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The effect of different levels of phosphorus from triple super phosphate chemical fertilizers and biological phosphate fertilizer (fertile 2) on yield components of corn (SC704) in Ahwaz weather conditions

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Abstract

In order to study the effect of different levels of triple super phosphate chemical fertilizer and biological phosphate fertilizer (fertile 2) on the yield components of corn (SC 704), this research was carried out in Shahid Salemi field located in Ahvaz in 2012 as a factorial experiment in randomized complete block design with 4 replications. The experiment included two factors: first, biological phosphate fertilizer (fertile 2) at three levels of 0, 100, 200 g/ha; second, triple super phosphate chemical fertilizer at three levels of 0, 60, 90 kg/ha of pure phosphorus (P_2O_5). The obtained results indicated the increase of biological yield, harvest index, grain yield and yield components of corn in the interactive treatments of biological phosphate fertilizer (fertile 2) and triple super phosphate chemical fertilizer. P_2B_2 treatment (100 g/ha biological phosphate fertilizer (fertile 2) and 60 kg/ha triple super phosphate fertilizer) had the highest biological yield and grain yield. Generally, it could be said that the increase of yield and elements uptake by the plant is related to the increase of soluble phosphorus in soil so that phosphorus plays an important role in root development and prevention of the accumulation of phosphorus compounds and their negative effects on the absorption of some elements by the soil. With regard to the results obtained it seems like that the decrease of application of triple super phosphate chemical fertilizer to less than a half together with the use of biological phosphate fertilizer (fertile 2) is particularly important to achieve more grain yield in Ahvaz weather conditions. The results showed that phosphate (fertile 2) significantly increased the grain yield.

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Introduction

In today's world, producing sufficient food is one of the most important priorities for human beings. What agriculture particularly agronomy is responsible to do is to produce more and better crops in order to remove hunger and poverty (Noor Mohammadi *et al.*, 1997). Due to limited arable lands, increasing the yield per area unit is one of the most important solutions to meet the need for food which requires the use improved farming and breeding techniques in order to take advantage of maximum potential per area unit. Corn is one of the most important and suitable cereal crops for human nutrition, but it is mainly used for feeding the livestock as fresh and silage forage (Noor Mohammadi *et al.*, 1997). Phosphorus is one of the main elements required by plants which has a basic role in the formation of seeds and is found in large quantities in fruits and seeds. However, unusual and inappropriate use of phosphorous fertilizers has unfortunately imposed deleterious effects on agricultural community (Karimian, 2000). Nutrients imbalance in plants and the decrease of crop yield are among these effects (Hossein Safari *et al.*, 2005). Even though the application of such fertilizers is necessary to provide nutrients, biological fertilizers could be used as supplement to reduce chemical fertilizer consumption (Heidary *et al.*, 2010). Biological fertilizers are made up of useful bacteria and fungi each of which is produced for a particular purpose. Such bacteria are usually settled around the roots and help absorb a certain element and cause the absorption of other elements and plant further growth (Yong *et al.*, 2005). One of these fertilizers is phosphate bio-fertilizer (fertile 2). Its high capability as a solvent for phosphate, climatic adaptability, stability during the storage, easy consumption, cheap transport, and compatibility with other fertilizers and pesticides are mentioned as the features of this kind of fertilizer (Hashemi, 2008). Jat and Shaktawat showed that phosphate bio-fertilizer in comparison to triple super phosphate fertilizers considerably increased the yield. Phosphate solubilizing bacteria secrete phosphatase and organic acids and thus make phosphate solution and increase the phosphate uptake by plants. . (Turan *et al*, 2006; Rodriguez *et al*, 1999). Toro *et al.* (1997) showed that the use of phosphate solubilizing bacteria increased the concentration of nitrogen and phosphorus in vegetative organs in comparison to the control treatment without using them. In an experiment, Peix *et al.* (2001) reported that the use of phosphate solubilizing bacteria caused the increase solubility of insoluble phosphorus, increase of phosphorus uptake, and significant increase of yield in barley and peas. Sylvia *et al.,* (1993) concluded that in treatments which used phosphate biological fertilizer, the concentration of phosphorus and copper increased in corn's shoots and seeds. Goenadi *et al.* (1998) reported that the use of bio-fertilizers and 50-75% chemical fertilizer led to a yield similar to the yield of the consumption of 100% chemical fertilizer. This research was carried out based on achieving the goals of sustainable agriculture and decreasing the use of chemical fertilizers and also examining the effects of phosphate bio-fertilizer (fertile 2),as an economically and environmentally efficient and a healthy fertilizer source, on the yield and yield components of corn.

