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Full Length Research Paper

A study on the effects of different biofertilizer combinations on yield, its components and growth indices of corn (*Zea mays* L.) under drought stress condition

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In order to study the combined effects of chemical phosphorus fertilizer, Phosphate-solubilising bacteria and mycorrhizal fungus they were determined on reducing drought stress damages of grain corn (SC704) under field conditions at College of Abouraihan, University of Tehran. The experiment was conducted as split plot RCBD with three replications. Experimental factors were drought stress as the main-plot (irrigation after 50 mm [without drought stress], 100 mm [low drought stress] and 150 mm [severe drought stress] evaporation from pan class (A), and fertilizer compounds as the sub-plot. Result of variance analysis showed that drought stress had significantly affected on most measured traits. All the measured traits in compounds phosphate-solubilising bacteria and Mycorrhiza fungies treatment were higher than other treatments under drought stress conditions except root colonization. Furthermore, grain yield in super phosphate triple treat under severe drought stress condition (3.55 ton/ha) was significantly less than normal irrigation (12.08 ton/ha) and low stress conditions (9.97 ton/ha). According to this experiment result, under drought stress condition, all calculated growth indices (such as LAI, CGR and NAR) decreased. Accordingly this experiment showed that phosphate-solubilising microorganisms can positively have effect on the increase of plant growth and phosphorus absorption in maize plant, leading to plant tolerance improving under drought stress conditions.

Key words: Mycorrhiza fungies, phosphate-solubilising bacteria, super phosphate triple, ear length.

INTRODUCTION

Intensive agriculture entails the risk of excessive fertilization. Microorganisms are important in agriculture in order to promote the circulation of plant nutrients and reduce the need for chemical fertilizers as much as possible. Organic agriculture is one of the ways that can produce high quality crops (Higa, 1994). Phosphorus (P) is an essential macronutrient for plant growth. Despite phosphorus being widely and abundantly distributed in the soil in both its inorganic and organic forms, many soils throughout the world are deficient in phosphorus. Phosphorus can be tightly bound with calcium, iron, or aluminium, leading to precipitation of phosphorus (Li et al*.,* 2003). Use of phosphorus fertilizers has become an expensive practice. The use of cheap, alternative sources of phosphorus, such as rock phosphate (RP) and microorganisms. Therefore, has received considerable attention in recent years (Rajan et al., 1996). Many bacteria (Rodriguez and Fraga, 1999) and fungi (Whitelaw, 2000) are able to improve plant growth by solubilising sparingly soluble inorganic and organic phosphates in the soil.

Sanders and Tinker (1971) and Hayman and Mosse (1972) indicated mycorrhizal plants take up phosphorus

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Table 1. Soil properties of experimental field.

PH	Ec ds.m-1	Clay %	Silt %	Sand %	Total N	P (mg/kg)	K (mg/kg)	soil texture
8	2.62	28	37	35	0.071	13	224	C.L

from the same source of readily soluble phosphorus as nonmycorrhizal plants. Production and release of organic acids is an important mechanism involved in inorganic phosphorus solubilisation (Richardson, 2001). Moreover, the use of bio stimulators in condition of environmental stress can decrease effects of stress and enhance soil water holding capacity, root growth and yield (Li and Ni, 1996). Drought is one of the most important abiotic stress factor (Bruce et al., 2002), which affects almost every aspects of plant growth (Aslam et al., 2006). Drought, or more generally, limited water availability is the main factor limiting crop production (Seghatoleslami et al., 2008). Drought is a permanent constraint to agricultural production in many developing countries, and an occasional cause of losses of agricultural production in developed ones (Ceccarelli and Grando, 1996). No exact figures on yield and economic losses in maize due to drought are available. In maize, grain yield reduction caused by drought ranges from 10 to 76% depending on the severity and stage of occurrence (Bolaoos et al., 1993). Sivasubramaniawn (1992) related the drought resistance of plants to the chlorophyll stability index that has been employed to determine the thermo stability of chlorophyll. Obviously, combined application of organic fertilizer and urea fertilizer or combination urea fertilizer and polyamines significantly increased yield, vegetative growth and chlorophyll index (Oad et al., 2004; Zeid, 2008). This experiment was conducted to investigate the effects of applications of biological fertilizer and chemical fertilizer on yield and component, yield, leaf area index, Crop Growth Rate (CGR), Net Assimilation Rate (NAR) of corn under drought stress.

