either at 10 or 20 ppm as compared with no zinc application. The highest records of macro and micro-nutrients content (N,P and K) and (Fe, Zn and Cu), respectively in mungbean shoots were observed with dual inoculation and zinc application at 20 ppm. Also, macro and micro-nutrients content was higher during flowering stage than vegetative one. Dual inoculation gave the highest seed yield, biological yield and yield components as well as protein yield of mungbean plants and this was obvious with zinc application (20 ppm).

Key words: Rhizobium, Mycorrhizae, Mungbean, Inoculation, Zinc foliar application, Growth and Yield

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INTRODUCTION

Mungbean (*Vigna radiata* L. wilczek) is a new summer food leguminous crop newly introduced to Egypt. Mungbean received increasing attentien and successfully grown in different locations of many Governorates. Although mungbean plant is a summer crop, a low rate of nitrogen ferilizer may be needed for early growth and during the entire growing season.

For increasing mungbean productivity, rhizobial and mycorrhizal inoculation could be practiced. Several investigators showed that inoculation of leguminous crops with specific strains of rhizobia or bradyrhizobia improved growth and yield due to their N_2-fixation and production of growth promoting substances. **Johal & Chahal (1994); Abd El-Ghaffar & Sherif (1995); Deka & Kakati (1996);Attia *et al* (1997); Gomaa & El-Kholy (1999) ; Tantawy *et al* (1999)** and **Hessein (2000)** found that rhizobial inoculation of mungbean significantly increased its growth characters, yield and yield components as well as protein, carbohydrate and oil contents.

Concerning the effect of VA-mycorrhizae inoculation, **Ahmed (1995)** and **Tarafdar & Rao (1997)** found that VAM stimulated growth, macro and micro-nutrients uptake, nodulation, N_2-ase activity and mycorrhizal root infection percentage as well as yield and yield components of mungbean plants.

The possibility of mycorrhizae for increasing the effectiveness of *Rhizobium* in mungbean and other legumes was reported by many investigators. **Thakur & Panwar (1995); El-Ghandour *et al*** (1997) and **Mikhaeel *et al* (2000)** suggested that the higher concentrations of plant phosphorus which result from mycorrhizal colonization could enhance nodulation, N_2-fixation, growth characters, macro and micro-nutrients content, yield and yield components.

Moreover, **Parasad & Ram (1991)** and **Abadi *et al* (1995)** reported that the interactive effect of *Bradyrhizobium* inoculation and zinc application improved nodulation, growth and yield of mungbean and soybean plants. Also, **Amara and Nasr (1995)** found that combined incoulation of the N_2-fixing bacteria and phosphate dissolvers + zinc application gave the highest seed yield of soybean.

The present study aimed to investigate the effect of dual inoculation with *Rhizobuium* sp and VA-mycorrhizae in the presence of zinc application on nodulation, N_2-fixation, growth and yield of mungbean c.v kawmy-1 plants.

MATERIAL AND METHODS

Two field experiments were carried out during the summer seasons of 2000 and 2001 at the Experimental Farm, Fac. of Agric. Moshtohor to study the effect of dual inoculation with *Rhizobium* sp (mungbean strain) and VA-mycorrhizae (*Glomus aggregatum*) in presence of zinc application on growth and yield of mungbean c.v kawmy-1. Physical and chemical properties of the experimental soil are presented in Table (1).

Physical analysis was determined according to **Jackson (1973)**. Whereas, chemical analysis was estimated according to **Black *et al* (1982)**.

Rhizobium sp (Mungbean strain) was obtained from Biofertilizers Production Unit, Soils, Water and Environment Res. Inst., Agric. Research Center, Giza

Table 1. Some physical and chemical properties of the experimental soil

Parameters	Season 2000	Season 2001	Parameters	Season 2000	Season 2001
Particle size distribution(%):			Soluble ions meq/l		
Coarse sand	16.70	15.48	Ca^{+2}	11.3	11.6
Fine sand	14.70	13.62	Mg^{+2}	7.24	7.08
Silt	15.20	16.10	Na^{+}	4.57	5.04
Clay	53.40	54.80	K^{+}	0.89	0.78
Textural class	Clay	Clay	CO_3^{-2}	-	-
Organic Matter (%)	1.96	2.01	HCO_3^{-}	9.75	10.2
P^H (1:2.5 suspension)	8.11	8.20	Cl^{-}	7.60	7.83
Total -N (%)	0.19	0.23	SO_4^{-2}	6.65	6.47
Total-P (%)	0.21	0.25	Microelements		
Total-K (%)	0.63	0.71	Available Fe (ppm)	21.10	22.00
$CaCO_3$ (%)	0.48	0.53	Available Zn (ppm)	4.21	5.10
E.C (dsm^{-1})	2.40	2.45	Available Mn (ppm)	3.60	3.82
			Available Cu (ppm)	2.44	2.63

Egypt. Whereas, mycorrhizal fungus (*Glomus aggregatum*) was obtained from Agric. Microbiol. Dept, Soils, Water and Environment Res. Inst., Agric. Res. Center, Giza, Egypt.

Inocula preparation

For preparation of rhizobial inoculum, yeast mannitol broth medium (**Vincent, 1970**) was inoculated with effective strain of *Rhizobium* sp, then incubated at 32°C for 7 days.

For preparation of *Glomus aggregatum* inoculum, pots of 30 cm diameter were filled with autoclaved soil. The soil of each pot was inoculated with VAM fungus *Glomus aggregatum*. Five onion seedlings were transplanted in each pot as a host plant. After 12 weeks, spores of VAM [illegible] collected from the rhizosphere and roots of onion were extracted by wet sieving and decanting technique (**Gerdmann and Nicolson, 1963**). VAM spores were counted by the method described by **Daniels and Skipper (1982)**.

Except for control treatments, mungbean seeds were successively washed with water and air dried. Then, seeds were soaked in cell suspension of *Rhizobium* sp (1ml contains about $9.2X10^7$ viable cells) for 30 min. Gum arabic (16%) was added as an adhesive agent prior to inoculation. The inoculated seeds were air dried for one hour before sowing. In uninoculated treatments with *Rhizobium*, mungbean seeds were treated by using uninoculated N- deficient medium instead of *Rhizobium* culture.

Before cultivation, the experimental soil plots were supplemented with calcium superphosphate at a rate of 30 kg P_2O_5/ fed.