Materials and methods

This research was carried out in Shahid Salemi field 36 km away from northeast of Ahvaz at latitude 31° 36′ and longitude 48° 53′ and 51 m above the sea level. The kind of soil used in the experiment was clay loam with pH=7.8 and EC=6.7. It was a factorial experiment as randomized complete block design with 4 replications and two factors. The first factor included biological phosphate fertilizer (fertile 2) at three levels of 0, 100, 200 g/h and the second factor included triple super phosphate chemical fertilizer at three levels of 0, 60, 90 kg/ha of pure phosphorus (P_2O_5). The needed corn seeds were moistened by a little water before planting and were mixed by the contents of a 100-g package of phosphate biological fertilizer (fertile 2) as the desired factors in the experiment and then after complete drying of the seeds in the shade, they were planted manually by considering the density of 75000 plants per hectare in a space of 18 cm from each other on one side of the stack. The seeds were planted in early August. Each plot contained 6 planting lines as long as 5 m and as distant as 75 cm from each other. Nitrogen was used from urea source as much as 180 kg in two stages, so that 90 kg was used during the planting and the rest was added then as the head. Triple super phosphate fertilizer was used to provide the needed phosphorus according to each treatment need.

Studied Traits

In this experiment traits such as biological yield, harvest index, grain yield, number of grains per row, number of grains per corn and 1000-grain weight were examined.

The harvest index was calculated through the following formula:

HI=(EY/BY).100

In which Hi: the harvest index

EY : economic yield

BY : biological yield

Data Analysis

The experiment data were analyzed by means of SAS software and in order to draw the diagrams Excel software was used and Duncan's multi range test was used to compare the means.

Results and discussion

Grain Yield

The effect of phosphate bio-fertilizer (fertile 2), triple super phosphate and their interactive effect on grain yield was significant (Table 1). The mean comparison results showed that the highest grain yield by 1128.29 g/m^2 belonged to the treatment with 60 kg/ha triple super phosphate chemical fertilizer and the treatment with 1261.98 g/m^2 phosphate bio-fertilizer (fertile 2) by 100 g/ha. (Table 2). The highest rate of grain yield by 1353.62 g/m^2 belonged to P_2B_2 treatment (100 g/ha phosphate fertilizer (fertile 2) and 60 kg/ha triple super phosphate) and the lowest rate belonged to P_1B_1(without phosphate fertilizer (fertile 2) and triple super phosphate) by 694.78 g/m^2. It seems like that the solubility of insoluble phosphates by microorganisms via producing organic acids and making oxoacids out of sugars and exchanging reactions in roots growth environment are other mechanisms of microorganisms in increasing nutrients uptake and consequently increasing the grain yield (Zaidi *et al.,* 2004). On the other hand, it could be concluded that the photosynthetic capacity of the plants treated with phosphorus solubilizing microorganisms has increased due to further phosphorus feeding and also the weight of grains has increased due to further assimilate mobilization to the seeds. Moreover, the studies done by Ortas (1996) showed that such microorganism would increase nutrition uptake and grain yield through decreasing soil pH. To explain this point, Tohidi Moghadam *et al* (2007) showed that the grain yield was more in treatments in which biological fertilizers and appropriate amount of phosphate chemical fertilizers were used. Mahdavi Damghani *et al.* (2008) reported that the interactive application of bio-fertilizers and chemical fertilizers increased the grain yield and decreased the consumption of chemical fertilizers.

Table 1. The ANNOVA results of grain yield and other traits of corn.

