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Response of Rice Fallow Maize (*Zea mays* L.) to Different Levels of Phosphorus and Its Time of Application under Zero Tillage Conditions

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ABSTRACT

A field experiment was conducted on clay loam soils of Agricultural College Farm, Bapatla during *rabi* seasons of 2009-10 and 2010-11. The treatments consisted of three levels of phosphorus (0, 60 and120 kg P_2O_5 ha^{-1}) as main plot treatments and three timings of phosphorus application at 10 days before harvesting of rice (T_1); 10 DAS of maize (T_2) and 40 DAS of maize (T_3) allotted to sub-plots. The experiment was laid out in split-plot design and the treatments were replicated thrice. During both the years of study, plant height, dry matter accumulation, chlorophyll (SPAD readings), cob length, number of kernels cob^{-1}, kernel weight cob^{-1}, test weight, kernel yield, stover yield, economic returns and nutrient uptake of maize recorded were higher at higher level of phosphorus than those of the plots without addition of phosphorus fertilizer. However, number of days taken to reach 50 per cent tasseling and silking reduced with increase in level of phosphorus from 0 to 120 kg P_2O_5 ha^{-1}. The maximum kernel yield of 72.8q ha^{-1} and 74.9 q ha^{-1} was recorded during 2009-10 and 2010-11, respectively, with the application of 120 kg P_2O_5 ha^{-1} than that of without phosphorus fertilizer but it did not reach the level of significance with 60 kg P_2O_5 ha^{-1} (68.9 and 70.1q ha^{-1}) during both the years of investigation. Irrespective of level of phosphorus applied to maize, the maize kernel yield increased significantly with application of phosphorus fertilizer at 10 days before harvesting of rice crop (69.8 and 72.4q ha^{-1}) than that applied at 10 DAS (67.1 and 69.6 q ha^{-1}) or 40 DAS(63.9 and 65.4 q ha^{-1}) during each year of the experimentation. However, significant reduction in kernel yield was observed when the phosphorus fertilizer was applied at 40 DAS (8.5 and 9.6% in first and second years of study) of maize than that applied at earlier stages of crop growth. The net returns, benefit cost ratio (BCR) and nutrient uptake by maize increased with increase in level of phosphorus.

Key words : Chlorophyll (SPAD readings), Nutrient uptake, Zero tillage.

Maize (*Zea mays* L.) is one of the most important cereals of the world's agricultural economy both as food for human consumption and feed for animal after rice and wheat. Maize has become a crop of interest in rice fallows among the farmers of coastal region of A.P., because of poor yields of pulses, increase of pests and diseases, weed menace and less remunerative prices. Potentiality of maize crop for its growth and development can be fully exploited by adopting suitable agronomic practices such as plant spacing, fertilizers especially, N and P. Phosphorus is a highly important plant nutrient that is in short supply in many soils around the world. After carbon and nitrogen, phosphorus is often the next most limiting element for crop growth. In many intensively cropped areas, optimum response to nitrogen is obtained only when P is also applied along with this nutrient. Phosphorus fertilization is imminent to all crops for maximizing crop yield. Application of fertilizer phosphorus at right time produces high crop yields and ensures more profit to farmers. The importance of phosphorus has been emphasized by many workers (Arya and Singh, 2001). The production technology is not available for rice fallow maize under zero-tillage in respect of phosphorus fertilizers and its time of application. In order to avoid the excess use of chemical fertilizers and to maintain the system sustainable productivity, the present investigation is proposed.

MATERIAL AND METHODS

A field experiment was conducted during *rabi* seasons for two consecutive years (2009-2010 and 2010-2011) at Agricultural College Farm (Field No.16A & Field No.5), Bapatla on sandy clay loam soil with pH 8.0, OC 0.3%, available N (178 &205 kg ha^{-1}), available P_2O_5(38 & 36 kg ha^{-1}) and available K_2O (721 and 758 kg ha^{-1}). The experiment was laid in split-plot design and the treatments were replicated thrice. There are nine treatment combinations in the study and the treatment combinations comprised three levels of phosphorus

Table 1. Growth parameters of rice fallow maize as influenced by phosphorus and its time of application during *rabi* 2009-10 and 2010-11.