Regarding the mycorrhizal treatments, plots which have been prepared for inoculation with VA-mycorrhizae were provided with a mycorrhizal spore suspension. The extracted mycorrhizal spore suspension containing about 150-180 spores/ml was used as a standard inoculum (20 ml/m^2) for mycorrhizal treatments. Ammonium nitrate (33.5 % N) was applied at a rate of 20 kg N/fed to all treatments in two equal doses i.e before the first and second irrigation.

With regard to zinc application treatments, zinc sulphate was used as a source of zinc in two concentrations (10 and 20 ppm). The amount of zinc sulphate was used in a rate of 200 L/fed by spraying onto the plants at the 30th and 60th day from planting.

Experimental design

A split plot desigen with four replicates was used in this study. The main plots were assigned to zinc foliar application (Zn0, Zn1, and Zn2). While, the four dual inoculation treatments (R0M0, R0M1, R1M0 and R1M1) were randomly distributed in the sub plots.

Cultivation process

Cultivation process was performed by sowing four inoculated or uninoculated seeds per hill. The sowing dates were 19th and 24th of May in 2000 and 2001 seasons, respectively. Planting was done at both sides of each ridge. The plot area was 10.5 m^2 (3x3.5 m) with five ridges. The distance between ridges was 60 cm and hills was 20 cm apart. Before the 1st irrigation, plants were thinned to two plants per hill. The preceding crop was clover in both seasons.

Sampling and determinations

Rhizosphere soil samples of the developed plants were taken at vegetative (35 days) and flowering (75 days) stages. The samples were analyzed for CO_2 evolution according to **Page *et al* (1982)**, NH_4-N and NO_3-N according to **Bremner and keeny (1965)** and available phosphorus according to **(A.P.H.A, 1992)**.

Data of nodules number, nodules dry weight/plant, N_2-ase activity of nodules and mycorrhizal root infection were estimated during flowering stage at the 75th day after cultivation. N_2-ase activity was estimated according to **Hardy *et al* (1973)**. Mycorrhizal root infection of mungbean plants was assessed microscopically according to **Mosse and Giovanetti (1980)**.

Total nitrogen, phosphorus and potassium content were determined in mungbean shoots at 35 and 75 days after planting according to **A.O.A.C (1980)**, **A.P.H.A (1992)** and **Dewis & Freitas (1970)**, respectively. Also, iron, zinc and copper were determined in mungbean shoots at 35 and 75 days after planting by the atomic absorption, Perkin Elmer model 3110

Crude protein was estimated in mungbean seeds. Crude protein was calculated according to the follwing equation:

% Crude protein = % total nitrogen x 6.25 (**A.O.A.C, 1980**).

Grwoth characters

After 75 days from sowing, ten guarded plants were chosen at random then plant height, number of branches/plant, dry weights of stem, leaves and pods were estimated.

Yield and its components

At harvesting, ten guarded plants were used to estimate number of pods/plant, pods weight/plant, 1000-seed weight, seed yield/plant. Seed yield/fed and biological yield/fed were recorded from three inner ridges from each experimental plot, then protein yield/fed was calculated.

Statistical analysis

Statistical analysis was carried out for growth and yield characters according to **Snedecor and Cochran (1989)**. The differences between the means values of various treatments were compared by Duncan multiple range test (**Duncan, 1955**).

RESULTS AND DISCUSSION

Effect of zinc foliar application, dual inoculation and their interaction on nodulation, N_2–ase activity and mycorrhizal root infection of mungbean plants.

Data in Table (2) show that nodules number and dry weight were highly increased in rhizobial inoculated treatments compared to uninoculated ones. Also, rhizobial inoculated treatments showed higher number and dry weight of nodules than mycorrhizal inoculated ones.

Dual inoculation with *Rhizobium* and mycorrhizae gave the highest number and dry weights of nodules and this was observed in the two growing seasons.

Data in Table (2) also show that mungbean plants sprayed with zinc in concentration of either 10 ppm or 20 ppm gave higher nodules number and dry weights than nonsprayed plants. Rhizobial inoculated plants which sprayed with zinc gave higher records of nodules number and dry weights than mycorrhizal inoculated ones. This observation was consistent in the two zinc concentrations.

Generally, zinc spraying at 20 ppm showed higher records of mungbean nodulation and the highest records of nodulation were observed in dual inoculation treatment with *Rhizobium* and mycorrhizae.

Data also show that N_2-ase activity was higher in case of rhizobial inoculated treatments than mycorrhizal inoculated ones. This result is in agreement with the results obtained by **Johal & Chahal (1994)**; **Deka & Kakati (1996)** and **Gomaa & El-Kholy (1999)** who noticed an increase of mungbean nodulation and N_2-ase activity due to rhizobial inoculation.

It is not a surprising result that mycorrhizal root infection percentage was higher in case of mycorrhizal inoculated treatments compared to

Table 2. Effect of zinc foliar application, dual inoculation and their interaction on nodulation, N_2-ase activity and mycorrhizal root infection of mungbean plants after 75 days of cultivation (flowering stage)

Zinc spraying	Dual inoculation	No. of nodules/plant		Dry weight of nodules (mg/plant)		N_2-ase activity (n moles C_2H_4 /hr/g dry nodules)		Mycorrhizal root infection (%)	
		2000	2001	2000	2001	2000	2001	2000	2001
Zn_0	Ro+Mo	16	19	141	160	73.6	76.5	6.0	8.0
	Ro+M1	21	23	196	210	75.3	80.1	31	33
	R1+Mo	28	32	248	264	83.2	84.6	14	15
	R1+M1	36	35	291	306	92.4	93.7	40	43
Mean		25.3	27.3	219	235	81.1	83.7	22.8	24.8
Zn_1	Ro+Mo	20	21	186	198	83.1	86.3	10	12
	Ro+M1	26	28	206	218	80.6	83.4	35	41
	R1+Mo	38	36	256	278	102.6	109.8	16	18
	R1+M1	42	45	348	360	109.1	112.3	61	63
Mean		31.5	32.5	249	264	93.9	98.0	30.5	33.5
Zn_2	Ro+Mo	22	25	231	245	82.4	91.3	12	14
	Ro+M1	30	33	263	278	111.6	118.5	40	44
	R1+Mo	40	42	336	351	133.1	142.3	18	22
	R1+M1	48	52	442	470	146.7	151.1	70	74
Mean		35.0	38.0	318	336	118.5	125.8	35.0	38.5
Over all mean	Ro+Mo	19.3	21.7	186	201	79.7	84.7	9.3	11.3
	Ro+M1	25.7	28.0	222	235	89.2	94.0	35.3	39.3
	R1+Mo	35.3	36.7	280	298	106.3	112.2	16.0	18.3
	R1+M1	42.0	44.0	360	379	116.1	119.0	57.0	60.0

