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Effect of bio-phosphate and chemical phosphorus fertilizer accompanied with micronutrient foliar application on growth, yield and yield components of maize (Single Cross 704)

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Abstract

The effects of bio-phosphate, chemical phosphorus fertilizer and micronutrient foliar application on growth, yield and yield components of maize (*Zea mays* L.) were studied in a field experiment at Kerman Agricultural and Natural Resources Research Centre (Iran). A split plot experiment based on randomized complete blocks design (RCBD) with four replications was followed in the study. The micronutrient foliar application in two levels (foliar application and non foliar application) were the main plots, and four levels of phosphate (T1: 0, T2: 100 kg/ha P_2O_5, T3: 100g bio-phosphate, T4: 100g bio-phosphate with 50 kg/ha P_2O_5) as the sub plots. Results showed that biological and chemical phosphorus fertilizers had a significant influence on growth, yield and yield components (except row number per ear). The maximum grain weight and grain number per ear was obtained by applying 50 kg/ha P_2O_5 plus bio-fertilizer. Significant effect of micronutrient foliar application was found on plant height, flag leaf length, grain and biological yield, however the effect of micronutrient foliar application on width of flag leaf, diameter of stem, number of rows per ear, number of grain per ear and weight of grain was not significant. Results indicate that applying the combined bio-phosphate and chemical phosphorus fertilizer can be practical and helpful method to increase maize yield and reduce the environmental pollution.

Keywords: Bio-phosphate; micronutrient; growth; yield; maize.
Abbreviations: S.C.704 - Single Cross 704; IAA – Indole-3 acetic acid; GA - Gibberellic acid; PGPR - Plant growth promoting rhizobacteria.

Introduction

Environmental problems caused by irregular application of chemical fertilizers, inappropriate energy production methods and excessive consumption costs have all had harmful effects on biological cycles and destroyed farming stability systems; these factors altogether encourage the application of bio fertilizers (Kannayan, 2002). Nowadays attention to biological fertilizer has been increased due to countries development, prices of chemical fertilizers and attention to sustainable agricultural systems (Ehteshami et al., 2007). Maize quantity and quality increased by utilization of fertilizer, (bio fertilizers especially), is the most important objectives of these products in worldwide (Ali et al., 2008; Hasaneen et al., 2009). Biological phosphate fertilizers containing beneficial bacteria and fungi increased phosphate solutions by increasing soil acidity or alkaline phosphatase enzyme, which can be absorbed by plants easily. Soil chemical and biological characteristics improved by bio fertilizer; moreover due to the use of low doses of chemical fertilizers, agricultural production will be free from contaminants (EL- Habbasha et al., 2007; Salimpour et al; 2010). In wheat, plant height, tiller number, panicle number, fresh weight, dry weight, and panicle height both before and after flowering were significantly influenced by seed inoculation with azospirilioum (Mubassara et al., 2008). Mehrvarz et al., (2008) in their study showed that maximum protein in barley was obtained by applying phosphate solubilizing microorganisms. Biological fertilizer with %50 of chemical fertilizers (nitrogen, phosphorus and potassium) led to an increase in plant growth, plant height, branch number, fresh and dry weight of safflower in comparison to applying chemical fertilizers alone, also utilization of azetobacter bio-fertilizer, bio-phosphate fertilizer, organic fertilizers, with half rate of chemical fertilizer, increased grain yield of safflower (Ojaghloo et al., 2007). Hassan-zadeh et al., (2006) reported grain yield and dry matter production in barley increased by utilization of phosphate-solution bacteria with chemical phosphorus fertilizer. El-Gizawy and Mehasen, (2009) showed that utilization of chemical phosphorus fertilizer with phosphate-solution bacteria had a significant effect on bean grain yield, yield components, nitrogen content, and the level of phosphorus and zinc in the grain. Maize plant growth and dry weight increased by plant growth promoting rhizobacteria (PGPR) application (Zahir et al., 1998). Maize qualitative and quantitative characteristics were significantly increased by phosphate-solution microorganisms; also phosphorus solution microorganisms increased the growth and resistance of plants in water deficit conditions (Ehteshami et al., 2007). In another study, stems and roots fresh weight of different varieties of maize increased by utilization of phosphorus (Hussein, 2009). The present research was done in order to evaluate the effect of bio-phosphate and chemical fertilizers on growth and