MATERIALS AND METHODS

Combined effects of phosphorus fertilizer, phosphate-solubilising bacteria and mycorrhizal fungus were determined on reducing drought stress damages of grain corn (KSC704 commercial hybrid) under field conditions in experimental farm College of Abouraihan, University of Tehran (35°28'N, 42.51°17'E, altitude 1024 m). The experiment was planted in 2009 as a randomized complete block design with split-plot arrangement and three replications. The soil texture was clay loam and the result of soil analysis presented in Table 1.

Treatment consisted of three levels of drought stress: without stress (irrigation after 50 mm evaporation from pan class A), low drought stress (irrigation after 100 mm evaporation from pan class A) and severe drought stress (irrigation after 150 mm evaporation from pan class A). In sub-plots five compound fertilizer such as: (b1) phosphate-solubilising bacteria with Mycorrhiza fungies, (b2) phosphate-solubilising bacteria and Mycorrhiza fungi with 50% super phosphate triple, (b3) phosphate-solubilising bacteria with 50% super phosphate triple, (b4) Mycorrhiza fungi with 50% super phosphate triple and (b5) phosphate chemical fertilizer (100% super phosphate triple) were used.

Phosphate solubilising microorganisms used in this experiment were included Mycorrhiza fungi (*Glomus mosseae*) (with 65-70% colonization rate). Also biofertilizer phosphate-solubilising bacteria (biophosphor ®) was included Bacillus and Pseudomonas with CFU=10^7.

Plants were grown in five-row plots with 5 m length and 0.75 cm spacing between rows. The plant density was 66000 plant/ha. Fertilizer was used based on soil test. Irrigation was performed on class A evaporation pan for each treatment. Data was recorded on 10 competitive plants of each plot and grain yield (kg ha^{-1}) was calculated for the entire plot. Each plot was harvested at maturity for yield and yield components and leaf area index and dry matter were measured each 15 days to calculate Crop Growth Rate (CGR), Net Assimilation Rate (NAR) and Leaf Area Index (LAI) according to below equations:

(1) $LAI = LA / SA$
(2) $CGR = (W_2 - W_1) / SA(t_2 - t_1)$ $g.m^{-2}.day^{-1}$
(3) $NAR = (W_2 - W_1) / (t_2 - t_1) * (\ln LA_2 - \ln LA_1) / (LA_2 - LA_1)$ $mg.mm^{-2}.day^{-1}$

In above abbreviations: LA = Leaf Area, SA = Ground area that occupied a plant. W = Dry matter, t = Day after planting.

Data was subjected to Analysis Of Variance (ANOVA) and the treatment means was compared using Duncan's multiple range test (alpha = 5%). The analysis was done by MSTATC and SAS (Ver. 9.1) software. Microsoft office Excel was used for figures drawing and indices calculation.

RESULTS

Analysis of variance showed that there are significant differences among most traits (Table 2). A significant effect of stress levels treatments on grain yield of maize. The highest grain yield of 12.08 ton/ ha was obtained for the normal irrigation treatment and lowest (3.55 ton/ha) for the severe Drought stress treatment (Table 3). The results showed that stress treatment significantly reduced ($P \leq 0.05$) grain yield, percent colonization and harvest index. There were no significant differences in stress levels for row number in ear but there was a significant difference in fertilizer compounds. The other researcher showed that drought stress declined seed yield and its components (Reca et al., 2001; Seghatoleslami et al., 2008).

All the assessed traits in b2 compound inoculate treatment were of higher values than other treats under drought stress condition. Furthermore, the investigated traits of b5 treat under severe drought stress were significantly less pronounced than normal irrigation and low stressed conditions. This finding was in agreement

Table 2. Analysis of variance of measured traits of corn under different fertilizer treatments and drought stress conditions.