Ro, Non rhizobial inoculation.
Mo, Non mycorrhizal inoculation.
Zn_0, Non zinc application.
R1, Rhizobial inoculation.
M1, Mycorrhizal inoculation.
Zn_1, Zinc application (10 ppm).
Zn_2, Zinc application (20 ppm).

rhizobial inoculated ones. Also, obtained data clearly indicate that mycorrhizal root colonization of mungbean plants was highly differed since the VAM inoculated mungbean plants grown showed higher records of root infection percentage than uninoculated ones which depended on the indigenous VAM in the soil. Low percentage of mycorrhizal infection in the uninoculated plants indicate that the native VAM fungi are presented in the soil but in a low density. These results are in harmony with those reported by **Ahmed (1995), Tarafdar & Rao (1997)** and **Mikhaeel *et al* (2000).**

The highest records of N_2-ase activity and mycorrhizal root infection were observed in case of dual inoculation compared to inoculation with either *Rhizobium* or VAM separately. Increasing the effectiveness of *Rhizobium* when combined with mycorrhizae was reported by several investigators on mungbean and other legumes **(Thakur & Panwar, 1995; El-Ghandour *et al* 1997 and Mikhaeel *et al* 2000).**

Data also indicate that N_2-ase activity and mycorrhizal root infection were higher when mungbean plants were sprayed with zinc than nonsprayed ones. Zinc spraying with 20 ppm solution gave higher N_2-ase activity and mycorrhizal root infection levels than zinc spraying with 10 ppm solution and this was observed in the two growing seasons.

With regard to the iteraction effect, data in Table (2) indicate that mungbean plants inoculated with *Rhizobium* + mycorrhizae and sprayed with zinc showed increases in mungbean nodulation, N_2-ase activity and mycorrhizal root infection percentage compared to either mungbean inoculation or zinc foliar application separately. The highest records of abovementioned parameters were observed in dual inoculation and zinc foliar application (20 ppm) treatments.

Generally, obtained data show that mungbean nodulation, N_2-ase activity were higher in the 2nd season than in the 1st one.

Effect of zinc foliar application, dual inoculation and their interaction on rhizospheric NH_4-N, NO_3-N, available phosphorus and CO_2 evolution.

Data presented in Table (3) show the changes of nitrogen forms, available-P and CO_2 evolution in rhizosphere soil of mungbean plants. Obtained data emphasize that ammoniacal and nitrate nitrogen content in rhizosphere of mungbean plants were increased in the treatments inoculated with either *Rhizobium* or mycorrhizae compared to uninoculated ones. Rhizobial inoculated treatments showed higher levels of NH_4-N and NO_3-N than mycorrhizal inoculated ones. The highest values of NH_4-N and NO_3-N were obtained in case of dual inoculation with *Rhizobium* and mycorrhizae compared to inoculation with either *Rhizobium* or VAM fungus singularly. This may be due to the synergistic effect between *Rhizobium* and VAM fungus. Rhizobial inoculated treatments which sprayed with zinc either in 10 or 20 ppm concentration gave higher records of NH_4-N and NO_3-N than mycorrhizal inoculated ones.

Data in Table (3) also indicate that zinc application in 20 ppm concentration showed higher levels of NH_4-N and NO_3-N in rhizosphere in comparison with zinc application at 10 ppm. This may be due to

Table 3. Effect of zinc foliar application, dual inoculation and their interaction on nitrogen forms, available phosphorus content and CO_2 evolution in rhizosphere soil of mungbean plants

Zinc spraying	Dual inoculation	NH_4-N (ppm)				NO_3-N (ppm)			
		Vegetative stage		Flowering Stage		Vegetative stage		Flowering stage	
		2000	2001	2000	2001	2000	2001	2000	2001
Zn_0	Ro+Mo	75.3	77.8	77.2	81.2	73.2	78.3	76.9	82.2
	Ro+M1	82.4	84.6	85.2	87.1	80.7	84.2	90.4	97.0
	R1+Mo	88.7	91.0	90.9	95.5	91.1	97.8	104.2	114.4
	R1+M1	112.3	114.5	119.2	127.6	101.0	108.2	112.5	121.8
Mean		89.7	92.0	93.1	97.9	86.5	92.1	96.0	103.9
Zn_1	Ro+Mo	78.1	81.0	80.1	83.8	84.1	80.2	86.2	85.7
	Ro+M1	85.6	88.2	88.2	89.6	90.3	90.2	91.1	92.8
	R1+Mo	91.2	92.5	93.1	98.7	107.2	101.4	113.2	116.0
	R1+M1	115.3	120.1	121.1	131.0	118.2	115.9	125.3	133.1
Mean		92.6	95.5	95.6	100.8	100.0	96.9	104.0	106.9
Zn_2	Ro+Mo	81.9	83.4	87.1	88.9	85.2	83.1	87.3	87.6
	Ro+M1	90.0	91.6	90.5	94.2	93.6	94.4	94.2	96.8
	R1+Mo	93.6	94.3	95.3	99.8	107.8	99.6	119.6	125.6
	R1+M1	120.2	126.1	124.8	133.4	120.3	121.8	128.7	138.2
Mean		96.4	98.9	99.4	104.1	101.7	99.7	107.5	112.1
Over all mean	Ro+Mo	78.4	80.7	81.5	84.6	80.8	80.5	83.5	85.2
	Ro+M1	86.0	88.1	88.0	90.3	88.2	89.6	91.9	95.5
	R1+Mo	91.2	92.6	93.1	98.0	102.0	99.6	112.3	118.7
	R1+M1	115.9	120.2	121.7	130.6	113.2	115.3	122.2	131.0

Table 3. Cont.

