



Effect of rice (*Oryza sativa*) establishment methods and levels of irrigation and phosphorus on P use efficiency of zero-tillage maize (*Zea mays*) under rice based cropping system

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ABSTRACT

A field experiment was conducted during two consecutive seasons of *kharif* and *rabi* of 2007-08 and 2008-09 at College farm, College of Agriculture, Rajendranagar, Hyderabad on sandy clay loam soil. The experiment was laid out in split-plot design replicated four times. During *kharif*, the experimental field was divided into two blocks in each replication wherein two methods of rice crop establishment (Transplanted and Aerobic method) were evaluated. During *rabi*, zero-tilled maize was grown in sequence to rice while considering the two previous rice (*Oryza sativa* L.) crop establishment methods as main-plot treatments and two levels of irrigation (1.0 and 0.8 IW:CPE) and four levels of phosphorus (0,30,60 and 90 kg P₂O₅/ha) as sub-plot treatments. The objective of the study was to evaluate the effect of rice crop establishment methods, levels of irrigation and phosphorus on P nutrition of zero-tilled maize (*Zea mays* L.) under rice-maize system. The grain yield of maize improved significantly from 0 to 60 kg P₂O₅/ha application. Higher P-use efficiency was recorded in maize crop grown after transplanted rice than that of aerobic rice and the irrigations scheduled at IW: CPE ratio of 1.0 than with IW: CPE ratio of 0.8 during both the years. There was significant decrease in P- use efficiency with increase in P₂O₅ levels from 30 to 60 and 90 kg/ha (53.91 to 24.95 and 57.17 to 25.61 kg grain/kg P₂O₅/ha during 2007-08 and 2008-09 respectively). The balance sheet of available soil P at the end of two years in rice-maize crop sequence indicated that, the uptake of P by maize crop was much higher than the rice crop and the depletion of available soil P was maximum when phosphorus was applied to rice during *kharif* and without phosphorus application to maize during subsequent *rabi*. However, maximum accumulation of phosphorus was noticed when two crops were fertilized with 60 kg P₂O₅/ha for both rice and maize. Based on the yield-input relationship, the optimum level of phosphorus was 85.4 kg P₂O₅/ha for realizing higher yield of 7 309 kg/ha.

Key words: Apparent P-recovery (%), Irrigation and phosphorus levels, P-use efficiency, Phosphorus balance, Rice crop establishment methods, Zero-tillage maize

Rice (*Oryza sativa* L.) -maize (*Zea mays* L.) is one of the pre-dominant cropping system of both command and non-command areas of Andhra Pradesh. Shortage of irrigation water and increased cost of transplanting in rice made several researchers to study the possibility of rice cultivation under irrigated dry conditions (aerobic). The results are encouraging with aerobic rice method of cultivation wherein the productivity levels were ranging from 4.5 to 5.0 tonnes/ha with significant saving of irrigation

water and enhanced water productivity. Of late, maize is finding place after *kharif* rice under zero-tilled conditions while replacing the traditional pulse crops due to yield decline caused by salinity, weed infestation, pests and diseases.

Irrigation as well as nutritional requirements, particularly, the phosphorus nutrition of zero-tilled maize is different from conventionally sown maize with due land preparation because of alteration of both physico-chemical properties of soil under rice-based situations. The differential response of phosphorus in rice-maize system is inconsistent because most of the soils under rice-based cropping are low to medium in available 'P'. The unique conditions created by submergence influence the transformation and availability of both native and applied fertilizer phosphorus. Drying of soil after submergence generally decreases the solubility of phosphorus due to its fixation by reactivated sesquioxides and also the crop response to phosphorus application is not apparent as in

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case of nitrogen. Similarly, in zero-tillage conditions due to less mineralization, more quantity of nutrients are required compared to normal tillage conditions. Therefore, rational phosphorus management in rice-based cropping system is imperative for P economy and sustainability in yield levels. Keeping above aspects in view, a study was undertaken for two years on rice performance under two different methods of cultivation in *kharif* and response of zero-tilled maize after *kharif* rice to irrigation and phosphorus levels.