Fig 1. Effect of fertilizer treatments on maize grain yield

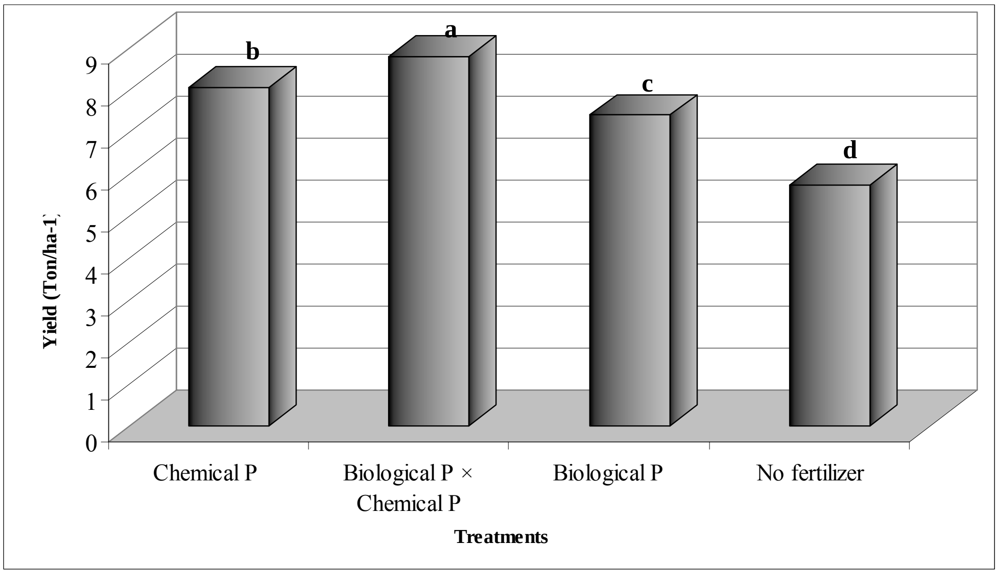

Table 1. Soil analysis result for physical and chemical characteristics

Characteristic	Soil depth (cm)	Soil texture	OC (%)	EC (dS/m^{-1})	PH	P	K	Zn	Fe	Mn	Cu
								(ppm)			
Value	0-30	loamy	0.82	0.52	8	6.5	200	0.42	6.02	8.1	0.78

quantitative characteristics of maize (S.C.704) in Kerman region.

Materials and methods

Description of the project site

This experiment was carried out in 2009 at the Kerman Natural Resources and Agriculture Research Center, Iran, located in 56º34´ longitude and 29º55´ latitude and, 2044m Altitude from sea level with an arid and semi-arid climate. The pH of soil field experiment was 8 with loamy texture, (physical and chemical properties of soil in experimental field were presented in table 1). Experiment was conducted in split plot within a randomized complete block design with four replications. The main plots included micronutrients foliar application containing Fe, Zn, Mn, and Cu elements together with control application (non foliar application), and sub plot were considered four levels of fertilizers: (T1: 0, T2: 100 kg/ha P_2O_5, T3: 100g bio-phosphate, T4: 100g bio-phosphate with 50 kg/ha P_2O_5). Sowing was done as rows in 75cm wide rows with 20cm spacing within-rows with six rows per subplot by Single Cross 704 cultivar, (Single Cross 704 was chosen because this cultivar had superiority relative to other cultivar in the last few years in experimental region). Foliar application was done in 4 liters per thousand at stem extension and staminate inflorescence emergence stages. Prior to planting, seeds were inoculated with biological phosphate fertilizer and chemical phosphorus fertilizer was utilized as strip takes under seed. All operations were done regularly during the growing season.

Crop sampling and calculation

Agronomic characteristics including plant height, stem diameter, length and width of flag leaf were determined at the end of staminate inflorescence emergence stage. Yield components such as grain number per ear, grain number per ear row, ear diameter, and grain weight were measured after of physiology maturity by selected five plants of each experimental plot randomly. Biological and seed yield were determined by eliminating the marginal effect. After drying, harvest index was obtained by divide seed yield to biological yield.