Treatments	Plant height(cm) at maturity			Days to 50% tasseling			Days to 50% silking			Chlor. content (SPAD) at 60 DAS		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
P_2O_5 (kg ha^{-1})												
P_1-0	236	240	238	62.8	61.6	62.2	70.2	69.9	70.1	41.0	44.0	42.5
P_2-60	256	261	259	60.4	59.6	60.0	69.1	68.2	68.7	44.0	46.4	45.2
P_3-120	267	272	270	59.4	58.4	58.9	67.2	66.8	67.0	45.8	48.1	47.0
SEm$\pm$	3.4	3.7		0.5	0.3		0.5	0.5		0.7	0.7	
CD (P=0.05)	13	15		1.8	1.1		2.0	2.1		2.7	2.6	
CV (%)	4.1	4.4		2.3	1.4		2.3	2.3		4.4	4.3	
Time of P application												
T_1-10 days before harvesting of rice	261	267	264	62.3	61.3	61.8	70.0	69.6	69.8	44.8	47.1	46.0
T_2 -10 days after sowing of maize	252	256	254	60.6	59.8	60.2	69.0	68.0	68.5	43.3	46.0	44.7
T_3 -40 days after sowing of maize	245	250	248	59.8	58.6	59.2	67.5	67.2	67.4	42.7	45.4	44.1
SEm$\pm$	3.9	4.0		0.5	0.4		0.4	0.5		0.3	0.2	
CD (P=0.05)	12	12		1.4	1.3		1.1	1.4		0.9	0.5	
CV (%)	4.6	4.7		2.2	2.2		1.6	2.0		2.0	1.0	
Interaction (PXT)	NS	NS		NS	NS		NS	NS		NS	NS	

(P) and time of its application (3) *viz.*, P_1: 0; P_2: 60 & P_3: 120 kg P_2O_5 ha^{-1} as main plot treatments and T_1: 10 days before harvesting of rice; T_2: 10 DAS of maize andT_3: 40 DAS of maize as sub-plot treatments and the treatments were replicated thrice. The remaining fertilizers (recommended) of N (120 kg ha^{-1}) and K (40 kg K_2O ha^{-1}) were applied at 10 days after sowing of maize. The maize hybrid "Pioneer 30V 92" was sown on 07-01-2010 and 10-1-2011 under zero tillage conditions by dibbling method with pointed bamboo peg and harvested on 21-4-2010 and 26-4-2011. A total of 14.1 and 137.5 mm rainfall was received during the study period of both the years, respectively.

Maize was sown under zero tillage conditions immediately after harvest of *kharif* rice by dibbling two seeds per hill with the help of pointed bamboo peg and marked nylon ropes as per the treatments. Thinning and gap filling was done at 10 DAS by keeping one seedling hill^{-1}. Calculated quantity of N, P and K through urea, single super phosphate (SSP) and murate of potash (MOP), respectively, were applied as per the treatments. Full dose of P_2O_5 was applied as per the treatments and full dose of K_2O was applied by pocketing method near the seedling at 10 days after sowing (DAS) of maize along with first split dose of urea. Nitrogen was applied in three splits at 10 DAS, knee high stage and tasseling stage. The crop was maintained by adopting the recommended package of practices. A total of three light irrigations were given immediately after application of fertilizers. Pre-emergence application of weedicides like Atrazine @5 g L^{-1} and Paraquat @10 ml L^{-1} were applied on second day after sowing of maize for prevention of regrowth of paddy stubbles and control of germinating weeds. Need based plant protection measures were taken up during crop growth period. The data on plant height, dry matter accumulation, yield attributes, yield, nutrient uptake and net returns were recorded in two years and analysed as per standard statistical procedures as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth parameters

