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Original Article

Effects of Different Levels of Phosphorus on Four Cultivars of Maize (*Zea mays* L)

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Abstract

A greenhouse pot culture experiment was conducted at Banaras Hindu University, Varanasi, Uttar Pradesh (India) to evaluate the effect of various levels of phosphorus (0, 25, 50 and 100 mg P kg^{-1} soil) on growth attributing character (shoot dry weight, root length) and phosphorus content in shoot and their uptake, % root infection and available phosphorus of four maize cultivars *viz* Pragati (V1), HQPM (V2), MRM-3845 (V3) and Kuwari (V4). The shoot dry weight, root length, phosphorus content and their uptake by shoot and available phosphorus at different interval of the maize crop were significantly increased by increasing levels of phosphorus. Whereas % root infection of mycorrhiza decreases with increasing levels of phosphorus. The mycorrhizal colonization of roots generally increased up to middle of the growing season among all the cultivars with maximum colonization at the third harvest (84 DAS). Varieties showed significant difference for shoot dry weight / plant, root length, phosphorus content and uptake in shoot. Overall, it is concluded that variety "Pragati" performed better as compared to other varieties like HQPM, MRM-3845 and Kuwari.

Keywords

Cultivars; Maize; Mycorrhiza; Phosphorus; Root Infection; Root Length.

Introduction

Maize (*Zea mays* L.) is the third most important cereal crop of the world and mostly consumed as human food and animal feed. It also provides raw material for food industry. It is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals as it has the highest yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% (782 m t) in the global grain production [1].

Phosphorus is second major essential nutrient after nitrogen for higher crop yields especially for maize, because it is frequently deficient for crop production and is required by crops in relatively large amounts. It plays an important role in many physiological processes during crop growth. It is involved in different enzymatic reactions in the plant and essential element for cell division because it is a constituent element of nucleoproteins which are involved in the cell reproduction processes. It is also important for seed and fruit formation and crop maturation. Phosphorus hastens the ripening of fruits thus counteracting the effect of excess nitrogen application to the soil [2]. Grain producers in India spend a huge amount annually on P fertilizer. However, only 15% of this applied P directly used by the crops in the year of application and subsequent usage of residual P rarely exceeds 50%.

In spite of favorable soil and climatic conditions the yield recovery is very low at the farmer's field in Uttar Pradesh. The possible reasons may be injudicious use of inputs, lack of hybrid varieties and lack of quality seed. Among strategies for achieving this, the possibility of selecting P efficient varieties

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has been stimulated by the increased knowledge about P uptake differences between crop plants and their cultivars [3]. The differences in P uptake among species [4] or cultivars will hopefully help to reduce costs of P fertilization and enhance plant productivity with more P efficient plants. The present study was therefore, carried out to evaluate the response of potentially high yielding maize cultivars to different rates of phosphorus under green house condition.

Materials and Methods

A study pertaining to the effect of varying levels of phosphorus on growth attributing character of four maize cultivars was conducted at Banaras Hindu University, Varanasi, Uttar Pradesh (India) on sandy loam soil. The physico-chemical properties of the soil are depicted in Table 1.The experiment was comprised of four P levels viz., 0, 25, 50 and 100 mg P kg^{-1} soil. The experiment was laid out in randomized complete block design with split plot arrangement giving more importance to fertilizer. Each treatment was replicated thrice. The study was conducted in earthen pots with 6 kg of soil in each. At the time of sowing, in addition to P treatments, each pot received a basal application of 100 mg N kg^{-1} soil through urea [CO(NH2)2], 50 mg K kg^{-1} soil through Potassium chloride (KCl) and 10 mg Zn kg^{-1} soil through Zinc sulfate (ZnSO4 +7H2O). Each pot contained two plants, which were frequently watered to maintain moisture at approximately field capacity. Thinning was done when crop attained the height of about 15 cm. The crop was harvested and data regarding shoot dry weight / plant, root length, root infection (%) of mycorrhiza, P concentration, P uptake and available phosphorus, were measured at different days after sowing of the maize. After harvesting the shoot was washed with distilled water for several times before drying. Plant material tops was dried to a constant weight in a forced-draft oven at about 70°C, and shoot dry weight were measured with the help of analytical balance and milled. Ground material (only tops) was digested with 2:1 mixture of nitric (HNO_3) and perchloric acids ($HClO_4$) for P determination. Phosphorus concentration in the shoot was analysed colorimetrically [5]. The roots were carefully separated from soil by washing and flooding over sieves. After cleaning of any foreign material, roots were preserved in 20 per cent ethanol and root length was measured by line interception method [6] using the formula: RL = (11 / 14) x N x G, Where, N is total numbers of intercepts of root with vertical and horizontal grid lines; G is grid square dimensions, cm; RL is root length, cm. For % root infection, the maize roots were cut into 1- 1.5 cm length and stained with trypan blue [7]. Mycorrhiza infection of each plant root was determined by estimating the percent of root segments colonised with arbuscular mycorrhiza (AM) [8].

