

Effect of Bio-phosphate and Chemical Phosphorus Fertilizer Accompanied with Foliar Application of Micronutrients on Yield, Quality and Phosphorus and Zinc Concentration of Maize

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Abstract

Field experiment was conducted at Kerman Agricultural and Natural Resources Research Centre (Iran) during 2008-2009 to evaluate the effect of bio-fertilizer, phosphorus and foliar application of micronutrients on dry matter accumulation, yield, and phosphorus and zinc concentration of maize (*Zea mays* L.). A split plot experiment based on randomized complete blocks design (RCBD) with four replications was followed in the study. The micronutrients foliar application in two levels (foliar application and non foliar application) were the main plots, and four levels of phosphate (T₁: 0 (no fertilizer), T₂: 100 kg ha⁻¹ P₂O₅, T₃: 100g bio-phosphate, T₄: 100g bio-phosphate with 50 kg ha⁻¹ P₂O₅) as the sub plots. Results showed that micronutrients foliar application and biological and chemical phosphorus fertilizers had a significant influence on dry matter accumulation. The maximum dry matter accumulation was obtained by applying 50 kg/ha P₂O₅ plus bio-fertilizer. Grain yield, 1000-seed weight and protein content of grain were significantly affected by micronutrients and phosphorus fertilizers treatments. Micronutrients foliar application and phosphorus fertilizers interaction had no significantly effect on grain yield, 1000-seed weight and grain protein content. Grain phosphorus and zinc concentration where significantly increased by application of micronutrients and phosphorus fertilizers.

Keywords: Bio-phosphate, Dry matter, Maize, Micronutrient, Yield

1. Introduction

Integration of chemical and bio-fertilizers is one of the ways to increase production in sustainable agriculture (Ali *et al.* 2008; Sharma, 1999). Phosphorus bio-fertilizers bacteria such as *Bacillus* and *Pseudomonas* increased soil soluble phosphorus by secreting organic acids and phosphatase enzyme (Ehteshami *et al.* 2007). 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). Ability of micronutrients absorption (especially zinc) is very important for optimum growth of plants. In most of the Iranian soils pH is high and they are also calcareous. In this type of soils solvability of micronutrients is less and it decrease absorption of micronutrients by plant, finally requirement of plants increasing to this elements (Mousavi *et al.* 2007). Maralin, (2009) showed that yield and Zn and Fe concentration of wheat increased by Zn and Fe foliar application. Plant height, stem diameter and leaf area index of maize where significantly increased by application of nitrogen and phosphorus fertilizer 8 weeks after sowing (Onasanya *et al.* 2009). Hamidi *et al.* (2008) in a study showed that fresh weight, number of leaves above the ear, yield of silage forage and vegetative growth of maize increased by application of PGPR (Plant growth promoting rhizobacteria). Hassanzadeh *et al.* (2006) reported grain yield and dry matter production in barley increased by application of

phosphate-solution bacteria and chemical phosphorus fertilizer. El-Gizawy and Mehasen, (2009) showed that application of chemical phosphorus fertilizer with phosphate-solution bacteria had a significant effect on bean grain yield, yield components, nitrogen content, and content of phosphorus and zinc in the grain. Maize growth and dry weight increased by plant growth promoting rhizobacteria (PGPR) application (Zahir *et al.* 1998; Javed *et al.* 1998). Application of bio-fertilizer with 50% of chemical nitrogen, phosphorus and potassium (NPK) fertilizers increased maize vegetative growth, plant height, branch number, fresh and dry weight and total carbohydrate on dry matter as compared to chemical fertilizers treatments (Mahfouze and Sharafeldin, 2007). (Note 2)

With regards to importance of phosphate absorption from soil on the maize feeding the present research was done in order to evaluate the effect of bio-phosphate and chemical fertilizers combined with micronutrients foliar application on dry matter accumulation trend, growth and qualitative characteristics of maize (S.C.704). (Note 1)