Zinc spraying	Dual inoculation	Available-P(ppm)				CO_2 evoluted (µg/g dry soil/hr)			
		Vegetative stage		Flowering stage		Vegetative stage		Flowering stage	
		2000	2001	2000	2001	2000	2001	2000	2001
Zn_0	Ro+Mo	50.2	54.6	63.3	52.3	21.5	26.7	28.7	32.3
	Ro+M1	91.4	92.1	96.9	96.7	41.8	44.5	47.2	58.3
	R1+Mo	81.7	85.8	87.9	89.3	36.2	39.4	42.5	48.1
	R1+M1	101.7	105.4	109.1	108.6	53.8	55.0	58.1	60.9
Mean		81.3	84.5	89.3	86.7	38.3	41.4	44.1	49.9
Zn_1	Ro+Mo	61.1	63.2	65.2	68.2	28.9	31.4	40.9	46.9
	Ro+M1	90.2	97.4	98.5	100.3	46.3	48.2	56.8	59.4
	R1+Mo	84.1	86.6	86.4	92.1	40.7	42.9	48.8	55.3
	R1+M1	113.2	118.7	116.1	121.7	56.0	59.2	65.0	62.3
Mean		87.2	91.5	91.6	95.6	43.0	45.4	52.9	56.0
Zn_2	Ro+Mo	63.4	68.9	71.9	74.9	30.0	33.6	35.8	37.8
	Ro+M1	93.4	99.6	98.1	107.9	49.9	49.3	54.6	58.2
	R1+Mo	85.0	88.5	88.7	96.2	43.1	46.6	52.3	56.2
	R1+M1	120.3	128.5	129.7	132.1	61.7	59.4	68.8	63.5
Mean		90.5	96.4	97.1	102.8	46.2	47.2	52.9	54.0
Over all mean	Ro+Mo	58.2	62.2	66.8	65.1	26.8	30.6	35.1	390
	Ro+M1	91.7	96.4	97.8	101.6	46.0	47.3	52.9	58.6
	R1+Mo	83.6	87.0	87.7	92.5	40.0	43.0	47.9	53.2
	R1+M1	111.7	117.5	118.3	120.8	57.2	57.9	64.0	62.2

Abbreviations: as those stated for Table (2).

the higher number and dry weights of developed nodules as well as N_2-ase which were observed in case of zinc application treatments at 20 ppm(Table, 2).

Ammoniacal and nitrate nitrogen content was higher during flowering stage than vegetative one. The same trend of results was observed with all treatments as well as in the two growing seasons. The higher levels of NH_4-N and NO_3-N recorded during the flowering stage could be attributed to the high multiplication of ammonifying and nitrifying bacteria during flowering stage as a result of the positive qualitative and quantitative changes in nature of the plant root exudates during different growth stages. This result is in accordance with the findings of **Neweigy *et al* (1997)** and **Hanafy *et al* (1998)** who found that the ammonifying and nitrifying bacterial densities in rhizosphere were higher during heading stage of plant growth rather than other plant growth stages.

Data also show that available phosphorus and CO_2 evolution in rhizosphere were increased with either mycorrhizal or rhizobial inoculated treatments in comparison with uninoculated ones. Mycorrhizal inoculated treatments gave higher records of available-P and CO_2 evolution than rhizobial inoculated ones. Moreover, dual inoculation with *Rhizobium* and *Glomus aggregatum* showed the highest records of available-P and CO_2 evolution. This result was consistent in the two growing seasons.

Regarding the effect of zinc application, obtained data show that zinc spraying of mungbean plants in a 20 ppm concentration gave higher records of available-P and CO_2 evolution than zinc application at 10 ppm. This may be due to the higher rates of mycorrhizal root infection which was observed in the treatments of zinc application at 20 ppm (Table, 2). Available phosphorus and CO_2 evolution were also higher during flowering stage than vegetative one. This results could be attributed to the higher multiplication rate of phosphate dissolving bacteria and mycorrhizal root infection which tended to increase progressively with plant growth. These results are in harmony with those reported by **Ahmed (1995)**; **Neweigy *et al* (1997)**, **Mikhaeel *et al* (2000)** and **Abou-Aly & Gomaa (2002)** who found that available phosphorus content increased during flowering stage when the plants were inoculated with phosphate solubilizing microorganisms.

With respect to the interaction effect, results in Table (3) emphasize that dual inoculation with *Rhizobium and* mycorrhizae combined with zinc foliar application gave higher rhizospheric $NH_4 - N$, NO_3- N , available – P and CO_2 evolution than inoculation only or zinc foliar application singularly. The highest values of tested parameters were observed in the treatment of dual inoculation combined with zinc foliar application (20 ppm).

Effect of zinc foliar application, dual inoculation and their interaction on growth characters of mungbean plants

Data recorded in Table (4) emphasize that growth characters of mungbean plants i.e. plant height, number. of branches/plant and dry weights of stem, leaves and pods / plant were significantly increased with either rhizobial or mycorrhizal inoculation compared to uninoculated controls. Several investigators

Table 4. Effect of zinc foliar application, dual inoculation and their interaction on growth characters of mungbean plants

Zinc spraying	Dual inoculation	Plant height (cm)		No. of branches per plant		Dry weight of stem (g/plant)		Dry weight of leaves (g/plant)		Dry weight of pods (g/plant)	
		2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Zn_0	Ro+Mo	89g	99j	3.5f	3.1e	8.8g	10.4g	12.9f	9.6a	5.7f	6.5a
	Ro+M1	111b	109h	4.3cde	3.9cd	10.7e	11.9ef	17.0bcd	10.6a	6.5e	6.9a
	R1+Mo	113cd	111g	4.4abcd	4.0bc	11.1cd	12.5de	17.2abc	11.1a	7.8c	7.5a
	R1+M1	115c	121c	4.5abcd	4.5a	11.2bc	13.7c	17.8ab	11.4a	8.1c	8.3a
Mean		107C	110C	4.2B	3.9B	10.5B	12.1C	16.2C	10.7B	7.0C	7.3C
Zn_1	Ro+Mo	98f	105i	4.1e	3.7d	10.5f	11.4f	14.5e	10.1a	6.3e	6.3a
	Ro+M1	108e	112g	4.4bcd	4.1bc	10.8e	12.4de	16.8cd	10.9a	7.2d	7.5a
	R1+Mo	119b	115e	4.5abcd	4.2b	11.0d	12.9d	17.6ab	11.1a	7.8c	7.8a
	R1+M1	118b	125b	4.7a	4.5a	11.4ab	14.4b	18.0a	12.2a	8.7b	9.1a
Mean		110B	114B	4.4A	4.1A	10.9A	12.8B	16.7B	11.1AB	7.5B	7.6B
Zn_2	Ro+Mo	108e	108h	4.3cde	3.9cd	10.3f	11.9ef	16.4d	10.3a	6.8de	6.7a
	Ro+M1	113cd	114f	4.3cde	4.2ab	10.8e	12.5de	17.1bcd	11.2a	7.9c	7.9a
	R1+Mo	118b	118d	4.6abc	4.3ab	11.1cd	13.0d	17.7ab	11.2a	7.9c	8.1a
	R1+M1	123a	131a	4.6ab	4.5a	11.5a	15.6a	18.0a	13.0a	9.5a	9.7a
Mean		115A	118A	4.4A	4.2A	10.9A	13.2A	17.3A	11.4A	8.0A	8.1A
Over all mean	Ro+Mo	98D	104D	3.9C	3.5C	9.9D	11.2D	14.6C	10.0C	6.3D	6.5D
	Ro+M1	111C	111C	4.3B	4.0B	10.8C	12.3C	17.0B	10.9B	7.2C	7.4C
	R1+Mo	116B	115B	4.5A	4.1B	11.1B	12.8B	17.5A	11.1B	7.8B	7.8B
	R1+M1	118A	126A	4.5A	4.5A	11.4A	14.6A	17.9A	12.2A	8.8A	9.0A