Experimented traits						d.f.	Variation sources
Harvest index	Biological yield	Grain yield	Number of grains per corn	Number of grains per row	1000-grain weight		
38.1 n.s	215014.06 n.s	14177.77*	374.37 n.s	2.71 n.s	644.32 *	2	block
402.09**	586360.25**	572438.17 **	15832.21**	91.16**	22849.28**	2	Super phosphate
136.11*	73758.17 n.s	96362.71**	6810.48**	14.63 n.s	1261.67**	2	Phosphate biological fertilizer (fertile 2)
38.93 n.s	115137.66 n.s	18567.71**	2793.54**	7.93 n.s	328.08 n.s	4	Interactive effect of triple super phosphate and fertile 2 biological fertilizer
29.27	40901.34	2966.25	236	5.54	172.99	16	error

Number of Grains per Row

The effect of phosphate bio-fertilizer (fertile 2) by itself and the interactive effect of phosphate bio-fertilizer (fertile 2) and triple super phosphate on the number of grain per row were not significant. Of course, the number of grains per row was significantly affected by triple super phosphate chemical fertilizer by itself ($P \leq 0.01$) (Table 1). The mean comparison results showed that the highest number of grains per row by the average of 31.54 belonged to the treatment by 60 kg/ha triple super phosphate chemical fertilizer and by the average of 33.57 grains per row belonged to the treatment by 100 g/ha phosphate bio-fertilizer (fertile 2) (Table 2). The highest number of grains per row by the average of 34.65 belonged to P_2B_2 treatment (100 g/ha fertile 2 phosphate and 60 kg/ha triple super phosphate) and the lowest number by the average of 26.61 belonged to P_1B_1 (without fertile 2 phosphate fertilizer and triple super phosphate). It seems like that this matter is due to more absorption of phosphorus by phosphorus solubilizing microorganisms and provision of better nutrition conditions such as the increase of nitrogen absorption by plant during the differentiation of spikelet and consequently the decrease of spikelet abortion and the increase of grains.The findings were consistent with the results obtained by Zahir *et al,* 2004) and (Rodriguez *et al,* 1999). The results were also consistent with the findings of Yazdani *et al.* (2007) who showed that the use of phosphorus solubilizing bacteria and growth enhancer bacteria (with enough input of NPK) increased the number of grains per row.

Table 2. Mean comparison of the effects of triple super phosphate and fertile **2** phosphate biological fertilizer on grain yield and other traits of corn.

Harvest index (%)	Biological yield (g/m²)	Grain yield (g/m²)	Number of grains per corn	Number of grains per row	1000-grain weight (g)	treatment
						Triple super phosphate fertilizer
52.7 [b]	1750.46 [a]	760.76 [c]	397.54 [c]	27.27 [c]	258.23 [c]	P_1 (0 kg/ha)
59.9 [a]	1886.02 [a]	1128.29 [a]	465.64 [a]	31.54 [a]	322.7 [a]	P_2 (60 kg/ha)
53.76 [b]	1922.18 [a]	1060.34 [a]	451.76 [a]	29.58 [b]	320.84 [a]	P_3 (90 kg/ha)
						Fertile 2 phosphate biological fertilizer
47.75 [c]	1628.35 [c]	921.57 [c]	411.16 [c]	29.05 [c]	301.33 [c]	B_1 (0 g/ha)
59.84 [a]	1799.81 [b]	1261.98[a]	480.79 [a]	33.57 [a]	354.53 [a]	B_2 (100 g/ha)
58.84 [a]	2130.5 [a]	1033.21 [b]	470.23 [a]	29.83 [c]	332.11 [b]	B_3 (200 g/ha)