2. Materials and methods

2.1 Description of the project site

This experiment was carried out during 2008-2009 at the Kerman Natural Resources and Agriculture Research Center, Iran, located in 56°34' longitude and 29°55' latitude and, 2044m Altitude from sea level with an arid and semi-arid climate. The pH of soil field experiment was 8 and soil texture was loamy, (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 foliar application of micronutrients containing Fe, Zn, Mn, and Cu elements together with control application (non foliar application), and sub plot were considered four levels of phosphorus fertilizers: (T₁: 0 (no fertilizer), T₂: 100 kg ha⁻¹ P₂O₅, T₃: 100g bio-phosphate, T₄: 100g bio-phosphate with 50 kg ha⁻¹ P₂O₅) 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 of micronutrients was done in 4 liters per thousand at stem extension and staminate inflorescence emergence stages. Prior to planting, seeds were inoculated with biological phosphorus fertilizer and chemical phosphorus fertilizer was utilized as strip takes under seed. All operations were done regularly during the growing season.

2.2 Crop sampling and calculation

Dry matter was determined 35 days after sowing of one square meter area in each plot after eliminating the marginal effect by oven at 70°C for 48 hours, and was repeated once every 15 days until the end of the growing period. 1000-seed weight and grain yield was measured at the end of growing season after of physiology maturity by harvesting 5 m² from each plot. Percent of protein was obtained by following formula after determining amount of nitrogen in the laboratory by Kjeldahl method (Jones, 1991).

$$Pr = 6.25 \times Nt \times DM$$

Pr = Percent of protein

Nt = Percent of total N

DM = Percent of dry matter

Concentration of zinc and phosphorus was obtained by atomic absorption and spectrophotometer methods respectively.

2.3 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.

3. Results and discussion

3.1 Dry matter accumulation

Analysis of variance showed that dry matter accumulation was significantly affected by phosphorus fertilizer treatments during the stages of sampling (from 35 to 125 days after sowing); Also dry matter accumulation was significantly affected by foliar application of micronutrients during the stages of sampling except the first stage (35 days after sowing) (Table 6 and 2). Trend of dry matter accumulation showed that seed inoculation by biological phosphorus fertilizer before sowing increased dry matter accumulation. Highest dry matter accumulation (1810 g/m²) was obtained by application of biological fertilizer + 50 kg ha⁻¹ P₂O₅ (Figure.

1). Maize resistant to lodging, precocity and its quality and quantity increased by increasing phosphorus availability; also grain yield increased by increasing weight and grain number per ear (Ehteshami *et al.* 2007). Bio-phosphate bacteria efficiency increased by application of biological phosphorus fertilizer combined with chemical phosphorus fertilizer. *Pseudomonas* bacteria in the bio-phosphate produced auxin and gibberellin hormones and vitamins, therefore dry matter increasing could be attributed to the ability of bacteria (Hassanzadeh *et al.* 2006). Effect of foliar application of micronutrients on dry matter accumulation appeared 50 days after sowing, the highest difference between foliar application of micronutrients and non foliar application treatments on dry matter accumulation was observed 95 days after sowing (Figure. 2).

3.2 1000-Seed weight

1000-seed weight was significantly affected by biological and chemical phosphorus fertilizers, but foliar application of micronutrients had no significant effect on 1000-seed weight (Table 3). Application of biological fertilizer + 50 kg ha⁻¹ P₂O₅ increased 1000-seed weight to 304.97g which was 9.77% higher as compared to control. Maize 1000-seed weight was dependent on the ability of plants to provide food for the reservoir and environmental conditions such as moisture and nutrients during grain filling (Andrade *et al.* 1999).