Abbreviations: as those stated for Table (2).
Means followed by the same letter (s) within each column, are not significantly different from each other at 5% level.

showed that inoculation of leguminous crops with either rhizobia or mycorrhizae improved plant growth characters (**Trafdar & Rao, 1997; Gomaa and El-Kholy, 1999; Hessein, 2000** and **Abd El-Fattah, 2001**).

Generally, significant increases in most plant growth characters were observed with rhizobial inoculation compared to mycorrhizal inoculation. This result was true in the two growing seasons. Mungbean growth characters were significantly increased in case of dual inoculation with *Rhizobium* and *Glomus aggregatum* and this was observed in the two growing seasons. These results are in agreement with those obtained by **Thakur & Panwar (1995); El-Ghandour *et al* (1997)** and **Mikhaeel *et al* (2000)** who demonstrated the possibility of mycorrhizal inoculation to increase the effectiveness of *Rhizobium* in mungbean and other legumes. They suggested that the higher concentration of plant phosphorus which results from mycorrhizal colonization could enhance nodulation, N_2-fixation and growth performance of the inoculated plants. Moreover, the positive effect of mycorrhizae on the growth of different plants was demonstrated by several workers (**Yassen, 1993; Fares, 1997** and **Zaghloul, 1999**). The stimulatory effect of mycorrhizae can be attributed to that mycorrhizae promote absorption of nutrients especially phosphorus and micro-nutrients from soil by the growing plants.

Data in Table (4) also show that zinc application either in 10 ppm or 20 ppm concentrations improved mungbean growth characters compared to no zinc application. Mungbean growth characters were slightly differed when zinc was sprayed at either 10 or 20 ppm and this was true in the two growing seasons.

Regarding the interaction effect, obtained data show that mungbean plants inoculated with both of *Rhizobium and* mycorrhizae accompanied with zinc foliar application showed significant increases in most studied growth characters compared to either mungbean inoculation or zinc foliar application separately. A high significant increase of plant growth was obtained in inoculated treatments with *Rhizobium* + mycorrhizae and sprayed with zinc in a concentration of 20 ppm.

These results are in accordance with those obtained by **Parasad & Ram (1991)** and **Abadi *et al* (1995)** who found that the interactive effect of *Bradyrhizobium* inoculation and zinc application improved nodulation and growth of mungbean and soybean plants.

Effect of zinc foliar application, dual inoculation and their interaction on macro-nutrients content of mungbean shoots

It is obvious from data presented in Table (5) that total nitrogen, phosphorus and potassium content in shoots of mungbean plants were increased in the treatments inoculated with either *Rhizobium* or mycorrhizae compared to uninoculated ones. Rhizobial inoculated treatments gave higher content of total nitrogen than mycorrhizal inoculated ones. While, mycorrhizal inoculated treatments gave higher records of total phosphorus and potassium compared to rhizobial inoculated ones.

Macro-nutrients content (NPK) of mungbean plants were higher in case of

Table 5. Effect of zinc foliar application, dual inoculation and their interaction on macro-nutrients content of mungbean shoots

Zinc Spraying	Dual Inoculation	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
		Vegetative stage		Flowering stage		Vegetative stage		Flowering stage		Vegetative stage		Flowering stage	
		2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Zn_0	Ro+Mo	1.66	1.75	1.77	1.82	0.11	0.12	0.12	0.14	1.60	1.63	1.74	1.77
	Ro+M1	1.85	2.13	1.96	2.24	0.18	0.23	0.26	0.28	1.88	1.90	1.91	1.96
	R1+Mo	1.92	2.18	1.98	2.30	0.16	0.20	0.23	0.25	1.60	1.70	1.88	1.92
	R1+M1	2.10	2.25	2.17	2.69	0.23	0.26	0.32	0.34	2.85	2.78	3.01	2.84
Mean		1.88	2.08	1.97	2.26	0.17	0.20	0.23	0.25	1.98	2.00	2.14	2.12
Zn_1	Ro+Mo	2.08	2.30	2.18	2.46	0.12	0.15	0.14	0.17	2.09	2.15	2.33	2.40
	Ro+M1	2.23	2.33	2.41	2.48	0.24	0.29	0.36	0.39	2.78	2.64	2.90	2.71
	R1+Mo	2.69	2.74	2.77	2.81	0.21	0.23	0.26	0.28	2.63	2.55	2.88	2.67
	R1+M1	2.94	2.86	3.29	3.41	0.26	0.30	0.38	0.43	2.96	2.95	3.10	2.98
Mean		2.49	2.56	2.66	2.79	0.21	0.24	0.29	0.32	2.62	2.57	2.80	2.69
Zn_2	Ro+Mo	2.30	2.46	2.49	2.74	0.15	0.18	0.17	0.20	2.23	2.16	2.48	2.32
	Ro+M1	2.38	2.80	2.51	2.91	0.29	0.31	0.39	0.42	2.56	2.19	2.70	2.94
	R1+Mo	2.71	2.83	2.99	2.97	0.23	0.24	0.27	0.29	2.52	2.74	2.67	2.84
	R1+M1	3.17	3.29	3.58	3.65	0.30	0.32	0.40	0.44	3.22	3.15	3.31	3.63
Mean		2.64	2.85	2.89	3.07	0.24	0.26	0.31	0.34	2.63	2.56	2.79	2.93
Over all mean	Ro+Mo	2.01	2.17	2.15	2.34	0.13	0.15	0.14	0.17	1.97	1.98	2.18	2.16
	Ro+M1	2.15	2.42	2.29	2.54	0.24	0.28	0.34	0.36	2.41	2.24	2.31	2.54
	R1+Mo	2.44	2.58	2.58	2.69	0.20	0.22	0.25	0.27	2.58	2.33	2.48	2.48
	R1+M1	2.74	2.80	3.01	3.25	0.26	0.29	0.28	0.40	3.01	2.96	3.14	3.15

Abbreviations : as those stated for Table (2).

dual inoculation with *Rhizobium* and mycorrhizae than those recorded in treatments inoculated with either of *Rhizobium* or mycorrhizae. This may be due to the synergistic effect between *Rhizobium* and VAM fungi.