Results and Discussion

Shoot Dry Weight/Plant (g)

Data pertaining to shoot dry weight (SDW) of maize at different interval with respect to P levels are presented in Table 2. Application of P improved shoot growth significantly. In the case of fertilizer treatments, mean shoot dry weight / plant was ranging from 0.50 to 1.03 g at 27 DAS, 8.41 to 13.89 g at 51 DAS, 20.60 to 38.67 g at 84 DAS and at harvesting stage the values were ranging from 29.97 to 47.86 g respectively. The maximum values of shoot dry weight were recorded with application of 100 mg P kg^{-1} at each of the stages significantly higher over control during the year of experiment. The treatments of 25, 50 and 100 mg P kg^{-1} soil increased the shoot dry weight / plant by 22, 56 and 106% at 27 DAS; 22.83, 38.41 and 65.16% at 51 DAS; 36.31, 51.75 and 87.72% at 84 DAS and 13.95, 30.36 and 59.69% at harvesting stage over the control during the experiment, respectively. The increase in shoot dry weight due to increase in P fertilizer doses were might be due to an increase in nutrient availability and therefore, significant increase in vegetative growth of plants was obtained. Increase in shoot yield with increase in P level of soil was reported by many scientists [9,10]. As regards of the extent of the varietals response to levels of P application, it may be observed that the behavior of the four varieties of maize were significantly different among each other. Based on the response pattern at the 100 mg kg^{-1} P application level, the genotypes were arbitrarily classified as efficient responsive (Pragati, MRM-3845) and inefficient responsive Kuwari (local variety). The responsive genotype exhibited 1.37 to 2.56 fold shoot dry weight increase over the inefficient responsive genotypes at the same P application rates. Genotypes “Pragati” produced the highest SDW among all the genotypes at all P levels and at each harvest. Genetic differences for SDW under differential P levels were also reported [11].

Root Length (m plant^{-1})

Data pertaining to root length for four maize cultivars in response to levels of P application at different days after harvest of maize is presented in Table 2. For all cultivars, root length also followed the same trend as shoot weight up to the middle age of the crop (84 DAS) and further decreases at harvest. At control, root length (RL) of cv. Kuwari was 1.5 times less and that of cv. Pragati was 1.3 times more than the average root length of cultivars i.e. 131.3m plant^{-1} in the beginning of the growth at 27 DAS. With application of 25, 50 and 100 mg P kg^{-1} soil, average root length of maize cultivars increased 1.2, 1.5 and 1.6 times, respectively as compared to control (131.3) at 27 DAS. The Average root length (RL) of all the cultivars increased significantly with the initial increment in P_{25} level to P_{50} (21.86 and 20.19%) and with further increase level P_{50} to P_{100}, RL increased but the increment was very less only 6.50%. At P_{25}, P_{50} and P_{100}, root length of maize cultivar was1.22, 1.10 and 1.07 times higher at 54 DAS and 1.20, 1.23 and 1.21 times higher than average RL of cultivars at third harvest (84DAS). It is reported that application of high doses of P greatly reduces root length of maize cultivars. [12] In respect of the cultivars "Pragati" have maximum root length at compared to other cultivars. The average values of root length varied from 132.3 to 212.0 at 27 DAS, 154.0 to 230.0 at 51 DAS, 170.3 to 244.0 at 84 DAS and at harvest 134.5 to 196.0 m per plant respectively, which were significantly higher in Pragati.