S.O.V	df	Row No./ Ear	Kernel No./Row	300 Kernel weight	Ear length	Total Yield	Percent colonization	Harvest index
Replication	2	6.22ns	214.60ns	247.83ns	27.75ns	10.0**	14.04*	61.79*
Stress	2	18.52ns	2473.51**	2679.04*	193.86*	296.42**	638.77**	2329.07**
Main error	4	4.25	79.45	157.70	15.02	3.27	1.02	21.81
Fertilizer	4	8.18**	158.2**	164.58**	14.11**	20.49**	2842.30**	199.00**
Stress*Fertilizer	8	0.55ns	15.76ns	67.12ns	1.52ns	1.00ns	44.69**	10.39ns
Sub error	24	1.23	23.20	31.11	1.99	0.82	3.60	16.51
Mean		13.72	40.17	66.93	18.47	8.53	40.42	42.00

*, **, ns : significant at 5%, 1% level and not significant, respectively.

Table 3. Means comparison of measured traits of corn under different fertilizer treatments and drought stress conditions using Duncan's multiple range test.

	Row No./ Ear	Kernel No./ Row	300 Kernel Weight (gr)	Ear Length (cm)	Total Yield (ton/ha)	Percent colonization (%)	Harvest index (%)
Irrigation							
Normal irrigation	14.456a	49.22a	78.004a	21.222a	12.087a	45.47a	52.42a
Low drought stress	14.26a	45.82a	70.712a	19.807a	9.9712b	43.03b	45.37b
Severe drought stress	12.444a	25.479b	52.089b	14.41b	3.5507c	32.75c	28.20c
Fertilizer							
b1	14.445a	42.95ab	69.858ab	18.9263ab	9.3667b	57.93a	45.68a
b2	14.6303a	45.25a	72.44a	20.2215a	10.352a	23.39b	46.72a
b3	13.746a	39.39b	65.239bc	18.121bc	7.815c	27.07d	38.08b
b4	13.574a	39.013b	65.644bc	18.3509b	8.7463b	47.07c	43.44a
b5	12.21b	34.27c	61.487c	16.7778c	6.4014d	16.63e	36.07b

Means with same phrases in each columns not significant at 5% probability.

with the results of Ehteshami et al. (2009).

A combination of Mycorrhiza fungi and phosphate-solubilising bacteria had effects on these traits although, there were no significant differences among b2 and b5 for traits except for grain yield and percent colonization. Our results concur partly with observations made by Ehteshami et al. (2009) who reported that Mycorrhiza fungies and phosphate-solubilising bacteria increased traits.

According to this experiment result, under drought stress condition, seed inoculums with b2 treatment significantly affected the reduction of plant damages and therefore increased the total yield. Results of this experiment showed that phosphate-solubilising micro-organisms can positively interact with promoting plant growth as well as with phosphorus uptake in maize plant, leading to plant tolerance improved under drought stress conditions.

Leaf area index with the use of b1 was 3.8, in addition to normal irrigation maximum LAI was obtained among other levels (Figure 1). Application chemical fertilizer treatment alone in different levels of irrigation observed that LAI in this treatment was decreased (Figure 2). This result showed that biological fertilizer to obtain relative resistance opposes the drought stress in corn. The lowest LAI at flowering stage was in b5 (2.85) and drought stress treatment (2.49).

The other researcher showed that the highest LAI was in 8 days period of irrigation (5.1) and drought stress in this treatment decreased 11% in LAI (Jafari et al., 2010).

Crop growth rate in b2 during the experiment was increased compared to other treatment (Figure 3). Probably in this experiment the crop growth rate is related to leaf area index, for the reason that crop growth changing rate is depended on two parameters: Namely leaf area index and net assimilation rate. This finding was in agreement with the results of Brogeham (2000). At flowering stage (75-90 day after planting), Severe drought stress condition had decreased CGR index compared to other irrigation treatments (Figure 4). Net assimilation rate with the use of b2 was increased compared to other treatments (Figure 5). Other fertilizer