3.3 Grain yield

Analysis of variance showed that grain yield was affected by phosphorus fertilizers and foliar application of micronutrients (Table 3). According to the results, highest and lowest yields were obtained by application of biological fertilizer + 50 kg ha⁻¹ P₂O₅ and control treatments respectively. 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 micronutrients sorption in the alkaline soil (Hassanzadeh *et al.* 2006). Tahir *et al.* (2009) reported that grain weight and yield of maize increased by application of zinc. Increase of grain yield under the influence of phosphate fertilizers, biological fertilizer + 50 kg ha⁻¹ P₂O₅, can be attributed to the ability of phosphate solution bacteria in bio-fertilizer in increasing available phosphorus of insoluble phosphorus sources. In another study Rokhzadi *et al.* (2004) reported that grain yield of chickpea increased by application of biological fertilizers.

3.4 Grain protein

Percent of grain protein was significantly affected by biological and chemical phosphorus fertilizers, but foliar application of micronutrients had no significant effect on grain protein (Table 3). Mean comparisons showed that maximum (9.74%) and minimum (8.22%) grain protein was obtained by application of biological fertilizer + 50 kg ha⁻¹ P₂O₅ and control respectively (Table 4). Phosphate solubilizing microorganisms increased available phosphorus and nitrogen in the soil which increases their concentration by plant, also increased the grain protein (Mehrvarz *et al.* 2008). Hemati (2005) reported wheat protein increased by application of micronutrients such as Zn, Mn and Fe.

3.5 Grain phosphorus concentration

Result showed that grain phosphorus concentration was significantly affected by biological and chemical phosphorus fertilizers and foliar application of micronutrients, also phosphorus fertilizers and foliar application interaction had a significant effect on percent of grain phosphorus (Table 3). Maximum phosphorous content (0.24%) was obtained by application of biological fertilizer + 50 kg ha⁻¹ P₂O₅ and foliar application of micronutrients which, was 25% higher as compared to control treatment (no fertilizer) (Table 5). Phosphorus uptake by plant decreased by increasing Zn in the soil, but Zn application by foliar application increased phosphorus absorption of soil by plants (Bukvic *et al.* 2003). Phosphate-solubilizing microorganisms had important role in phosphorus solubility and uptake. The bacteria released phosphorus from organic and inorganic soils during the mineralization process also increased the absorption of phosphate from phosphate rock, and save a reservoir of phosphorus in the presence of carbon unstable by mineralization process (Alikhan *et al.* 2009).

3.6 Grain zinc concentration

Phosphorous fertilizers and foliar application of micronutrients interaction had a significant effect on grain zinc concentration (Table 3). Mean comparisons showed that maximum zinc concentration (16.15 mg/kg) was obtained by application of biological fertilizer + 50 kg ha⁻¹ P₂O₅ and foliar application of micronutrients; also minimum zinc concentration (14.95 mg/kg) was obtained by control. There wasn't significant difference between biological, chemical, biological fertilizer and 50 kg ha⁻¹ P₂O₅, foliar and non foliar application on zinc concentration (Table 5). Foliar application is very fast method for providing requires elements in plants because nutrients are uptake quickly as compare to uptake that through plant roots. Zinc transferred to grain by remobilization and it remobilization was higher than other micronutrients (Ranjbar and Bahmaniar, 2007;

Kochian, 1991). The concentration of zinc in wheat increased to three times by Zn and Fe foliar application in the tillering and heading stage (Maralian, 2009). Zinc absorption reduced by phosphorus application in the soil, but biological phosphorus fertilizers due to having phosphate solubilizing bacteria had no interfere on other elements uptake (Salimpour *et al.* 2010). Zakaria *et al.* (1997) reported phosphorus and zinc uptake by cotton increased by application of biological phosphorus fertilizers and zinc foliar application.

