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ROLE OF INOCULATION WITH PHOSPHOROUS SOLUBILIZING BACTERIA ON YIELD AND QUALITY OF FODDER MAIZE

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Abstract

Phosphorus is one of the primary nutrients for plants which influence their yield and quality. Effect of inoculation with phosphorous solubilizing bacteria and different levels of phosphorous application on fodder yield, growth and quality of maize was evaluated in a field experiment at Agronomy Research Area, University of Agriculture, Faisalabad in the month of February, 2012. The experiment comprised of phosphorous levels as 24, 36, 48 and 60 kg $ha^{-1}$and seed inoculation with phosphorous solubilizing bacteria keeping un-inoculated seeds as control treatment. The experiment was laid out in RCBD with factorial arrangement using three replications. The application of phosphorous significantly improved the growth, yield and quality of maize forage. The maximum green forage yield (63.15 t ha^{-1}) was recorded with phosphors @ 60 kg ha^{-1}. Seed inoculation had a significant influence on plant height, leaf area per plant, stem diameter, fresh weight per plant and forage yield. The maximum green forage yield (58.10 t ha^{-1}) was obtained when seeds were inoculated with *Azosprillum spp.* Phosphorus application at the rate of 60 kg ha^{-1} to maize crop raised from inoculated seed with phosphorus solubilizing microbial inoculation seems to be the optimum dose for obtaining higher maize forage yield having good quality.

Keywords: Inoculation, Phosphorus, Solubilizing bacteria, Yield and quality, Maize fodder

Introduction

Maize (*Zea mays* L.) is grown as food, feed and fodder crop in Pakistan. It has vital role in animal feed and provides adequate amount of energy and protein. It can be grown as fodder crop throughout the Kharif season (Rashid and Iqbal, 2012). Its fodder mainly contains 0.30% fat (Nazir *et al*., 1996), 10% protein, 66.7% starch and 7% ash contents (Noor *et al*., 2010). The green stalks of maize contain high amount of vitamin A and leaves are rich in carotene contents as compared to other parts. Protein contents of maize fodder are less yet it is relished by the animals being palatable and succulent (Ali *et al*., 2004). The average fodder production of maize is very low in Pakistan as compared to other maize growing countries of the world. In the year 2012, maize fodder was grown on an area of 0.09 million hectare with a total fodder production of 0.96 million tons (GOP, 2012). Among various factors responsible for low fodder yield of poor quality, unbalanced and inappropriate application of NPK fertilizer is considered the most limiting factor.

Phosphorus is the second essential nutrient for plant growth and development after nitrogen (Wua *et al*., 2005). It plays role in many biological and physiological processes in plants including respiration, metabolism and photosynthesis and thus helps to increase the yield of various crops. Application of phosphatic fertilizers stimulates flowering and formation of seeds in maize. For increasing production of fodder crops, the timely application of phosphorus fertilizers in adequate amount is indispensible (Demkin and Ageev, 1990). Most of the farmers in Pakistan do not use phosphatic fertilizers for fodder crops (Rashid and Iqbal, 2012). Use of P along with N and K increased the yield (Ayub*et al.*, 2002), crude fiber, crude protein, dry matter (%), ash contents and P concentration (%) in maize (Cheema, 2000). Phosphate solubility is

inhibited due to the existence of aluminum and iron in acidic soils and calcium in alkaline and neutral soils (Ponmurugan and Gopi, 2006). Gyaneshwar *et al*. (2002) stated that huge amount of phosphorus applied as fertilizer arrives in to the immobile pools due to precipitation reactions with highly reactive ions of Ca^{2+} in calcareous or normal soils and Al^{3+} and Fe^{3+} in acidic soils.

Soil microorganisms perform important mechanisms in soil to make the bounded phosphorus available for the crops (Richardson, 1994). They may be helpful in increasing forage yield and improving forage quality of maize. Microorganisms integrate the soluble phosphorus and save it from being fixed (Khan and Joergensen, 2009). Microbial inoculation increases the availability of phosphorus to crop plants because microorganisms solubilize precipitated phosphates and mineralize organic phosphorus (Kang *et al.*, 2002; Chen *et al.*, 2006). Mehrvarz *et al*. (2008) concluded that mycorrhiza and *Pseudomonas putida* improved leaf chlorophyll contents in barley. Phosphorus solubilizing microorganisms could decrease the phosphorus requirements up to 50 % without any substantial decrease in yield of fodder maize (Jilani *et al.*, 2007; Yazdani *et al.*, 2009). Therefore, it is necessary to study the impact of phosphorus solubilizing microbial inoculation and phosphorus application on forage yield and quality of maize. Present study was, therefore conducted, to evaluate the response of maize to seed inoculation with phosphorus solubilizing bacteria in combination with different levels of phosphorus application.