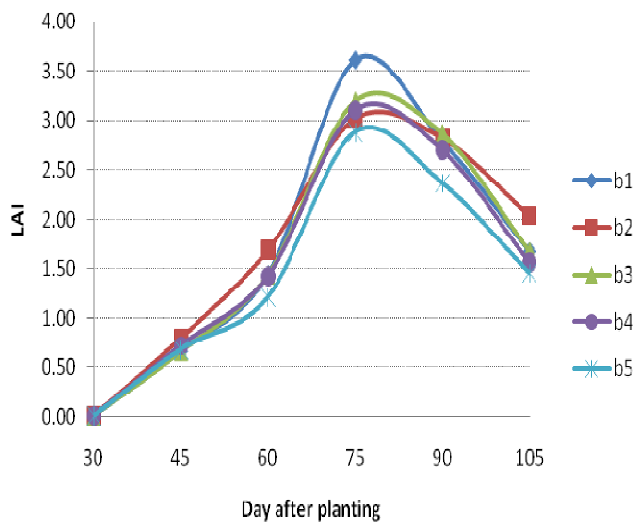

Figure 1. Leaf area index in five fertilizer treatment in during period of growth.

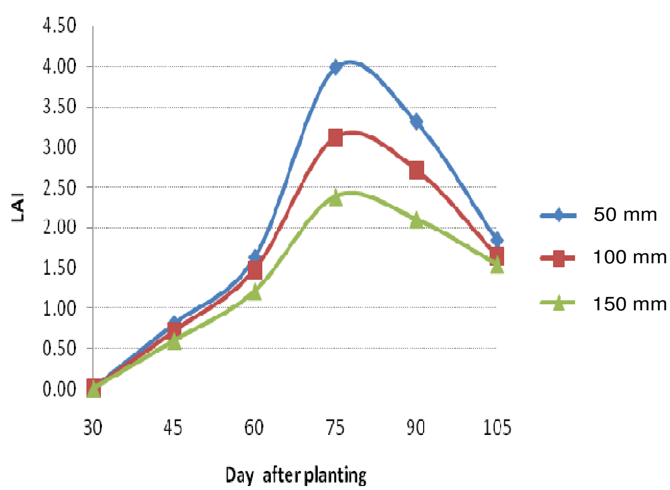

Figure 2. leaf area index in different levels irrigation in during period of growth.

compounds were not different from each other (Figure 5). The normal irrigation and low drought stress had overlapped on each other (Figure 6).

In biological fertilizer compounds the highest NAR was 0.055 ($mg.mm^{-2}.day^{-1}$). Result of this experiment showed that chemical fertilizer used under drought stress condition can decrease NAR index more than biological fertilizer. Balak (1993) showed that NAR would decrease with the increase of LAI. This trend of decrease will continue from the beginning till the end of growth season.

Conclusion

Results of this study showed that, drought stress caused

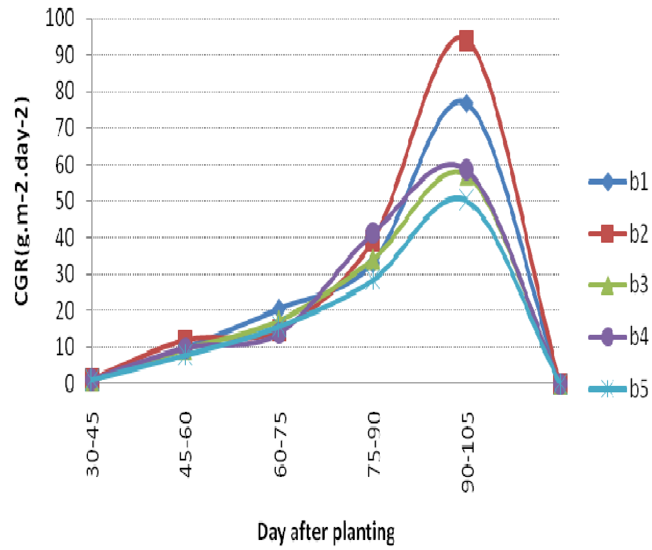

Figure 3. Crop growth rate in five fertilizer treatment in during period of growth.