4. Conclusion

Application of phosphorus fertilizers combined with foliar application of micronutrients increased dry matter accumulation. Biological phosphorus fertilizers efficiency increases if combined with 50% chemical phosphorus fertilizers. Integrating biological and chemical phosphorus fertilizers with foliar application of micronutrients increased grain yield as compared to control. Biological phosphorus fertilizer with 50kg chemical phosphorus fertilizer combined with foliar application of micronutrients increased grain zinc and phosphorous concentration. Zinc was available through foliar application for plant, thus application of phosphorus fertilizers had no negative effect on zinc uptake by plant in the soil, thereupon zinc and phosphorus concentration increased in the grain. Application of biological fertilizer was significantly increased 1000-seed weight and percent of grain protein, because nutrients absorption capability and plant absorption balance increased by phosphate-solubilizing microorganisms. Grain yield and quality increased by foliar application of micronutrients due to increasing elements transfer from leaves to grain. Application of chemical phosphorus fertilizer decreased to 50% by integrating biological and chemical phosphorus fertilizers without yield loss. Also environmental pollution was reduced by decreasing consumption of chemical fertilizers. Overall application of biological phosphorus fertilizers with chemical phosphate fertilizer in addition to yield increasing could be a strategy to achieve sustainable agriculture.

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Notes

Note 1. Single Cross 704 (S.C.704)

Note 2. Nitrogen, phosphorus and potassium (NPK)

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 (ppm)	Fe	Mn	Cu
Value	0-30	loamy	0.82	0.52	8	6.5	200	0.42	6.02	8.1	0.78

Table 2. ANOVA of the effects of biological and chemical phosphorus fertilizers with foliar application of micronutrients on dry matter accumulation (g/m^2)

SOV	df	35 ¹	50	65	MS	80	95	110	125
Replication	3	18.90	39.25	148.33	13545.44	2894.97	2937.11	2975.23	
Micronutrients foliar application	1	1.00 ^{ns2}	5021.02**	4328.90**	6308.20**	140495.10**	97887.60**	49905.90**	
Error	3	0.71	112.26	8119.81	1606.92	17427.54	9978.76	12050.45	
Phosphorous fertilizers	3	358.20**	2900.50**	55788.80**	79283.80**	147601.30**	162077.40**	137026.60**	
Phosphorous fertilizers× Micronutrients foliar application	3	4.53 ^{ns}	327.45 ^{ns}	1135.28 ^{ns}	4757.80 ^{ns}	3747.63 ^{ns}	2283.25 ^{ns}	4361.60 ^{ns}	
Error	18	10.44	149.76	2256.94	5469.04	1946.44	9325.73	9718.57	
CV (%)		7.27	10.37	9.43	8.38	8.49	6.22	6.79	

1- Days after sowing

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

Table 3. ANOVA of the effects of biological and chemical phosphorus fertilizers with foliar application of micronutrients on yield and quality characteristics of maize

SOV	df	Grain yield (ton/ha^{-1})	MS	1000-seed weight (g)	Protein (%)	P (%)	Zn (mg/kg)
Replication	3	0.17	53.58	0.48	0.00005	0.14	
Micronutrients foliar application	1	2.39* ¹	155.01 ^{ns}	0.23	0.0004**	1.50**	
Error	3	0.62	5.14	0.18	0.0000006	0.10	
Phosphorous fertilizers	3	13.67**	1146.10**	3.47**	0.001**	0.90**	
Phosphorous fertilizers× Micronutrients foliar application	3	0.15 ^{ns}	15.75 ^{ns}	0.13 ^{ns}	0.0001*	0.40*	
Error	18	0.35	35.63	0.16	0.00002	0.10	
CV (%)		7.97	2.04	4.50	2.04	2.05	

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

Table 4. Means comparison of effects of biological and chemical phosphorus fertilizers with foliar application of micronutrients on yield and quality characteristics of maize

Treat		Grain yield (ton/ha)	1000-seed weight (g)	Protein (%)	P (%)	Zn (mg/kg)
Micronutrients	Micronutrients foliar application	7.79a	294.52a	9.06a	0.24b	15.76a
	Non micronutrients foliar application	7.23a	290.12a	8.89b	0.23b	15.33b
Fertilizer	Chemical P	8.09b	298.61b	9.24b	0.24b	15.64a
	Biological P × Chemical P	8.81a	304.97a	9.74a	0.25a	15.86a
	Biological P	7.32c	287.90c	8.69c	0.24b	15.62a
	No fertilizer	5.75d	277.81d	8.22d	0.22c	15.07b