The results on growth parameters *viz*., plant height, dry matter accumulation, 50 per cent tasseling , 50 per cent silking and chlorophyll content (SPAD) were significantly (Table 1) influenced by levels phosphorus and its time of application during both the years of investigation. Plant height (at maturity), chlorophyll content (30, 60 and 90DAS) and dry matter accumulation at 60, 90 DAS and at maturity were significantly higher with 120 kg P_2O_5 ha^{-1} than without application of phosphorus and was on a par with 60 kg P_2O_5 ha^{-1} during both the years of research study. This phenomena showed that increased phosphorus availability at higher level of P might have attributed to faster cell elongation resulting in more root proliferation and greater leaf area resulting in production of more photosynthates responsible for increased growth parameters. These findings are in agreement with those of Arya and Singh (2001). However, days to 50 per cent tasseling and silking decreased with increasing level of phosphorus from 0 to 120 kg P_2O_5 ha^{-1}. Application of phosphorus at higher levels might have helped in enhanced reproductive growth and development resulting early appearance of tassels and silks. These results are in line with the findings of Suryavanshi *et al*. (2009). Irrespective of level of phosphorus application, early application of phosphorus fertilizer at 10 days before sowing of maize resulted more growth and development than that applied at later stages of crop growth (40 DAS). The higher dry matter accumulation was with higher level of P at early stages of crop growth might be due to extended period of availability of nutrients from the soil and production of more photosynthates enhancing the plant root growth and development which inturn helped in accumulation of more photosynthates in stems. These findings are in close conformity with those of Alley *et al.* (2007).

Yield attributes and Yield

Phosphorus is known to be one of the essential nutrients required for maize growth and development and appreciable quantities are required for good yields. Yield attributes like cob length, number of kernels cob^{-1}, kernel weight cob^{-1}, shelling percentage and test weight were significantly higher with application of 60 kg P_2O_5 ha^{-1} than without application but was on a par with 120 kg P_2O_5 ha^{-1} (Table 2 &3). Significant response to applied phosphorus was up to 60 kg P_2O_5 ha^{-1} during both the years. Thereafter no significant difference was observed with higher levels of phosphorus. The maximum kernel yield of maize in the study, 72.8 q ha^{-1} and 74.9 q ha^{-1} during 2009-10 and 2010-11, respectively, was recorded with the application of 120 kg P_2O_5 ha^{-1} than that of without phosphorus fertilizer but it did not reach the level of significance with 60 kg P_2O_5 ha^{-1} during both the years of investigation (Fig 1 & 2). The increased levels of phosphorus accomplished the requirement of phosphorus nutrition and caused rapid root development that resulted in improved plant growth consequently showed significant translocation and storage of photosynthates from source to sink which resulted in significant enhancement in all the yield attributing characters and greater kernel and stover yields. A similar trend of improvement in yield was reported by Sutaliya and Singh (2005) and Manimaran and Poonkodi (2009). Irrespective of level of phosphorus, kernel yield was increased significantly with application of phosphorus fertilizer at 10 days before harvesting of rice crop than that applied either at 10 DAS or 40 DAS during both the years of experimentation. Significant reduction in yield attributes and yield of maize was recorded with delay (40 DAS) in application of phosphorus than that applied at 10 days before harvesting of rice or immediately after sowing under zero tillage conditions. However, significant reduction in kernel yield was also observed when the phosphorus fertilizer applied was at 40 DAS of maize than that applied at earlier stages of crop growth. It might be due to the phosphorus availability at early stages which is very crucial for plant growth and formation of roots especially under zero tillage conditions. For this reason, starter fertilizers most often contained phosphorus along with nitrogen as basal. These results are in close conformity with those of Alley *et al*. (2007). Harvest index was significantly higher with increase in level of phosphorus application from 0 to 120 kg P_2O_5 ha^{-1} but the difference between 60 and 120 kg P_2O_5 ha^{-1} was comparable. The influence of phosphorus on yield components such as cob length and test weight was resulted in favourable effects on the harvest index. Time of phosphorus application had significant effect on harvest index during first year only .Similar kind of result was also reported by Hussaini *et al.* (2002). Irrespective of level of phosphorus, kernel yield increased significantly with application of phosphorus fertilizer at 10 days before harvesting of rice crop than applied at 10 DAS or 40 DAS during both the years of the experimentation. However, significant reduction in kernel yield was observed when the phosphorus fertilizer applied was at 40 DAS of maize than applied at earlier stages of crop growth. Harvest index was