Regarding the zinc application effect, obtained results show that macro-nutrients content increased in the treatments sprayed with either 10 or 20 ppm compared to the treatments which no zinc application. The highest plant NPK levels were observed with dual inoculation and zinc application (20 ppm) and this was observed in the two growing seasons. This result can be attributed to the higher N_2-ase activity and mycorrhizal root infection recorded in such case (Table, 2).

With respect to the interaction effect, data in Table (5) clearly show that dual inoculation with *Rhizobium and* mycorrhizae combined with zinc foliar application gave the highest macro-nutrients content in shoots of mungbean plants than either mungbean inoculation or zinc foliar application solely. The highest plant NPK content were obtained in the treatment of dual inoculation combined with zinc foliar application in a concentration of 20 ppm.

These results are confirmed those obtained by **Abadi *et al* (1995)** and **Amara and Nasr (1995)** who found that combined inoculation of N_2-fixing bacteria and phosphate dissolvers + zinc application gave the highest macro-nutrients content of plant shoots.

Data also indicate that macro-nutrients content of mungbean shoots was higher during flowering than vegetative stage. This was observed in all treatments as well as in the two growing seasons. The higher records of macro-nutrients content during flowering stage is likely to be due to the increase in ammoniacal, nitrate nitrogen and available phosphorus in rhizosphere soil which was observed during flowering stage under different treatments (Table, 3). Generally, macro-nutrients content in mungbean shoots were higher in the 2^{nd} season than in the 1^{st} one. This difference between the two seasons may be due to the changes in the climatic conditions.

Effect of zinc foliar application, dual inoculation and their interaction on micro-nutrients content in shoots of mungbean plants

It is clear from data presented in Table (6) that micro-nutrients (iron, zinc and copper) content of mungbean shoots were remarkably increased in the treatments inoculated with either *Rhizobium* or mycorrhizae compared to uninoculated ones. Mungbean shoots contained higher concentrations of micro-nutrients in the treatments inoculated with *Rhizobium* than those detected in the treatments inoculated with mycorrhizae. The same trend was recorded in both growing seasons and different growth stages of mungbean plants.

The highest micro-nutrients content was observed in the case of dual inoculation compared to the application of either *Rhizobium* or VAM inoculation. These results are in harmony with those reported by **Parasad & Ram (1991)** and **Abadi *et al* (1995)** who found that dual fixation, mycorrhizal colonization and increased their macro and micro-nutrients content. inoculation of legumes with symbiotic N_2-fixers and mycorrhizae enhanced N_2-.

Table 6. Effect of zinc foliar application, dual inoculation and their interaction on micro-nutrients content in shoots of mungbean plants

Zinc spraying	Dual inoculation	Iron (ppm)			
		Vegetative stage		Flowering stage	
		2000	2001	2000	2001
Zn_0	Ro+Mo	800	819.3	867.1	936.2
	Ro+M1	1600	1675	1715	1893
	R1+Mo	1800	1837	1818	1885
	R1+M1	2032	2103	2123	2231
Mean		1558	1609	1631	1736
Zn_1	Ro+Mo	968.1	982.5	1021.3	1133
	Ro+M1	1810	1896.1	2105	2153
	R1+Mo	2040	2156	2266	2287
	R1+M1	2250	2268	2365	2379
Mean		1767	1826	1939	1988
Zn_2	Ro+Mo	1200	1209	1280.2	1270
	Ro+M1	1900	1983.2	2309	2439
	R1+Mo	2300	2356	2370	2407
	R1+M1	2363	2408	2460	2482
Mean		1941	1989	2105	2150
Over all mean	Ro+Mo	989	1004	1056	1113
	Ro+M1	1770	1851	2043	2162
	R1+Mo	2047	2116	2151	2193
	R1+M1	2215	2260	2316	2364

Table 6. Cont.

Zinc spraying	Dual inoculation	Zinc (ppm)			
		Vegetative stage		Flowering stage	
		2000	2001	2000	2001
Zn_0	Ro+Mo	118.0	120.2	134.3	145.9
	Ro+M1	171.6	183.4	178.7	185.2
	R1+Mo	183.5	191.5	188.5	199.1
	R1+M1	180.3	181.0	203.1	199.2
Mean		163.4	169.0	176.2	182.4
Zn_1	Ro+Mo	142.0	146.4	151.5	161.8
	Ro+M1	232.0	235.1	240.3	251.6
	R1+Mo	260.7	282.8	269.2	290.1
	R1+M1	274.6	278.1	281.1	285.7
Mean		227.3	235.6	235.5	247.3
Zn_2	Ro+Mo	160.0	163.7	181.7	188.5
	Ro+M1	243.1	238.5	249.2	262.6
	R1+Mo	281.2	288.0	292.8	297.3
	R1+M1	295.8	293.1	305.4	319.2
Mean		245.0	245.8	257.3	266.9
Over all mean	Ro+Mo	140.0	143.4	155.8	165.4
	Ro+M1	215.6	219.0	222.7	233.1
	R1+Mo	241.8	254.1	250.2	262.2
	R1+M1	250.2	250.7	263.2	268.0

Table 6. Cont.