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

Table 5. Effects of biological and chemical phosphorus fertilizers and foliar application of micronutrients interaction on grain phosphorus and zinc concentration

Treatments		P (%)	Zn (mg/kg)
	Chemical P	0.242b ¹	15.99ab
Micronutrients foliar application	Biological P × Chemical P	0.257a	16.15a
	Biological P	0.242b	15.97ab
	No fertilizer	0.220d	15.19cd
	Chemical P	0.234c	15.29cd
Non micronutrients foliar application	Biological P × Chemical P	0.242b	15.57bc
	Biological P	0.232c	15.27cd
	No fertilizer	0.223d	14.95d
LSD		0.007	0.46

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

Table 6. Means comparison of the effects of biological and chemical phosphorus fertilizers with foliar application of micronutrients on dry matter accumulation (g/m²)

		Days after sowing						
		35	50	65	80	95	110	125
Micronutrients	Micronutrients foliar application	44.57a ¹	130.52a	540.10a	928.73a	1711.64a	1607.32a	1490.44a
	Non micronutrients foliar application	44.21a	105.47b	466.54b	839.42b	1579.12b	1496.71b	1411.45b
Fertilizer	Chemical P	47.12b	117.74b	518.91b	899.97b	1651.65b	1582.93b	1433.34b
	Biological P × Chemical P	51.43a	142.87a	611.38a	988.45a	1810.41a	1721.75a	1628.78a
	Biological P	43.35c	114.80b	467.54c	899.28b	1641.62b	1525.47b	1428.32b
	No fertilizer	35.66d	96.85c	415.46d	748.60c	1477.86c	1377.93c	1313.33c

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

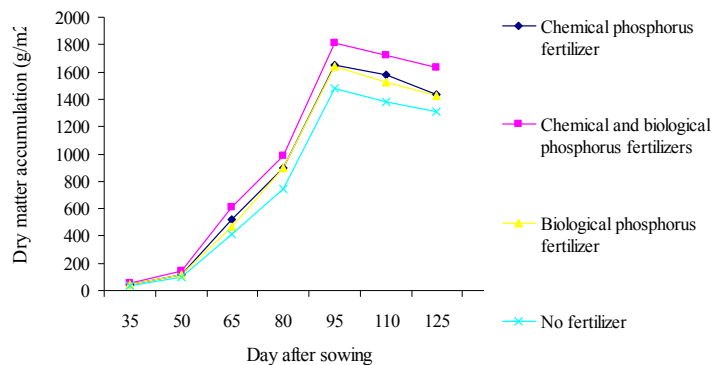


Figure 1. Effects of biological and chemical phosphorus fertilizers on dry matter accumulation (g/m^2) (Error bars are the standard error of the mean)

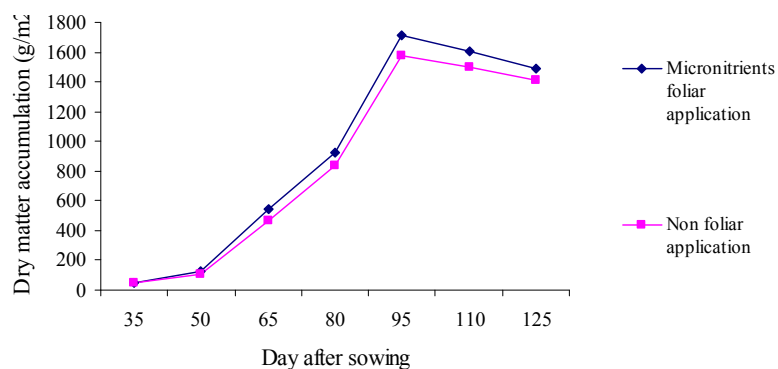


Figure 2. Effects of foliar application of micronutrients on dry matter accumulation (g/m^2) (Error bars are the standard error of the mean)