Table 2. Dry matter accumulation and yield attributes of rice fallow maize as influenced by phosphorus and its time of application during *rabi* 2009-2010 and 2010-11.

Treatments	DMA at maturity(q ha^{-1})			Cob length (cm)			No. of kernels cob-1			Kernel weight cob^{-1}(g)		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
P_2O_5 (kg ha^{-1})												
P_1-0	121.3	126.8	124.1	16.0	16.3	16.2	376	406	391	99	102	101
P_2-60	137.6	142.6	140.1	18.1	18.2	18.2	477	527	502	114	118	116
P_3-120	147.5	153.5	150.5	19.2	20.2	19.7	552	595	574	122	126	124
SEm$\pm$	2.1	4.1		0.3	0.4		17.5	15.6		2.3	2.3	
CD (P=0.05)	8.2	16.1		1.3	1.4		69	61		9	9	
CV (%)	3.3	8.7		5.8	6.1		11.2	9.2		6.2	6.0	
Time of P application												
T_1-10 days before harvesting of rice	143.9	149.3	146.6	18.5	19.0	18.8	490	547	519	116	121	119
T_2 -10 days after sowing of maize	135.1	139.8	137.5	17.9	18.2	18.1	462	503	483	114	116	115
T_3 -40 days after sowing of maize	127.5	133.8	130.7	17.0	17.5	17.3	452	478	465	105	109	107
SEm$\pm$	3.8	3.6		0.3	0.4		9.4	12.7		2.0	2.8	
CD (P=0.05)	11.7	11.2		0.8	1.1		29	39		6	9	
CV (%)	8.4	7.7		4.7	5.9		6.0	7.4		5.4	7.3	
Interaction (PXT)	NS	NS		NS	NS		NS	NS		NS	NS	

DMA: Dry matter accumulation

Table 3. Yield attributes and yield of rice fallow maize as influenced by phosphorus and its time of application during *rabi* 2009-10 and 2010-11.

Treatments	Shelling percentage			Test weight(g)			Kernel yield (q ha-1)			Stover yield (q ha-1)			HI (%)		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
P_2O_5 (kg ha^{-1})															
P_1-0	70.9	71.5	71.2	26.6	28.1	27.4	59.3	62.5	60.9	78.0	80.1	79.1	43.3	43.7	43.5
P_2-60	74.3	76.4	75.4	27.9	30.0	29.0	68.9	70.1	69.5	86.6	87.9	87.3	44.3	44.3	44.3
P_3-120	76.0	78.2	77.1	28.7	31.1	29.9	72.8	74.9	73.9	91.1	92.0	91.6	44.4	44.8	44.6
SEm$\pm$	0.8	1.2		0.3	0.3		1.9	2.0		2.4	2.2		0.2	0.2	
CD (P=0.05)	3.3	4.9		1.0	1.3		7.4	7.8		9.4	8.6		0.6	0.6	
CV (%)	3.4	4.9		2.9	3.2		8.5	8.8		8.5	7.5		1.0	1.1	
Time of P application															
T_1-10 days before harvesting of rice	75.6	76.8	76.2	28.8	30.7	29.8	69.8	72.4	71.1	86.8	90.1	88.5	44.5	44.5	44.5
T_2 -10 days after sowing of maize	73.6	75.7	74.7	27.7	29.8	28.8	67.1	69.6	68.4	85.7	87.0	86.4	44.0	44.4	44.2
T_3 -40 days after sowing of maize	72.0	73.6	72.8	26.7	28.7	27.7	63.9	65.4	64.7	83.2	83.7	83.5	43.5	43.9	43.7
SEm$\pm$	0.9	0.8		0.5	0.5		1.5	1.8		2.0	2.4		0.2	0.4	
CD (P=0.05)	2.7	2.4		1.4	1.4		4.5	5.5		NS	NS		0.6	NS	
CV (%)	3.6	3.2		4.9	4.8		6.6	7.7		7.1	8.4		1.4	2.5	
Interaction (PXT)	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