MATERIALS AND METHODS

The field study was conducted during rainy and winter seasons of 2007-08 and 2008-09 at Water Technology Centre, Agricultural College Farm, Rajendranagar (78°23 E and 17°1 N and 524.6 m above MSL), Hyderabad, Telangana. The climate falls under Semi Arid Tropical and characterized by hot summer and cold winters. The mean maximum and minimum temperatures ranges from 31.2°C and 15.6°C in 2007-08 and 32.1°C and 17.0°C in 2008-09 and with an average annual rainfall of 398.5 mm and 1095.6 in 2007-08 and 2008-09 which was received in 38 and 39 rainy days, respectively. The experimental soil was sandy clay loam with pH 7.4, low in organic carbon (0.51%) and available nitrogen (240.6 kg/ha), medium in available phosphorus (15.39 kg/ha) and high in available potassium (631.6 kg/ha). The experiment was conducted in split-plot design with four replications. During rainy (*kharif*) season, the two methods of rice crop establishment (Transplanted and aerobic method) were evaluated where in during winter season zero-tillage maize was grown in sequence to rice while considering the two previous rice crop establishment methods as main-plot treatments and combination of two levels of irrigation (1.0 and 0.8 IW: CPE) and four levels of phosphorus (0, 30, 60 and 90 kg P₂O₅/ha) as sub-plot treatments. During rainy season a thirty day old seedlings (three/hill) of semi dwarf rice variety Cottondora sannalu (MTU 1010) were transplanted at a spacing of 20 cm × 15 cm in a puddled field. Whereas under aerobic method, direct seeding of dry seed was sown in solid rows at row spacing of 20 cm at the same date when nursery sowing was done for transplanted rice. A fertilizer dose of N, P and K @ 120-60-40 kg/ha was applied in the form of urea, single super phosphate and muriate of potash. Half of N, entire P and K was applied as basal and remaining N in two splits at maximum tillering and at PI stages. In case of aerobic rice the weeds were controlled by spraying pendimethalin 35 EC @ 1.0 kg/ha in 500 l of water in 24 hours after direct seeding. This was followed by push hoeing done at 25 and 45 days after sowing and for transplanted rice butachlor 50 EC @1.25 kg/ha mixed with sand was applied at 48 hr after transplanting maintaining thin film of water followed by one HW at 30 DAT. Two sprays of 0.2% ferrous ammonium sulphate solution were also given at weekly interval for aerobic rice to correct the iron deficiency.

For transplanted rice, at each irrigation 2 cm up to PI

stage and later 5 cm of standing water level was maintained. Whereas, for aerobic rice initially, one soaking irrigation was given. One week after germination, the irrigations were scheduled. When the soil moisture reaches to around 28% which is equivalent to 0.2 bar or -20 KPa, 50 mm of irrigation water was given. The soil moisture tension is measured with theta probe soil moisture sensor ML2. As the experimental site is sandy clay loam soil, the soil moisture tension of -20 KPa generally reaches within 4 days. For both methods at each irrigation the amount of water applied was measured and directly delivered into the plot through water meter attached to the water source by fixing it to a hose pipe and shifting it from plot to plot.

During winter (*rabi*) season, paraquat 50 EC (non-selective herbicide) @ 1.25 kg/ha was sprayed immediately after rice harvest to control the existing weeds as well as to arrest the re growth of rice stubbles. Maize hybrid DHM 117 seeds were dibbled at a spacing of 60 cm × 20 cm under zero-tillage condition. One day after sowing, atrazine a pre-emergence herbicide was sprayed @1.0 kg/ha. A recommended dose of N and K fertilizers were applied @ 120 N and 40 K kg/ha and P fertilizer was applied as per the treatments imposed. The entire phosphorus and potash was applied as basal in the form of single super phosphate and muriate of potash and N was applied in three splits (1/3 as basal, 1/3 at knee high and 1/3 at tasseling and silking) in the form of urea. Pests and disease control were adopted as per the recommendations for the region. One pre-sowing irrigation followed by one common irrigation each of 25 mm immediately after sowing of the crop was given to ensure uniform germination. Subsequent irrigations were scheduled based on IW: CPE ratio. In IW: CPE approach, 50 mm depth of irrigation water was applied uniformly when cumulative pan evaporation (CPE) reached the level of 62.5 and 50 mm in order to get IW: CPE ratio of 0.8 and 1.0, respectively. By multiplying the depth of irrigation (50 mm) and area of the plot, volume of irrigation water required for each plot was arrived. Calculated volume of water was delivered to respective plots through the water meter attached to the water source by fixing it to a hose pipe and shifting it from plot to plot. The Cumulative Pan Evaporation values were obtained from standard USWB Class A pan. Plant samples were analyzed for the N, P and K contents. Total uptake of nutrients were computed by multiplying the per cent nutrient content with dry matter. Phosphorus fertilizer use efficiency was worked out in terms of apparent recovery of phosphorus (%), phosphorus use efficiency (kg grain/kg P₂O₅) by using the following formula.