Phosphorus Content (%) in Shoot

Results on phosphorus content recorded at different harvest of maize as influenced by P levels are presented in Table 3. Application of increasing levels of P from 0, 25, 50 and 100 mg P kg^{-1} significantly increased the P content in shoot of maize over control at all the stages. Average P content increase by 0.06 % (control) at 27 DAS and 0.15% with application of 100 mg P kg^{-1} soil at 51 DAS and after that the per cent P content in maize shoot decreased. Among the cultivars the average P content in shoot varied from 0.07% to 0.11% at 27 DAS and significantly increased up to 51 DAS (0.15%). Further with the advancement of the crop the P content decreases. The rate of increase in shoot P content with increased P level was higher for maize cultivars "Pragati", it might be the possible reason for higher relative shoot dry weight of maize. Increase of shoot P content with the increase of P level of soil was also reported [13] for different genotypes of wheat and maize. [14-15]

Phosphorus Uptake (µ mol pot^{-1})

P uptake significantly increased with increasing doses of P application (Table 3). The mean maximum P uptake 307.27, 200.44, 136.51 and 159.15 per cent was recorded at 27, 51, 84 DAS and at harvest with application of 100 mg P kg^{-1} soil over control. The P uptake increase with increasing rate of P levels upto the 84 DAS after that the uptake was decreased. The P uptake was significantly different among all the cultivars at different harvest. Among maize cultivars, Pragati could obtain 1.8, 0.98, 1.4 and 1.9 times higher P uptake than mean P uptake under low P supply conditions during 27 DAS, 51 DAS, 84 DAS and at harvest respectively. P uptake increases with increasing levels of P application were also reported [16,17]. With the 0.08% and 0.07 % shoot P content at control (P_0) maize cultivar Pragati produced more shoot dry weight than cultivar MRM-3845 and other. Thus Pragati had lower internal P requirement and higher P uptake than all other maize cultivars under low P supply conditions. From P_0 to P_{100}, maize cultivar Pragati had 1.77, 1.65, 1.14 and 1.65 times higher P uptake than mean P uptake of all the cultivars of the crop at 27 DAS. The P uptake was increased up to third harvest of the crop (84DAS) and after the uptake was decreased at harvest of the crop. This provides evidence in their support of being more efficient cultivar than others. The similar result was also reported [14,18].

Root Infection (%)

The percentage of root infection in unfertilized pot was significantly higher as compared to different P levels *e.i.* P_{25}, P_{50} or P_{100} levels among all the cultivars at each harvest. On an average, phosphorus supply affected percentage of root infected by AM which was 60 % of the roots at P_0, and decreased to around 55 %, 49% and 40 % at P_{25}, P_{50} and P_{100} levels respectively in all the cultivars during the different growth stages. The mean extent of decrease ranging from control to highest doses of phosphorus (100 mg P kg^{-1}) were 33.8 to 18.3, 67.5 to 47.3, 79 to 56.5 and 65.5 to 40.0 at 27, 51, 84 and harvest respectively (Table 4). So, when P is limiting, mycorrhizal infection probably increases the P supply by extending the volume of soil accessible to plant which, resulted in the improvement relative yield in P deficient soil. As the magnitude of the observed AM infection on P uptake was affected by the increased amount of P, it may be assumed that AM generally contributes significantly to P uptake under P deficient soil. In red gram and maize, root infection started in between 0-30 days and attained maximum at 120 and 90 days after sowing of the crops respectively which decreased thereafter [19]. Different levels of colonization between the cultivars may be related to differences in the rate of growth of the fungus through root cortex. Among the cultivars Pragati registered the highest percentage of root infection at each stages of harvest. The mycorrhizal colonization of roots generally increased up to middle of the growing season for all the cultivars with maximum

Table 1: Some physical and chemical properties of the experimental soil

Sand (%)	Silt (%)	Clay (%)	Soil texture	Bulk density (Mg m^{-3})	Particle density (Mgm^{-3})	WHC (%)	pH	EC (dSm^{-1})	Organic matter (g kg^{-1})	Free $CaCO_3$(%)	Available phosphorus (ppm)
48.76	30.88	20.36	Sandy loam	1.43	2.56	45.40	7.1	0.25	612	0.37	18.3

Table 2: Effect of different levels of phosphorus on Shoot dry weight and Root length of maize cultivars at different interval