Statistical analysis

Data analysis was done by using SAS and MSTATC software. The ANOVA test was used to determine significant ($p \leq 0.01$ or $p \leq 0.05$) treatment effect and Duncan Multiple Range Test to determine significant difference between individual means.

Results and discussion

Plant height

Results showed that, plant height was significantly affected by foliar application and phosphorus fertilizers treatments (Table 2). This suggests the increase in plant height under influence of foliar application with micronutrients and phosphorus fertilizers treatments, as the highest plant height

Table 2. ANOVA of the effects of biological and chemical phosphorus fertilizer with micronutrients foliar application on plant height, stem diameter, flag leaf length and flag leaf width

SOV	df	Flag leaf width (cm)	Flag leaf length (cm)	Stem diameter (mm)	Plant height (cm)
Replication	3	0.09^{ns1}	2.13*	0.12^{ns}	10.01^{ns}
Micronutrients foliar application	1	0.34^{ns}	3.12*	0.60^{ns}	30.59*
Error	3	0.14	0.30	0.04	7.08
Phosphorous fertilizers	3	0.61**	30.33**	6.44**	114.92**
Phosphorous fertilizers× Micronutrients foliar application	3	0.10^{ns}	0.46^{ns}	0.04^{ns}	14.34*
Error	18	0.09	0.63	0.19	4.00
CV (%)		5.87	2.19	1.46	1.02

1- ns= Non significant, ** = $p < 0.01$ and * = $p < 0.05$

Table 3. Effect of phosphorus fertilizers coupled with micronutrients foliar on the plant height

Treatments		Plant height
Micronutrients foliar application	Chemical P	194.77b[1]
	Chemical P + Biologic P	202.32a
	Biologic P	196.64b
	Non fertilizer	190.92c
Non micronutrients foliar application	Chemical P	194.71b
	Chemical P + Biologic P	196.44b
	Biologic P	196.27b
	Non fertilizer	189.68c
LSD		2.97

1- Column means followed by the same letter are not significantly different at 0.05 or 0.01 probability level

was obtained by application of biological fertilizer + 50 kg/ha P_2O_5 with micronutrient foliar application, and the lowest plant height was obtained in control treatment (non micronutrients foliar and fertilizer application) (Table 3). Biological phosphorus fertilizer increased root uptake through root development. Micronutrients such as iron and zinc have a structural role in chlorophyll. These elements can be easily sprayed on leaf, thus leaves chlorophyll concentration increased by micronutrient foliar application, which in turn, lead to an increase in plant height and yield. Also zinc, increased plant height via increasing internodes distances (Kaya and Heggs, 2002). Furthermore, application of biological fertilizer increased plant height by increasing plant growth regulator hormones production (such as IAA and GA) (Senthil-Kumar et al., 2009).

Stem diameter

Effect of micronutrients foliar application on stem diameter wasn't significant, but phosphorous fertilizers had a significant effect on stem diameter (Table 2). Results showed that maximum stem diameter was obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5; there weren't any significant differences between biological and chemical phosphorus fertilizer treatments in terms of stem diameter increasing. Stem diameter increased 2.87% by utilization of biological fertilizer + 50 kg/ha P_2O_5 in compare with control (Table 4). Bio-fertilizer by plant growth regulator hormones production such as GA and IAA hormones had an important role in cells division and stem diameter increasing (Hamidi et al., 2008).

Flag leaf length

Results showed that the flag leaf length was significantly affected by phosphorus fertilizer and micronutrient foliar application (Table 2), so that the flag leaf length increased by micronutrients foliar application and phosphorus fertilizers (Table 4). Biological fertilizer + 50 kg/ha P_2O_5 increased 5.79% on the flag leaf length in compare with control. Utilization of biological fertilizers increased the flag leaf length and durability, which increased photosynthesis and dry matter accumulation (Ahmad et al., 2004).