Zinc spraying	Dual inoculation	Copper (ppm)			
		Vegetative stage		Flowering stage	
		2000	2001	2000	2001
Zn_0	Ro+Mo	36.4	39.1	45.8	49.5
	Ro+M1	39.3	42.5	54.5	57.2
	R1+Mo	45.6	48.7	63.6	66.8
	R1+M1	62.4	63.4	82.7	94.5
Mean		45.9	48.4	61.7	67.0
Zn_1	Ro+Mo	42.1	45.2	50.5	53.1
	Ro+M1	48.5	59.1	60.1	67.5
	R1+Mo	56.8	58.3	79.0	87.2
	R1+M1	78.3	79.6	91.7	98.1
Mean		56.4	60.6	70.3	76.5
Zn_2	Ro+Mo	48.2	47.5	52.0	58.6
	Ro+M1	56.7	63.2	68.6	71.6
	R1+Mo	65.4	69.1	88.2	92.7
	R1+M1	84.6	86.3	102.0	108.1
Mean		63.7	66.5	77.7	82.8
Over all mean	Ro+Mo	42.2	43.9	49.4	53.7
	Ro+M1	48.2	54.9	61.1	65.4
	R1+Mo	55.9	58.7	76.9	82.2
	R1+M1	75.1	76.4	92.1	100.2

Abbreviations : as those stated for Table (2).

With respect to the effect of zinc application, obtained data emphasize that iron, zinc and copper contents of mungbean shoots were increased in the treatments sprayed with zinc solution either of 10 or 20 ppm concentration. Zinc spraying using a concentration of 20 ppm gave higher content of micro-nutrients than using a concentration of 10 ppm. This trend of results was observed in the two plant growth stages. The highest contents of micro-nutrients in shoots were observed with dual inoculation and zinc application in a concentration of 20 ppm.

Concerning the interaction effect, data indicate that dual inoculation with *Rhizobium and* mycorrhizae combined with zinc foliar application gave higher micronutrients shoot content than inoculation or zinc foliar application singularly.

It was also noticed that micronutrients content of mungbean shoots was higher during flowering stage than vegetative one and this was true during the two growing seasons.

Effect of zinc foliar application, dual inoculation and their interaction on yield, yield components and protein yield of mungbean plants

Data given in Table (7) indicate that pods number, weight of pods/plant, weight of seeds/plant, 1000-seed weight, seed yield/fed and biological yield/fed were significantly increased with either rhizobial or mycorrhizal inoculated treatments compared to uninoculated ones and this observation was consistent in the two growing seasons.

These results are in accordance with the findings of **Deka & Kakati (1996)**; **Hamed (1998)**; **Tantawy *et al* (1999)** and **Hessein (2000)** who found that rhizobial inoculation of mungbean significantly increased growth characters, yield and yield components. Concerning the effect of VA-mycorrhizae, **Ahmed (1995)** and **Tarafdar & Rao (1997)** found that VAM inoculation stimulated growth, yield and yield components of mungbean plants.

Data also show a significant increase in most studied yield criteria with rhizobial inoculation compared to mycorrhizal inoculation when each of them was used solely.

Data in Table (7) also show a dual inoculation of mungbean plants with *Rhizobium* and *Glomus aggregatum* gave higher yield and yield components in comparison to the application of each one alone. These results are in harmony with those obtained by **Thakur & Panwar (1995)**, **El-Ghandour *et al* (1997)**; **Hamed (1998)** and **Abd El-Fattah (2001)** who found that dual inoculation of mungbean and other legumes gave significant increases in yield and yield components compared to individual inoculation.

With respect to zinc foliar application effect, obtained data show that zinc application either in 10 ppm or 20 ppm concentration increased yield and yield components of mungbean plants compared to the treatments which no zinc application. Also, yield and yield components of mungbean were significantly increased when zinc was sprayed in a concentration of 20 ppm in the two growing seasons. The high yield and yield components of mungbean due to dual inoculation and zinc application can be attributed to the high N_2-ase activity, mycorrhizal root infection percentage (Table, 2). In

Table 7. Effect of zinc foliar application, dual inculation and their interation on yield, yield componencts, seed protin % and protein yield of mungbean plants

Zinc spraying	Dual inoculation	No. of pods/plant		Weight of pods (g/plant)		Weight of seeds (g/plant)		1000-seed weight (g)	
		2000	2001	2000	2001	2000	2001	2000	2001
Zn_0	Ro+Mo	18.7a	21.7h	10.6h	10.3a	8.4a	7.1h	39.1i	38.6a
	Ro+M1	20.2a	24.8fg	11.6fg	12.0a	8.3a	9.9f	42.3g	41.8a
	R1+Mo	21.0a	26.1de	12.3c	13.7a	8.5a	11.3de	43.9e	43.5a
	R1+M1	22.6a	27.6c	13.1c	18.3a	8.9a	12.5bc	45.8c	45.2a
Mean		20.6C	25.0C	11.9C	13.5C	8.5A	10.2C	42.8C	42.3C
Zn_1	Ro+Mo	19.0a	23.8g	11.3g	11.4a	8.0a	8.8g	41.4h	40.1a
	Ro+M1	20.8a	25.1ef	11.6fg	12.7a	8.4a	10.9e	42.9f	42.2a
	R1+Mo	21.5a	26.3d	12.4g	15.2a	8.6a	11.9cd	44.0e	44.0a
	R1+M1	23.4a	29.3b	13.8b	19.8a	9.1a	13.1b	46.6b	46.0a
Mean		21.2B	26.1B	12.3B	14.8B	8.5A	11.2B	43.7B	43.1B
Zn_2	Ro+Mo	19.5a	24.5fg	11.4g	12.0a	5.1a	9.6fg	41.9g	41.1a
	Ro+M1	21.2a	26.3d	11.8g	14.2a	8.5a	11.6de	43.1f	42.8a
	R1+Mo	22.3a	26.8cd	12.7d	16.2a	8.8a	12.1cd	44.9d	44.0a
	R1+M1	24.7a	31.2a	14.7a	21.5a	9.6a	15.2a	48.3a	46.9a
Mean		21.9A	27.2A	12.7A	16.0A	8.7A	12.1A	44.5A	43.7A
Over all mean	Ro+Mo	19.1B	23.3D	11.1D	11.2D	8.2C	8.5D	40.8D	39.9D
	Ro+M1	20.7C	25.4C	17.7C	12.9C	8.4BC	10.8C	42.8C	42.3C
	R1+Mo	21.6B	26.4B	12.5B	15.0B	8.6B	11.8B	44.3B	43.8B
	R1+M1	23.6A	29.3A	13.9A	19.9A	9.2A	13.6A	46.9A	46.0A

Table 7. Cont.