Number of grains per corn

The number of grains per corn was significantly affected by fertile 2 phosphate bio-fertilizer alone and also by triple super phosphate chemical fertilizer . The interactive effect of fertile 2 phosphate bio-fertilizer and triple super phosphate on the number of grains was significant at 1% probability level (Table 1). The mean comparison results showed that the highest number of grains per corn by the average of 465.64 grains was observed in the treatment with 60 kg/ha triple super phosphate chemical fertilizer and also by the average of 480.79 grains in the treatment with 100 g/ha fertile 2 phosphate bio-fertilizer (Table 2). The highest rate of the number of grains per corn by the average of 507.64 grains, belonged to P_2B_2 treatment (100 kg/ha triple super phosphate) and the lowest rate was related to P_1B_3 treatment (200 g/ha fertile 2 phosphate bio-fertilizer without triple super phosphate) by the average of 396.04 grains. The increase of the number of grains per corn is due to more phosphorus uptake by phosphorus solubilizing microorganisms and provision of appropriate nutritional conditions such as the increase of nitrogen uptake by plant during the spikelet differentiation and the growth of flowers and consequently the decrease of spikelet abortion and the increase of the number of grains and leaf area and the improvement of photosynthesis and better distribution of assimilates in grains. The results were consistent with the findings of Zahir *et al.* (2004), Swedrzynska and Sawicka, (2000), Sturz *et al.* (2003), Rodriguez *et al.*(1999).

1000-grain weight

With regard to table (1) the simple effect of fertile 2 phosphate bio-fertilizer or triple super phosphate on grain yield was significant ($P \leq 0.01$), but the interactive effects of fertile 2 phosphate fertilizer and triple super phosphate was not significant. The mean comparison results showed that the highest weight of 1000-grain by 322.70 g belonged to the treatment with 60 kg/ha triple super phosphate chemical fertilizer and also the treatment with 100 gr/ha fertile 2 phosphate bio-fertilizer by 354.53 g (Table 2). Moreover, the highest rate of 1000-grain weight by 360.33 g, was related to P_2B_2 treatment (100 g/ha fertile 2 phosphate bio-fertilizer and 60 kg/ha triple super phosphate) and the lowest was related to P_1B_1 treatment (without triple super phosphate and fertile 2 phosphate bio-fertilizer) by 236.06 g. this might be due to useful effects of bio-fertilizer on the increase of root growth, appropriate nutrients supply, leaf area increase, and photosynthesis improvement and better distribution of assimilates in grains. Some researchers believe that the increase of 1000-grain weight is due to the release of phosphorus and its absorption by phosphorus solubilizing microorganism (Khaliq and Sanders, 2000). Also, it has been reported that the assimilates exchange would increase in inoculated plants (Auge *et al.,* 2001). According to Sanchez Diaz *et al.* (1995) biological coexistence increases the number of chloroplasts. The studies carried out by Ruiz Lozano and Azcon, (1995) showed that coexistence with phosphorus solubilizing microorganisms increased the efficiency of photosynthetic phosphorus consumption in comparison to non-symbiotic plants. Therefore, it could be concluded that photosynthetic capacity of the plants which are treated by phosphorus solubilizing microorganisms increases due to more phosphorus nutrition. Due to more assimilates distribution to grains the weight of grains increases, too (Koide, 1993).

Biological yield

According to table (1) the simple effect of triple super phosphate fertilizer on grain yield was significant ($P \leq 0.01$), but the simple effect of fertile 2 biological phosphate fertilizer and the interactive effects of fertile 2 phosphate bio-fertilizer and triple super phosphate was not significant. The mean comparison results showed that the highest biological yield by the average of 1922.18 g/m^2 belonged to the treatment with 90 kg/ha triple super phosphate chemical fertilizer and the treatment with 200 g/ha fertile 2 phosphate bio-fertilizer by 2130.5 g /m^2 (Table 2). The highest rate of biological yield by 2271.97 g/m^2 belonged to P_2B_2 treatment (100 g/ha fertile 2 phosphorus fertilizer and 60 kg/ha triple super phosphate) and the lowest rate was related to P_1B_1treatment (without triple super phosphate and fertile 2 phosphorus fertilizer) by 1173.51 g.