DAS	Cultivar (C)	Shoot dry weight (g $plant^{-1}$) P applied (mg kg^{-1}soil)				Mean	Root length (m $plant^{-1}$) P applied (mg kg^{-1})				Mean
		P 0	P 25	P 50	P 100		P 0	P 25	P 50	P 100	
	Pragati (V1)	0.74	0.84	1.0	1.46	1.01	165	205	223	255	212.0
27	HQPM (V2)	0.46	0.56	0.68	0.89	0.65	135	165	185	172	164.3
	MRM-3845 (V3)	0.55	0.66	0.96	1.19	0.84	137	176	196	210	1 79.8
	Kuwari (V4)	0.26	0.36	0.48	0.57	0.42	88	94	165	182	132.3
	Mean	0.50	0.61	0.78	1.03		131.3	160.0	192.3	204.8	
	CD		C & P = S					C & P = S			
51	Pragati (V1)	9.26	11.28	12.42	15.78	12.19	186	224	244	268	230.5
	HQPM (V2)	8.61	10.03	11.16	13.19	10.75	410	181	191	203	178.8
	MRM-3845 (V3)	8.76	10.60	12.05	15.05	11.62	148	184	205	211	187.0
	Kuwari (V4)	7.01	9.41	10.91	11.54	9.72	128	144	165	179	154.0
	Mean	8.41	10.33	11.64	13.89		150.5	183.3	201.3	215.3	
	CD		C & P = S					C & P = S			
84	Pragati (V1)	25.48	35.44	37.93	45.41	36.07	205	234	265	272	244.0
	HQPM (V2)	18.87	24.64	28.13	36.26	26.98	146	182	198	208	183.5
	MRM-3845 (V3)	22.83	34.91	36.08	44.17	34.50	152	194	205	221	193.0
	Kuwari (V4)	15.23	17.34	22.91	28.82	21.08	136	156	191	198	170.3
	Mean	20.60	28.08	31.26	38.67		159.8	191.5	214.8	224.8	
	CD		C & P = S					C & P = S			
	Final Pragati (V1)	36.97	40.05	43.68	53.37	43.52	179	186	194	225	196.0
	harvest HQPM (V2)	29.63	33.73	39.69	49.41	38.12	139	165	180	181	166.3
	MRM-3845 (V3)	31.34	39.23	42.46	1.55	41.15	141	178	181	189	172.3
	Kuwari (V4)	21.94	23.57	30.44	37.12	28.27	106	121	137	174	134.5
	Mean	29.97	34.15	39.07	47.86		141.3	162.5	173.0	192.3	
	CD		C & P = S					C & P = S			

C = Cultivar, P = Phosphorus levels, S = Significant

Table 3: Effect of different levels of phosphorus on P content, Uptake of maize cultivars at different interval

DAS	Cultivar (C)	Phosphorus content (%) in shoot P applied (mg kg^{-1} soil)				Mean	Phosphorus uptake (µ mol pot^{-1}) P applied (mg kg^{-1} soil)				Mean
		P0	P25	P50	P100		P0	P25	P50	P100	
27	Pragati (V1)	0.08	0.10	0.11	0.16	0.11	19.51	27.61	34.89	73.90	39.0
	HQPM (V2)	0.06	0.08	0.10	0.13	0.09	9.22	14.08	21.55	37.66	20.6
	MRM-3845 (V3)	0.07	0.09	0.10	0.14	0.10	11.73	18.00	30.41	51.37	27.9
	Kuwari (V4)	0.04	0.06	0.08	0.10	0.07	3.59	7.01	12.39	16.4	9.8
	Mean	0.06	0.08	0.10	0.13		11.0	16.7	24.8	44.8	
	CD		C & P = S					C & P = S			
51	Pragati (V1)	0.11	0.13	0.16	0.19	0.15	223.14	466.25	632.73	948.03	567.5
	HQPM (V2)	0.08	0.10	0.12	0.15	0.11	228.24	324.11	425.69	614.42	398.1
	MRM-3845 (V3)	0.10	0.13	0.15	0.16	0.14	279.22	437.58	574.18	764.67	513.9
	Kuwari (V4)	0.07	0.10	0.11	0.11	0.10	178.22	298.81	368.48	403.18	312.2
	Mean	0.09	0.12	0.14	0.15		227.2	381.7	500.3	682.6	
	CD		C & P = S					C & P = S			
84	Pragati (V1)	0.10	0.11	0.11	0.14	0.12	808.69	1237.94	1361.80	2018.37	1356.7
	HQPM (V2)	0.08	0.09	0.09	0.10	0.09	479.37	730.92	803.88	1112.85	781.8
	MRM-3845 (V3)	0.09	0.11	0.12	0.12	0.11	628.06	1214.34	1336.76	1683.25	1215.6
	Kuwari (V4)	0.07	0.08	0.05	0.06	0.07	338.81	459.39	339.08	518.28	413.9
	Mean	0.09	0.10	0.09	0.11		563.7	910.6	960.4	1333.2	
	CD		C & P = S					C & P = S			
Final harvest	Pragati (V1)	0.05	0.06	0.09	0.10	0.08	900.37	763.18	1202.54	1694.55	1140.2
	HQPM (V2)	0.03	0.06	0.06	0.08	0.06	313.84	643.29	798.13	1255.73	752.7
	MRM-3845 (V3)	0.05	0.05	0.07	0.07	0.06	531.09	664.19	988.77	1200.34	846.1
	Kuwari (V4)	0.02	0.03	0.05	0.06	0.04	139.4	174.33	515.58	733.83	390.8
	Mean	0.04	0.05	0.07	0.08		471.2	561.2	876.3	1221.1	
	CD		C & P = S					C & P = S			