Zinc spraying	Dual inoculation	Seed yield (kg/fed)		Biological yield (ton/fed)		Protein percentage in seeds		Protein yield (kg/fed)	
		2000	2001	2000	2001	2000	2001	2000	2001
Zn_0	Ro+Mo	759g	763h	3.23d	3.51h	26.63a	27.25e	203.0a	207.4h
	Ro+M1	845def	917efg	4.1bc	4.14fg	28.23a	29.40cd	238.4a	269.7fg
	R1+Mo	872cd	960de	4.22abc	4.30ef	28.23a	29.67cd	247.6a	284.8de
	R1+M1	938b	1016bc	4.51abc	4.68bc	29.17a	30.23bc	273.5a	307.2c
Mean		853C	913B	3.99B	4.16C	28.06A	29.14B	240.6B	267.3C
Zn_1	Ro+Mo	819f	893g	3.80cd	4.03g	27.75a	29.08d	227.2a	259g
	Ro+M1	865cde	949def	4.13abc	4.20efg	28.25a	29.52cd	244.3a	280ef
	R1+Mo	883c	973d	4.29abc	4.43de	28.38a	29.58cd	250.5a	288.4de
	R1+M1	977a	1045b	4.69ab	4.83ab	29.40a	30.70ab	287.5a	321.1b
Mean		886B	965A	4.23A	4.37B	28.44A	29.72A	252.4A	287.3B
Zn_2	Ro+Mo	832ef	907fg	3.91c	4.14fg	27.70a	29.50cd	230.4a	267.5g
	Ro+M1	881c	962de	4.17abc	4.31ef	28.27a	29.63cd	249.2a	285.0de
	R1+Mo	897c	985cd	4.41abc	4.59cd	28.67a	29.88cd	257.1a	294.3d
	R1+M1	1010a	1088a	4.84a	5.00a	28.63a	31.25a	299.1a	339.9a
Mean		905A	985A	4.33A	4.51A	28.32A	30.06A	258.9A	296.7A
Over all mean	Ro+Mo	803D	854D	3.64C	3.89C	27.36B	28.61C	220.2C	244.8D
	Ro+M1	864C	943C	4.10B	4.22B	28.25A	29.52B	243.98B	278.2C
	R1+Mo	884B	973B	4.30B	4.44B	28.42A	29.71B	251.7B	289.2B
	R1+M1	975A	1050A	4.68A	4.83A	29.07A	30.73A	286.7A	322.7A

Abbreviations : as those stated for Table (2).

Means followed by the same letter (s) within each column, are not significantly different from each other at 5% level.

addition, higher levels of different N-forms and available phosphorus were detected in rhizosphere of such treatment (Table, 3).

It is also clear that protein percentage of mungbean seeds and protein yield (kg/fed) significantly increased in dually inoculated treatments compared to individual inoculation with either *Rhizobium* or mycorrhizae. This result confirmed those obtained by **Thakur & Ram (1995)**; **El-Ghandour *et al* (1997)** and **Mikhaeel *et al* (2000)**. Also, protein yield significantly increased as a result of zinc application either in 10 or 20 ppm concentration compared to the treatments which no zinc application. Zinc application in a concentration of 20 ppm gave higher records of protein yield compared to zinc application at 10 ppm and this was obvious in the two growing season.

Obtained results clearly show that mungbean plants inoculated with *Rhizobium* + mycorrhizae and sprayed with zinc showed significant increases in most yield criteria compared to either mungbean inoculation or zinc foliar application separately. The highly significant increase of yield and yield components was observed in the mungbean plants inoculated with *Rhizobium and* mycorrhizae accompanied with zinc spraying in a concentration of 20 ppm.

Obtained data obviously show that yield and yield components as well as protein yield/fed were higher in the 2nd season than in the 1st one. Again, such differences between the two growing seasons may be due to the changes in the climatic conditions.

CONCLUSION

Summing up, it can be concluded that mungbean inoculation with the specific strains of rhizobia resulted in higher growth performance and yield. Such application can be reduced inorganic nitrogen fertilization requirements and consequently minimize the environmental pollution by using less chemical fertilizers. Mungbean inoculation with mycorrhizae increased phosphorus availability, macro and micro-nutrients uptake and remarkably improved plant growth.

Zinc foliar application was found to strengthen the possitive effect of biofertilization. So, dual inoculation of mungbean with *Rhizobium* and mycorrhizae accompanied with zinc foliar application resulted in a considerable improvement of mungbean growth, yield and yield components as well as protein yield.

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تأثير التلقيح المزدوج بالميكوريزا والريزوبيوم والرش بالزنك على نمو ومحصول فول المانج

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أقيمت تجربتان حقليتان خلال موسمي ٢٠٠٠، ٢٠٠١ بمزرعة التجارب بكلية الزراعة بمشتهر لدراسة تأثير التلقيح [illegible]

إصابة الجذور بالميكوريزا وذلك بالمقارنة بالتلقيح الفردى بأي من الريزوبيوم والميكوريزا. أيضاء لوحظ من نتائج هذه الدراسة أن القياسات سابقة الذكر قد ازدادت

أظهرت تركيزات أعلى من الفوسفور الميسر ومعدل انطلاق ثانى أكسيد الكربون الناتج من نشاط الميكروبات فى منطقة الريزوسفير.

لوحظت فروقاً معنوية فى صفات النمو التى دُرست حيث ازدادت صفات النمو معنوياً عند التلقيح المزدوج مقارناً بالتلقيح الفردى وذلك خلال موسمى الدراسة. أيضاً، لوحظ تحسن في صفات النمو عند الرش بالزنك سواء بتركيز ١٠ أو ٢٠ جزء فى المليون وذلك بالمقارنة بعدم الرش بالزنك.

كذلك أوضحت نتائج هذه الدراسة أن محتوى المجموع الخضرى لنباتات فول المانج من العناصر المغذية الكبرى (نيتروجين وفوسفور وبوتاسيوم) والعناصر الصغرى (حديد وزنك ونحاس) كان أعلى فى حالة التلقيح المزدوج والرش بالزنك بتركيز ٢٠ جزء فى المليون.

أيضاً، وجد أن تركيز العناصر المغذية سواء الكبرى أو الصغرى قد ازداد خلال طور الإزهار وذلك بالمقارنة بطور النمو الخضرى لنباتات فول المانج.

أعلى محصول من البذور ، المحصول البيولوجى ومكوناته وكذلك محصول البروتين (كجم/فدان) لُوحظ عند التلقيح المزدوج بالريزوبيوم والميكورهيزا حيث كان ذلك أكثر وضوحاً عند الرش بالزنك بتركيز ٢٠ جزء فى المليون.

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