The findings of Subramanian *et al.* (1997) showed that the simultaneous use of chemical fertilizer and bio fertilizer, affects the plants physiology through increasing assimilates, changing the flow of assimilates in stems and roots and also absorbing minerals from soil. It seems like that the increase of plants biomass in appropriate nutritional conditions and plants access to sufficient water and nutrients especially phosphorus and nitrogen have been very affective in the increase of plant height via influencing the cells division and growth. Moreover, the solubility of insolvable phosphates by phosphorus solubilizing microorganisms and the secretion of growth enhancer hormones such as auxin, gibberellin, and cytokinin by these microorganisms increased the growth of the roots and the plants (Sattar and Guar, 1987). In different studies it has been observed that interactive treatments have increased the vegetative growth of plants and consequently the yield of cereal crops and legumes have increased under farming conditions

(Hoflich *et al.,* 1994). Moreover, phosphorus has increased nitrogen uptake and plants resistance to diseases and has controlled the negative effect of additional nitrogen and also has improved photosynthesis and assimilates production due to the increase of leaf area, increase of chlorophyll in leaves and increase of macro and micro elements absorbed by the plant roots. More importantly, more expansion and better continuity of leaf area induced sufficient strong physiological sources for receiving maximum light and producing dry matter. The results were consistent with the findings of Kazemi Posht Mesari *et al.* (2007) who showed that the highest rate of biological yield was achieved by consuming bio-fertilizers. Also, the results were consistent with the findings of Cavaglieri *et al.* (2004).

Index harvest

The simple effect of fertile 2 phosphate bio-fertilizer at 5% level and the simple effect of triple super phosphate at 1% level on the harvest index were significant. However, the interactive effect of fertile 2 phosphate bio-fertilizer and triple super phosphate on the harvest index was not significant (Table 1). The mean comparison results showed that the highest rate of harvest index by 59.9 was observed in the treatment with 60 kg/ha triple super phosphate and also in the treatment with 59.84 fertile 2 phosphate bio-fertilizer by 100 g/ha (Table 2). The highest rate of harvest index by 63.17 belonged to P_3B_2 treatment (100 g/ha fertile 2 phosphate fertilizer and 90 kg/ha triple super phosphate) and the lowest rate belonged to P_1B_1 treatment (without fertile 2 phosphate bio-fertilizer and triple super phosphate) by 42.11. Insignificant harvest index of the interactive treatments of chemical and bio-fertilizers in this research could lead to the conclusion that under appropriate nutritional conditions, the matters produced in total plant organs were more; however, the use of bio-fertilizer in comparison to the treatment without chemical and bio-fertilizer reduced the harvest index by affecting plant dry matter distribution and allocating less dry matter to the grain. The results were consistent with the findings of Cavaglieri *et al.* (2004).

Conclusion

The obtained results indicate the significant role of phosphorus in increasing biological yield, grain yield, and generally, the improvement of corn production. On the other hand, interactive treatments of fertile 2 phosphate bio-fertilizer and triple super phosphate chemical fertilizer increased the yield and yield components of corn. In this regard, P_2B_2 treatment (100 g/ha fertile 2 phosphate bio-fertilizer and 60 kg/ha triple super phosphate fertilizer) had the highest yield of total dry matter and grain yield. On the whole, it could be said that the increase of yield was related to the increase of consumed phosphorus by plant and also to the important role of this element in developing the root and preventing the accumulation of phosphorus combinations and their negative effects on the absorption of some elements in soil. Nutrients availability to plants largely depends on soil biological and chemical conditions. Phosphorus chemical fertilizers fixation under the soil existing conditions and changing them to forms which are not accessible for plants is the main problem. Therefore, fertile 2 phosphate bio-fertilizer in combination with appropriate amount of triple super phosphate chemical fertilizer reduces the need to phosphorus chemical fertilizers and increases their efficiency by releasing phosphorus gradually and changing it to absorbable form by plant.in fact, by settling in rhizosphere area, microorganisms use the roots exudates and provide the conditions for transforming insoluble phosphorus to usable form by for plants by changing pH or secreting enzymes. Moreover, such microorganisms have an important role in increasing correlation between the absorption of some elements like phosphorus, potassium, calcium, and nitrogen. Phosphate solubilizing bacteria in fertile 2 phosphate bio-fertilizer, by releasing organic acids and phosphatase acid, will cause enzymatic analysis of organic compounds and nutrients solution in soil and increase nutrients absorption in soil. Therefore, the importance of such microorganisms is not only due to their contribution to the absorption of certain elements but also other elements uptake and improvement of soil structure are the positive consequences of fertile 2 phosphate bio-fertilizer and thus the increase of phosphorus which is available for plants. Moreover, by using biological fertilizer in this experiment, the rate of phosphorus fertilizer consumption decreased as much as 50% without the significant decrease of the yield which is economically and environmentally considerable.