Materials and methods

This field experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad during spring season of 2012. The climate of the region is semi-arid and subtropical.

The experimental site was located at 73^{o} East longitudes, 31^{o} North latitude and at an altitude of 184.4 meters. Experiment was laid in a randomized complete block design under factorial arrangement with three replications. The soil analysis was carried out before the start of experiment the soil was a silt loam with slight alkaline reaction and total available phosphorus as found 10.42 ppm. The plot size was 6.0 m × 1.8 m. Seed of maize cv. Pak-Afgoi was collected from Fodder Section, Ayub Agricultural Research Institute, Faisalabad. The experiment comprised of four phosphorous levels as 24, 36, 48 and 60 kg ha^{-1} and inoculation with the phosphorous solublizing bacteria. An un-inoculated treatment was kept as check .Recommended dose of nitrogen fertilizer was applied in the form of urea in two splits. Half of the nitrogen was applied at the time of sowing and the remaining half was applied with first irrigation. The whole dose of phosphorus was applied at the time of sowing. The crop was sown with hand drill in 30 cm spaced rows using a seed rate of 100 kg ha^{-1} on23^{rd} February, 2012. All other agronomic practices i.e. irrigation, weeding etc. were kept uniform for all the treatments. The total of four irrigations was given to the crop from sowing to harvest. Weeds were removed before the crop emergence by blind hoeing and then hoeing was done when weeds emerged in the field. Crop was harvested manually at 50% tasselling stage. All fodder yield attributes were recorded using standard procedures. A chemical analysis of samples was carried out for quality evaluation following procedures of A.O.A.C. (1990). Data was statistically analyzed using Fisher's analysis of variance technique and the least significance difference at 5% probability level test was used to compare the difference/s among treatment means (Steel *et al.*, 1997). Economic analysis was done to determine the economy of the experimental trial. Benefit cost ratio of produce was calculated from the total yield of forage according to procedures devised by CIMMYT (1988).

Results and discussion

Inoculation with phosphorus solubilizing bacteria and different rate of phosphorus application significantly affected plant height, stem diameter, no. of leaves per plant, leaf area per plant, fresh and dry weight per plant of maize but both did affected the plant population per m^2. The interaction between both factors was also found to be non-significant (Table 1). Among other parameters like green yield, dry yield, were also affected markedly. Similarly the quality parameters such as crude protein %, crude fiber % and ash % were also improved significantly by different levels of phosphorus and seed inoculation (Table 2). Plant height (176.63 cm), stem diameter (1.22 cm), no. of leaves (13.6), leaf area per plant (3450.4 cm^2), fresh weight per plant (304.97g), dry weight per plant (73.03 g), green fodder yield (58.10 t ha^{-1}), dry fodder matter yield (15.93 t ha^{-1}),

dry matter percentage (27.42%) and crude protein (8.68%) crude fat (29.89%), were improved with inoculation. Plant population (22.09 m^{-2}), ether extractable fat (1.775%) and total ash content (9.259%) were remained unaffected (Table 1 & 2). These results are in line with the finding of Shrivastava *et al*. (2011).

The maximum value for all above parameters was recorded at 60 kg ha^{-1} and was followed by the phosphorus levels of 48, 36 and 24 $kgha^{-1}$, respectively. The minimum value for all the parameters were recorded from the plots where phosphorus was applied at the rate of 24 kg ha^{-1}. Plant population and ether extractable fat % were the only parameters which did not responded significantly to phosphorus application and seed inoculation. Maximum plant height (186.48 cm), stem diameter (1.35 cm), no. of leaves (14.6), leaf area per plant (3743.5 cm^2), fresh weight per plant (331.72g), dry weight per plant (77.90 g), green fodder yield (63.15t ha^{-1}), dry fodder matter yield (16.36 t ha^{-1}), dry matter percentage (26.88%) and crude protein (10.11%) crude fat (31.30%), ether extractable fat (1.685%) and total ash content (9.99%) was noted in plots where phosphorus was applied at the rate of 60 kg ha^{-1} (Table 1 & 2).