Flag leaf width

Micronutrient foliar application had not significant effect on flag leaf width, but this parameter was significantly affected by phosphorus fertilizers (Table 2). Mean comparisons showed that maximum and minimum flag leaf widths were

Table 4. Means comparison of effects of biological and chemical phosphorus fertilizer with micronutrients foliar application on plant height, stem diameter, flag leaf length and flag leaf width

	Treatments	Plant height (cm)	Stem diameter (mm)	Flag leaf length (cm)	Flag leaf width (cm)
Micronutrients	Micronutrients foliar application	196.17a1	30.30a	36.59a	5.43a
	Non micronutrients foliar application	194.21b	30.02a	35.97b	5.22a
Fertilizer	Chemical P	194.74b	30.26b	36.56b	5.46a
	Biological P ×Chemical P	199.39a	31.13a	38.71a	5.53a
	Biological P	196.33b	30.30b	35.85b	5.40a
	No fertilizer	190.30c	28.96c	34.00c	4.92b

1- Columns means followed by the same letter are not significantly different at 0.05 or 0.01 probability level

Table 5. ANOVA of the effects of biological and chemical phosphorus fertilizer with micronutrients foliar application on yield compounds and cob diameter of maize

SOV	df	Number of grains per ear	Number of grain rows per ear	Grain weight (g)	Cob diameter (mm)	Yield grain (ton/ha)	Biological yield (ton/ha)	Harvest index (%)
Replication	3	109.11	0.08	53.58	0.16	0.17	1.02	2.41
Micronutrients foliar application	1	1725.87^{ns}	1.12^{ns}	155.01^{ns}	1.00^{ns}	2.39^{*}	13.03^{**}	3.75^{ns}
Error	3	1011.19	1.54	5.14	0.05	0.62	1.89	3.39
Phosphorous fertilizers	3	3582.03^{*}	2.16^{*}	1146.09^{**}	4.09^{*}	13.67^{**}	25.08^{**}	80.80^{**}
Phosphorous fertilizers× micronutrient foliar application	3	1213.28^{ns}	0.12^{ns}	15.75^{ns}	0.23^{ns}	0.15^{ns}	1.63^{ns}	2.42^{ns}
Error	18	714.32	0.70	35.63	0.37	0.35	1.49	4.87
CV (%)	-	4.33	5.82	2.04	1.54	7.97	4.44	8.12

1- ns= Non significant, ** = p < 0.01 and * = p < 0.05

obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5 and control respectively. Biological fertilizer + 50 kg/ha P_2O_5 treatment increased 12.39% in the flag leaf width in compare with control, but there wasn't significant difference between biological, chemical fertilizer and biological fertilizer + 50 kg/ha P_2O_5. Chemical and biological fertilizers increased flag leaf area, that it was a factor which increased biological yield per unit area (Yazdani et al., 2009).

Yield components

Number of grain per ear

Table 2 reveals that grain number per ear was significantly influenced by phosphorous fertilizers. However the utilization of phosphorus fertilizers increased grain number per ear but micronutrient foliar application had not significant effect on grain number per ear. The highest number of grain per ear was obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5, that it was 6.01% more than control treatment (Table 6). Utilization of rhyzobacteria increased the number of grain per ear in maize by promoted plant growth as production of phitohormon (Yazdani et al., 2009).

Number of grain rows per ear

The results showed that phosphorous fertilizers had a significant effect on number of grain rows per ear, but the effect of micronutrient foliar application on number of grain rows per ear was not significant (Table 5). The highest number of grain rows per ear was obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5, and there wasn't significant difference among phosphorus fertilizers. The lowest number of grain rows per ear was obtained in control treatment (Table 6). Probably at the time of number of grain rows per ear formation was not competition between physiological sink for uptake of resources. The number of grain rows per ear controlled by genetic usually, and uninfluenced by inputs and environmental conditions; in other words, in different environmental conditions, the number of grain rows per ear had an almost constant rate in similar figures (Ghaderi and Majidian, 2003).

Cob diameter

Table 5 showed that cob diameter was significantly affected by phosphorus fertilizers treatments; nonetheless cob diameter wasn't under influence of micronutrient foliar application (Table 5). The results showed that the highest and lowest diameters of ears were obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5 and control treatments respectively. There wasn't significant difference between biological and chemical phosphorus fertilizer (Table 6).