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References

Tohidi Moghadam HR, Sani B, Zahedi H, Pak Nejad F. 2007. Optimizing the use of nitrogen and phosphorus fertilizers by using biological fertilizers on soybean farming, 2nd National Conference on Iranian Ecological Agriculture.

Heidary KH, Ghaderi j. 2010 . the results of biologic fertilizer consumption in Kermanshah in recent years. 1st Congress on Fertilizer Challenges In Iran.

Safari H, Malek Zadeh A. 2005. The effect of chemical and microbial phosphorus fertilizers on the yield and yield components of corn, 9th Conference on Iranian Soil Science.

Kazemi Posht Mesari H, Pirdashti HA, Bahmanyar MA. 2006. Comparing the effects of mineral and biological phosphorus fertilizers on agronomic traits of two cultivars of broaden bean, Journal of Agriculture and Natural Resources, 4–13.

Mahdavi Damghani AM, Ebrahimpoor F, Sabahi H. 2008. the effects of the rate and method of bio-fertilizers consumption in combination with chemical fertilizers on yield and yield components of Maize, E-journal of Producing Crops, 4th year, No.3. magiran.com/p966853.

Noormohammadi GH, Siadat SA, Kashani A. 1997. Cereal crops agriculture, 1st volume, Shahid Chamran University Publications, Ahwaz, 308-325 p. 4 -03-6710-964.Code(Book):633 .

Hashemi A. 2008. Irrigated and rain-fed wheat farming using fertile 2 phosphate bio-fertilizer, summer.

Yazdani M, Pirdashti HA, Ismaeili MA, Bahmanyar MA. 2007. the effect of inoculation of phosphorus solubilizing and growth enhancer bacteria on the efficiency of nitrogen and phosphorus fertilizers consumption in planting corn (sc 604), E-journal of Crops Production **3(**2**).** magiran.com/p799265.

Auge RM, Duan X, Ebel RC, Stodola AJW. 2001. Non-hydraulic signalling of soil drying in mycorrhizal maize. Planta **197,**74-82. http://dx.doi.org/10.1007/BF00191609

Cavaglieri LR, Passone AMG. Etcheverry. (2004) Correlation between screening procedures to select root endophytes for biological control of Fusarium verticillioides in Zea mays.Biological Control **31,** 259-62. http://dx.doi.org/10.1016/j.biocontrol.2004.07.006

Goenadi DH. 1998. Fertilization efficiency of oil palm through biofertilizer application. 370-376 p. In: Proceedings of International Oil Palm Conference, Nusa Dua, Bali. http://agris.fao.org/aos/records/ID2003000234

Hoflich G, Wiehe W, Kuhn G. 1994. Plant growth stimulation with symbiotic and associative rhizosphere microorganisms. Experientia **50,** 897-905. http://dx.doi.org/0014.4754/94/10089709s1. 500.20

Jat BL, Shaktawat MS. 2003. Effect of residual phosphorus, sulphur and biofertilizers on productivity, economics and nutrient content of pearl millet (Pennisetum glaucum L.) in fenugreek

(Trigonella foenum-graecum L.)-pearl millet cropping sequence. Indian Journal of Agricultural Sciences **73 (3),** 134-137.

Khaliq A, Sanders FE. 2000. Effects of vesicular – arbuscular mycorrhizal inoculation on the yield and phosphorus uptake of field – grown barley. Soil Biology and Biochemistry **32,** 1691-1696. http://dx.doi.org/10.1016/S0038-0717(00)00086-9

Karimian N. 2000. Consequences of excessive consumption of phosphat chemical fertilizers. Soil and Water Research Institute of Iran Publication No. 12. (In Persian).