C = Cultivar, P = Phosphorus levels, S = Significant

Table 4: Effect of different levels of phosphorus on % root infection and available phosphorus of maize cultivars at different interval

DAS	Cultivar (C)	Root infection (%) P applied (mg kg^{-1} soil)				Mean	Available phosphorus (ppm) P applied (mg kg^{-1} soil)				Mean
		P_0	P_{25}	P_{50}	P_{100}		P_0	P_{25}	P_{50}	P_{100}	
27	Pragati (V1)	39	35	29	20	30.8	16.0	18.1	20.1	24.5	19.7
	HQPM (V2)	30	24	20	16	22.5	17.67	19.3	22.8	26.9	21.7
	MRM-3845 (V3)	34	26	22	17	24.8	17.0	18.5	21.5	25.2	20.6
	Kuwari (V4)	32	27	23	20	25.5	17.2	19.1	22.1	26.7	21.3
	Mean	33.8	28.0	23.5	18.3		17.0	18.8	21.6	25.8	
	CD		C & P = S					C & P = S			
51	Pragati (V1)	73	64	61	50	62.0	15.1	17.1	19.2	22.3	18.4

	HQPM (V2)	63	60	50	43	54.0	16.3	18.0	21.5	23.9	19.9
	MRM-3845 (V3)	70	64	56	48	59.5	15.5	17.6	19.5	22.8	18.9
	Kuwari (V4)	64	62	53	48	56.8	16.1	18.1	21.4	23.8	19.9
	Mean	67.5	62.5	55.0	47.3		15.8	17.7	20.4	23.2	
	CD		C & P = S					C & P = S			
84	Pragati (V1)	86	72	68	61	71.8	14.8	15.9	18.1	21.1	17.5
	HQPM (V2)	70	65	62	52	62.3	15.8	16.5	20.1	22.0	18.6
	MRM-3845 (V3)	82	70	68	58	69.5	15.1	16.1	18.5	21.7	17.9
	Kuwari (V4)	78	70	62	55	66.3	15.9	16.7	20.2	22.1	18.7
	Mean	79.0	69.3	65.0	56.5		15.4	16.3	19.2	21.7	
	CD		C & P = S					C & P = S			
Final harvest	Pragati (V1)	74	65	59	45	60.8	14.2	14.8	17.1	18.9	16.3
	HQPM (V2)	61	58	48	35	50.5	15.1	15.9	18.9	19.9	17.5
	MRM-3845 (V3)	65	62	56	41	56.0	14.8	15.3	17.9	19.3	16.8
	Kuwari (V4)	62	60	52	39	53.3	15.2	15.8	18.8	20.5	17.6
	Mean	65.5	61.3	53.8	40.0		14.8	15.5	18.2	19.7	
	CD		C & P = S					C & P = S			

C = Cultivar, P = Phosphorus levels, S = Significant

colonization at the third harvest (84 DAS).

Available Phosphorus (ppm)

Data presented in Table 4 revealed that application of increasing levels of P to maize significantly increased available P status of rhizospheric soil at 27, 51, 84 days after sowing and harvest of maize. The mean extent of increase in available P is due to increasing P- levels recorded over control was of the order of 10.59, 27.06 and 51.76 per cent at 27 days after harvest, 12.03, 29.11 and 46.84 per cent at 51 days after harvest, 5.84, 24.68 and 40.91 per cent at 84 days after harvest while at harvest stage 4.73, 22.97 and 33.11 per cent with the application of 25, 50 and 100 mg kg^{-1}, respectively. The available P increases exponentially with P fertilization [14]. It is clear from the table that at control (P_0) the available P in the rhizsospheric soil was clearly decreased as compared to the initial bulk soil available P. This effect was most pronounced in cv. Pragati compared to the other cultivars.

Conclusion

Based on the above all results among maize cultivars, one efficient and one inefficient cultivar were screened out. Maize cv. Pragati was screened out as efficient cultivars while maize cv. Kuwari was screened out as inefficient cultivar. This indicate that the species and their crop varieties develop different strategies for P use efficiency under P deficient to medium conditions.

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