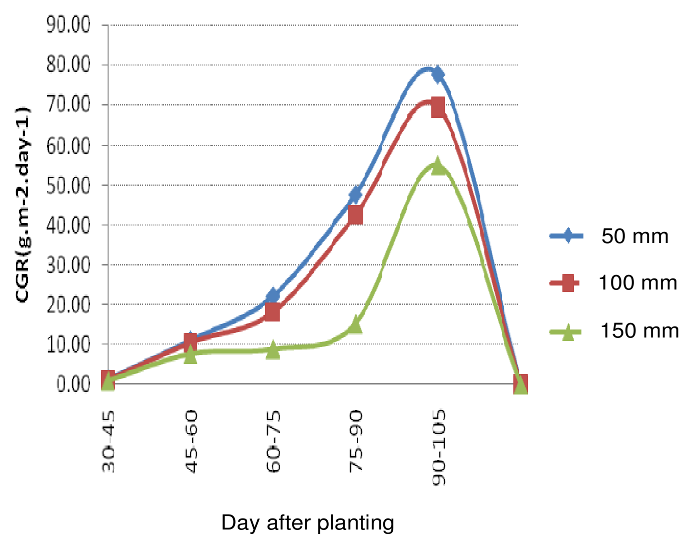

Figure 4. Crop growth rate in different levels irrigation in during period of growth.

decreases of yield and its component and measured indices such as LAI, CGR and NAR. Drought stress is a major abiotic constraint responsible for heavy production losses (Khan et al., 2007).

Application of biological fertilizer (b2) has given the highest grain yield in this study. El-Karmany (2001) showed that integrated chemical and biological fertilizer obtained highest kernel number per ear compared to sole application of them (4). Also our study showed that chemical fertilizer combined with biological fertilizer was beneficial to the environment because with decreasing the use of chemical fertilizer and use of organic inputs we

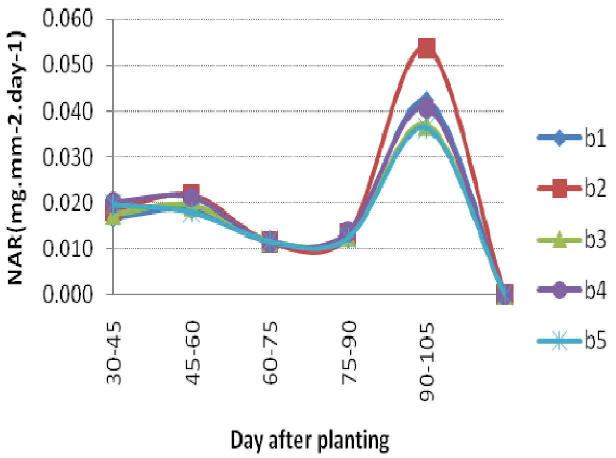

Figure 5. Net assimilation rate in five fertilizer treatment in during period of growth.

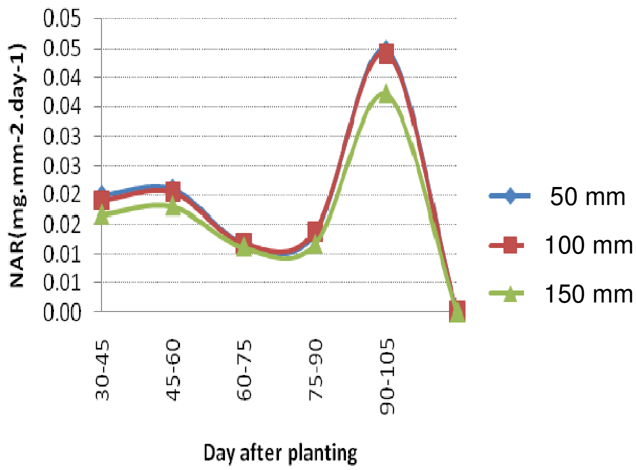

Figure 6. Net assimilation rate in different levels irrigation in during period of growth.

can side with sustainable agriculture, and increase the efficiency of water.

REFERENCES

Aslam M, Khan IA, Saleem M, Ali Z (2006). Assessment of water stress tolerance in different maize accessions at germination and early growth stage. Pak. J. Bot., 38(5): 1571-1579.