Koide R. 1993. Physiology of the mycorrhizal plant. Advance Plant Pathology **9,** 33-54. University Park,Pennsylvania,16802, USA. ISBN 0-12-033709-6

Ortas I. 1996. The influence of use of different rates of mycorrhizal inoculum on oot infection, plant growth, and phosphorus uptake. Communication Soil Science and Plant Analyses **27(18-20),** 2935-946. http://dx.doi.org/10.1080/00103629609369753

Peix A, Rivas-Boyere AA, Mateos PF. 2001. Growth promotion of chickpea and barley by a phosphate solubilizing strain of mesorhizobium mediterraneum under growth chamber conditions. Soil Biology and Biochemistry **33(1),** 110-103. http://dx.doi.org/10.1016/S0038-0717(00)00120-6

Rodr Guez H, Fraga R. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. Biotecnology Advances **17,** 319-339. http://dx.doi.org/10.1016/S0734-9750(99)00014-2

Ruiz-Lozano JM, Azcon R. 1995. Hyphal contribution to water uptake in mycorrhizal plants as affected by the fungal species and water status. Plant Physiology **95,** 472-478. http://dx.doi.org/10.1111/j.1399-3054.1995.tb00865.x

Sanchez-Diaz M, Pardo M, Antolin Pena J, Aguirreolea J. 1990. Effect of water stress on photosynthetic activity in the Medicago – Rhizobium – Glomus symbiosis. Plant Science **71,** 215 – 221. http://dx.doi.org/10.1016/0168-9452(90)90011-C

Sattar MA, Gaur AC. 1987. Production of auxins and gibberellins by phosphate dissolving microorganisms. Zentrabl Mikrologie **142,** 393-395. http://dx.doi.org/10.1016/S0232-4393(87) 800860

Swedrzynska D, Sawicka A. 2000. Effect of Inoculation with Azospirillum brasilense on development and yielding of maize under different cultivation conditions. Environmental Studies **6,** 506-509. ISSN 1230-1485.R .N .20013014582

Sturz AV, Christie BR. 2003. The management of soil quality and plant disease with rhizobacteria. Soil and Tillage Research. **72,** 107-123. http://dx.doi.org/10.1016/S0167-1987(03)00082-5

Subramanian KS, Charest C, Dwyer LM, Hamilton RI. 1997. Effects of arbuscular mychoriza on leaf water potential, sugar content and content during drought and recovery of maize. Canadian Journal of Botany **75,** 1582-1591. http://dx.doi.org/10.1139/b97-870

Sylvia DM, Hammond LC, Bennett JM, Haas JH, Linda SB. 1993. Field response of maize to a VAM fungus and water management. Agronomy Journal **85,** 193-198. http://dx.doi.org/10.2134/agronj1993

Toro M, Azcon R, Barea JM, 1997. Improvement of arbuscular mycorrhiza development by inoculation of soil with phosphate- solubilizing rhizobacteria to improve rock phosphate bioavailability (32p) and nutrient cycling. Applied and Environmental Microbiology **63(11),** 4408- 4412. http://aem.asm.org/content/63/11/4408

Turan M, Ataoglu N, Sahin F. 2006. Evaluation of the capacity of phosphate solubilizing bacteria and fungi on different forms of phosphorus in liquid culture. Sustainable Agricultural **28,** 99–108. http://dx.doi.org/10.1300/J046728n03_08

Yong K, Bae B, Choung Y. 2005. Optimization of biological phosphorus removal from contaminated sediments with phosphate- solubilizing microorganisms. Journal of Bioscience and Bioengineering **99,** 23-29. http://dx.doi.org/10.1263/jbb.99.23

Zahir AZ, Arshad M, Frankenberger WF. 2004. Plant growth promoting rhizobacteria: Advances in Agronomy **81,** 97-168. http://dx.doi.org/10.1016/S0065-2113(03)81003-9

Zaidi PH, Rafique S, Singh NN, Srinivasan G. 2004. Tolerance to excess moisture in maize (*Zea mays* L.) under excessive soil moisture stress. Field Crops Research **90,** 189-202. http://dx.doi.org/10.1016/j.fcr.2004.03.002