Biological yield

Effect of phosphorus fertilizers and micronutrient foliar application on maize biological yield was significant (Table 5).

Table 6. Means comparison of effects of biological and chemical phosphorus fertilizer with micronutrients foliar application on yield compounds and cob diameter of maize

Treat		Number of grains per ear	Number of rows per ear	Grain weight (g)	Cob diameter (mm)	Yield grain (ton/ha)	Biological yield (ton/ha)	Harvest index (%)
Micronutrients	Micronutrients foliar application	44.42a	199.72a	294.52a	39.85a	7.79a	28.15a	27.53a
	Non micronutrients foliar application	43.68a	187.47b	90.12a	39.50a	7.24b	26.88b	6.85a
Fertilizer	Chemical P	44.92b	197.30b	298.61b	39.75b	8.09b	27.83b	29.12b
	Biological P × Chemical P	47.12a	209.45a	304.97a	40.54a	8.81a	29.23a	30.09a
	Biological P	44.61b	98.98b	287.90c	39.61b	7.42c	27.97ab	26.58c
	No fertilizer	39.55c	186.65c	277.81d	38.79c	5.75d	25.03c	22.97d

1- Columns means followed by the same letter are not significantly different at 0.05 or 0.01 probability level

Highest and lowest biological yield was obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5 and control treatment respectively (Table 6). Biological yield increased 16.77% by biological fertilizer + 50 kg/ha P_2O_5 in compare with controls. Foliar application of micronutrient increased biological yield. These results are consistent with previous researches (Russel et al., 1984).

Grain yield

Analysis of variance showed that grain yield was affected by phosphorus fertilizer and micronutrients foliar application (Table 5). According to the results, highest and lowest yields were obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5 and control treatments respectively (Figure 1). Tahir et al., (2009) reported that grain weight and yield of maize increased by utilization of zinc. Increase of grain yield under the influence of phosphate fertilizers, biological fertilizer + 50 kg/ha P_2O_5, can be attributed to the ability of phosphate solution bacteria in fertilizer in increasing phosphorus liberalization of insoluble phosphorus sources. In another study Rokhzadi et al., (2004) reported that grain yield of chickpea increased by utilization of biological fertilizer.

Harvest index

Results showed that harvest index was significantly affected by phosphorus fertilizer, but the effect of micronutrients foliar application on the same wasn't significant (Table 5). Mean comparisons indicated that the highest harvest index was obtained by utilization of biological fertilizer + 50 kg/ha P_2O_5, and the lowest was obtained by control treatment. Biological fertilizer + 50 kg/ha P_2O_5 increased harvest index 30.99% in compare with control (Table 6). Biological fertilizer increased harvest index due to increasing economic performance. Results were in agreement with finding most of the workers like: (Aslam-khan et al., 2005).

Conclusion

Utilization of biological fertilizer increased flag leaf length and width, grain rows number per ear, grain weight and yield, biological yield and harvest index. Maize yield increased by application of biological phosphate fertilizer, that it could be due to increasing other nutrient absorption, also biological phosphate fertilizer can be used as a solution for increasing phosphate and micronutrient sorption in the alkaline soil. Utilization of chemical phosphorus fertilizer with bio-phosphorus fertilizer increased the biological efficiency of bacteria in the bio-fertilizer, thus root and shoot growth increased by increasing nutrients absorption by plant. Foliar application is very fast method for providing requires elements in plants because nutrients are absorbing quickly in compare with absorption that through plant roots. It seems that combination of chemical phosphorus fertilizers and biological phosphorus fertilizer was necessary for obtained maximum performance. As in this study maximum yield in compared to control was obtained by this method application of fertilizer. Utilization of chemical phosphorus fertilizer decreased to 50% by integrating biological phosphorus fertilizers and chemical phosphorus fertilizer without yield loss. Also environmental pollution was reduced by decreasing consumption of chemical fertilizers. Overall utilization of biological phosphate fertilizers with chemical phosphate fertilizer in addition to increased yield could be a strategy to achieve sustainable agriculture.

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