Balak DGR (1993). A growth analysis comparison of corn growth in conventional and equidistant plant spacing. Crop Sci., 24: 1184-1191.

Bolaòos J, Edmeades GO, Martinetz L (1993). Eight cycles of selection for drought tolerance in lowland tropical, maize. III. Responses in drought adaptive physiological and morphological traits. Field Crops Res., 31: 269–286.

Brogeham B (2000). A growth stage key for rape. Can. J. Plant Sci., 53: 473-482.

Bruce WB, Edmeades GO, Barker TC (2002). Molecular and physiological approaches to maize improvement for drought tolerance. J Exp Bot., 53: 13–25.

Ceccarelli S, Grando S (1996). Drought as a challenge for the plant breeder. Plant Growth Reg., 20: 149-155

Ehteshami SMR, M.Aghaalikhani M, Chaichi R, Khavazi K (2009). Effect of phosphate Biofertilizers on yield and yield components of grain corn (S.C704) under water deficit stress.Iranian J, Field Crop. Sci., 40: 15-26.

El-Karmany M (2001). Effect of organic manure and slow-release n-fertilizer on the productivity of wheat in sandy soil. Acta Agronom. Hungarica, 49: 379-385.

Hayman DS, Mosse B (1972). Plant growth responses to vesicular-arbuscular mycorrhiza. III. Increased uptake of labile P from soil. New Phytol., 71: 41-47.

Higa T (1994). The Complete Data of Em Encyclopedia. 2nd Edn., Sogo-Unicom in Japanese, Tokyo, pp. 385-388.

Safari Haghighi B, Yarmahmodi Z, Alizadeh O (2010). Evaluation the effects of biological fertilizer on physiological characteristic and yield and its components of corn (Zea mays L.) under drought stress. Am. J. Agric. Biol. Sci., 5: 189-193.

Khan H, Link TJ, Hocking F, Stoddard L (2007). Evaluation of physiological traits for improving drought tolerance in faba bean (*Vicia Faba* L.). Plant Soil. 292: 205-217.

Li WJ, Ni YZ (1996). Researches on application of microbial inoculants in crop production. In: Researches and application of En technology, Agriculture University Press, Beijing, China, pp: 42-84.

Li ST, Zhou J\I, Uang HY, Chen XQ, Du CW (2003). Characteristics of fixation and release of phosphorus in three soils. Acta Pedologzca Sznica (in Chinese). 40: 908-914.

Oad FCV, Buriro A, Agla SK (2004). Effect of organic and inorganic fertilizer application maize fodder production. Asian J. Plant Sci., 3: 375 377.

Rajan SSS, Watkinson JH, Sinclair AG (1996). Phosphate rocks for direct application to soil. Advances in Agronomy. 57: 77-159.

Reca J, Roldan J, Alcaide M, Lopez R, Camacho E (2001). Optimisation model for water allocation in deficit irrigation systems. I. Description of the model. Agric. Water Manage., 48: 103-116.

Richardson AE (2001). Prospects for using soil microorganisms to improve the acquisition of phosphorus by plants. Aust. J. Plant Physiol., 28: 897–906.

Rodriguez H, Fraga R (1999). Phosphate solubilizing bacteria and their role in plant growth promotion. Biotech. Adv., 17: 319–339.

Sanders FE, Xnker PB (1971). Mechanisms of absorption of phosphate from soil by Errdogorw mycorrhiza. Nutwr 233: 278.-279.

Seghatoleslami MJ, Kafi M, Majidi E (2008). Effect of drought stress at different growth stage on yield and water use efficiency of five proso millet (*Panicum Miliaceum L.*) genotypes. Pak. J. Bot., 40(4): 1427-1432.

Sivasubramaniawn K (1992). Chlorophyll stability index: methods for determining drought Hardness of Acacia species. Nitrogen Fixing Tree Res. Rep., 10: 111-112.

Whitelaw MA (2000). Growth promotion of plants inoculated with phosphate-solubilizing fungi. Adv. Agron., 69: 99–151.

Zeid IM (2008). Effect of Arginine and urea on polyamines content and growth of bean under salinity stress. Acta Physiologiea Plantarum, 10: 201-209.