Table 1: Effect of phosphorous and microbial inoculation on yield attributes of maize fodder

Treatments	PP (m^{-2})	PH (cm)	SD (cm)	NL	LA(cm^2)	FW (g)	DW (g)
Seed Inoculation							
No inoculation	21.57	167.93 b	1.16 b	13.0 b	3305.4 b	291.00b	70.55 b
Inoculation	22.09	176.63 a	1.22 a	13.6 a	3450.4 a	304.97a	73.03 a
LSD at 0.05	NS	5.98	0.0293	0.3361	99.38	5.0568	1.0795
Phosphorus (kg ha^{-1})							
24	20.87	160.20 c	1.05 d	12.0 d	3005.3 d	259.73d	66.00d
36	21.79	168.28bc	1.13 c	12.8 c	3230.9 c	285.77 c	69.62c
48	22.19	174.13 b	1.23 b	13.8 b	3531.9 b	314.73 b	74.05b
60	22.47	186.48a	1.35 a	14.6 a	3743.5 a	331.72 a	77.90a
LSD at 0.05	NS	8.4572	0.0415	0.4753	140.54	7.1514	0.8826

Means not sharing the same letter differ significantly at 5% level of probability. PP, plant population; PH, plant height; SD, stem diameter; NL, no. of leaves; LA, leaf area; FW, fresh weight, DW, dry weight.

Table 2: Effect of phosphorous and microbial inoculation on quality attributes of maize fodder

Treatments	GY(t ha^{-1})	DY(t ha^{-1})	CP (%)	CF (%)	EEF (%)	TA (%)
Seed Inoculation						
No inoculation	56.04 b	15.11 b	8.1 b	29.26 b	1.780	8.95
Inoculation	58.10 a	15.93 a	8.68 a	29.89 a	1.775	9.25
LSD at 0.05	0.749	0.7633	0.4395	0.5044	NS	NS
Phosphorus (kg ha^{-1})						
24	50.87 d	13.59 c	6.52 d	27.56 c	1.865	7.99 c
36	54.84 c	14.89 b	7.55 c	28.91 b	1.81	8.81 b
48	59.43 b	16.36 a	9.35 b	30.61 a	1.75	9.62 a
60	63.15 a	17.23 a	10.11a	31.23 a	1.685	9.99 a
LSD at 0.05	1.0593	1.07	0.6216	0.7133	NS	0.6766

Means not sharing the same letter differ significantly at 5% level of probability. GY, green matter yield; DY, dry matter yield; CP, crude protein; CFC, crude fiber; EEF, ether extractable fat; TA, total ash.

Economic analysis was done to find out the best treatments combination. The data presented in the table 3 shows that phosphorus solubilizing bacterial inoculation and different levels of phosphorus application resulted in different net income and benefit-cost ratio (BCR). Highest net income of 105950 rupees ha^{-1} was obtained in treatment where seeds were inoculated and 60 kg P_2O_5 ha^{-1} was applied. It resulted in BCR 2.21. Lowest net income of 76125 rupees ha^{-1} was obtained in treatment where seeds were un-inoculated and 24 kg P_2O_5 ha^{-1} was applied which resulted in BCR 1.85.

Table 3: Benefit-cost ratio (BCR) of fodder maize influenced by phosphorus solubilizing microbial inoculation and different rate phosphorus application.

Treatments	Green forage yield	Total/Gross Income	Total fixed cost	Total variable cost	Total cost of production	Net benefit	BCR
	(t ha^{-1})	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	
I_0P_1	49.96	124900	45675	3100	48775	76125	1.85
I_1P_1	51.78	129450	45675	3700	49375	80075	1.90
I_0P_2	53.7	134250	45675	4500	50175	84075	1.95
I_1P_2	55.97	139925	45675	5100	50775	89150	2.0
I_0P_3	58.02	145050	45675	5900	51575	93475	2.1
I_1P_3	60.83	152075	45675	6500	52175	99900	2.14
I_0P_4	62.48	156200	45675	7300	52975	103225	2.17
I_1P_4	63.81	159525	45675	7900	53575	105950	2.21

PKR=Pakistan Rupee

Conclusion

From the results of present study it is concluded that phosphorus application at the rate of 60 kg ha^{-1} to maize fodder crop which is raised from seeds inoculated with phosphorus solubilizing bacteria is the optimum dose for obtaining higher maize green forage yield having good quality. Economic analysis also favored these results. On the basis of dry fodder yield P_3 can also be recommended because phosphorus application at 48 and 60 kg ha^{-1} remained at par when inoculated with phosphorus solubilizing bacteria.

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