Table 4. Net returns, BCR and nutrient uptake by rice fallow maize at maturity and soil fertility status after harvest as influenced by phosphorus and its time of application during *rabi* 2009-10 and 2010-11

	Net returns			BCR			Nutrient uptake (kg ha^{-1}) N			P			K		
Treatments	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
P_2O_5 (kg ha^{-1})															
P_1-0	30582	44980	**37781**	**1.48**	**2.18**	**1.83**	90.2	101.4	95.8	34.7	37.6	36.2	113.1	129.6	121.4
P_2-60	37698	51697	44698	1.73	2.36	2.10	106.8	118.3	112.6	43.8	48.3	46.1	137.0	156.6	146.8
P_3-120	39874	55261	47568	1.73	2.36	2.10	125.8	129.8	127.8	51.4	54.8	53.1	156.4	173.8	165.1
SEm±							4.0	3.1		2.5	1.3		5.5	5.9	
CD (P=0.05)							15.8	12.2		9.7	5.3		21.7	23.0	
CV (%)							11.3	7.9		17.0	8.7		12.3	11.4	
Time of P application															
T_1-10 days before harvesting of rice	38545	54049	46297	1.76	2.45	2.11	115.3	124.1	119.7	47.7	50.7	49.2	144.4	165.0	154.7
T_2 -10 days after sowing of maize	36176	51169	43673	1.65	2.32	1.99	108.1	115.6	111.9	43.2	46.7	45.0	134.9	152.7	143.8
T_3 -40 days after sowing of maize	33433	46720	40077	1.53	2.13	1.83	99.3	109.7	104.5	39.0	43.3	41.2	127.0	142.3	134.7
SEm±							2.2	1.8		0.9	1.0		3.1	3.7	
CD (P=0.05)							6.8	5.7		2.8	3.1		9.6	11.5	
CV (%)							6.1	4.7		6.2	6.2		7.0	7.3	
Interaction (PXT)							NS	NS		NS	NS		NS	NS	

significantly higher with 120 kg P_2O_5 ha^{-1} than without addition of phosphorus fertilizer but on a par with 60 kg P_2O_5 ha^{-1} during both the years of investigation.

Nutrient uptake:

Uptake of N, P and K recorded were the highest with 120 kg P_2O_5 ha^{-1} and was significantly superior over no phosphorus but comparable with 60 kg P_2O_5 ha^{-1} during both the years of experimentation. Nutrient uptake by the crop increased progressively with increase in level of phosphorus which might be due to increased biomass production as well as concentration of nutrients in grain and kernel. These findings are in line with those of Narang *et al*. (1989) and Sutaliya and Singh (2005).

ECONOMICS:

Application of 60 kg P_2O_5 ha^{-1} at 10days before harvesting of rice crop resulted in maximum net returns of Rs.43,513/- in first year, however, in second year Rs.60,766/- with application of 120 kg P_2O_5 $ha^{-1}$and similar trend in benefit cost ratio (1.90 and 2.60 in first and second years, respectively) were obtained during both the years of study. Irrespective of the time of phosphorus application, the profitability increased with increasing level of phosphorus application in rice fallow maize indicating the need for fertilizer phosphorus as maize is an exhaustive crop. These results are in accordance with those of Sharma and Behera (2009).

From the study conducted for two consecutive years, it was indicated that early application of phosphorus at 10 days before harvesting of preceding rice crop with 60 kg P_2O_5 ha^{-1} realised significantly superior yields than without phosphorus fertilizer application to rice fallow maize under zero tillage conditions.

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