Apparent recovery of phosphorus (%) (Fageria *et al.* 1997)

$$\text{Recovery of applied phosphorus} = \frac{P_u - P_{uo}}{P_t}$$

where, P_u, Total uptake of P (kg/ha) in a given treatment; P_{uo}, total uptake of P (kg/ha) in control, i.e. without P application; P_t, applied P (kg/ha) in given treatment.

Phosphorus use efficiency (kg grain/kg P₂O₅) (Dobermann 2005)

$$PUE = \frac{Y_t - Y_o}{P_t}$$

where, PUE, Phosphorus use efficiency; Y_t and Y_o, grain yield (kg/ha) in treatment and under control, respectively; P_t, amount of P₂O₅ (kg/ha) applied in treatment 't'.

The Phosphorus balance for the crop sequence at the end of second year was worked out with the following relationship.

Phosphorus balance

$$X = a - [(b + c) - d]$$

where, X, Phosphorus (kg) gain or loss at the end of second year; a, actual balance of available phosphorus at the end of second year; b, initial status of available phosphorus; c, addition of phosphorus by inorganic source to the crop sequence; d, quantity of phosphorus (kg) removed by crop sequence.

RESULTS AND DISCUSSION

Response of zero-tilled maize to phosphorus application on growth and yield

There was an increase in grain yield of 2 204 kg in 2007-08 and 1 928 kg in 2008-09 with the application of 60 kg P₂O₅/ha over the control (0 kg P₂O₅/ha). Significant difference in grain yield was also observed between 30 and 60 kg P₂O₅/ha and there was marginal increase in grain yield beyond 60 kg P₂O₅/ha (Table 1). The significant

increased yield and yield attributes with increased levels of phosphorus application was also reported by Ahmad Alias *et al.* (2003), Gill *et al.* (2006) and Iqbal Hafiz (2003). Similar response in stover yield was observed up to 60 kg P₂O₅/ha. The significant improvement in these yield contributing characters due to increasing levels of phosphorus up to 60 kg P₂O₅/ha was the result of improved growth particularly dry matter production and its partitioning at the time of differentiation. Dry matter accumulation of maize increased with increased rates of 'P' by 7.23, 12.52 and 15.87% due to 30, 60 and 90 kg P₂O₅/ha, respectively over control was also reported by Hussein *et al.* (2009). These results are in agreement with Mahakulkar *et al.* (1992), Hussein and Khater (2003) and Wasongo *et al.* (2008).

Study on the interaction among three factors on maize grown after rice indicated that there was a strong relation between irrigation levels and phosphorus levels rather than crop establishment methods and phosphorus levels. The influence of phosphorus was more pronounced at higher irrigation levels (IW: CPE ratio of 1.0), on yield attributes and final grain yield. Higher irrigation frequency (IW : CPE ratio of 1.0), increase in level of phosphorus up to 60 kg P₂O₅/ha resulted in increased grain yield (Table 2 and 3). It is due to availability of adequate moisture in the soil favoured for greater phosphorus supply to crop plants under zero tilled conditions. Selles *et al.* (1997) reported that zero-tillage increased total P in the surface 10 cm soil by 15% compared to conventional tillage which was mainly due to adequate availability of soil moisture in the zero-tillage conditions for a prolonged period. The response to applied phosphorus application was more because the native soil

Table 1 Influence of rice crop establishment methods, irrigation and phosphorus levels on dry matter, yield and nutrient uptake of zero-tillage maize

Treatment	Dry matter (kg/ha)		Grain yield (kg/ha)		Stover yield (kg/ha)		Nutrient uptake (kg/ha)					
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08		2008-09		2007-08	2008-09
<i>Main-plots: Crop establishment methods (M)</i>							<i>N</i>		<i>P</i>		<i>K</i>	
Transplanted rice	14 723	15 333	6 139	6 533	7 675	8 391	107.68	116.12	17.58	17.68	98.29	101.20
Aerobic rice	16 589	16 635	6 545	6 803	7 965	8 824	110.73	110.12	18.18	18.20	103.17	106.17
SEm ±	311	330	68	62	93	106	1.19	1.50	0.23	0.30	1.08	0.92
CD (P=0.05)	991	924	156	199	279	318	2.49	3.26	0.48	0.65	2.16	2.02
<i>Sub-plots: Irrigation levels (I), IW:CPE ratio</i>												
0.8	14 997	15 263	6 130	6 396	7 790	8 184	101.63	107.04	15.18	16.92	93.36	96.34
1.0	16 314	16 704	6 554	6 940	7 850	9 033	116.79	119.20	18.78	18.95	108.10	111.04
SEm ±	256	395	107	89	83	103	1.56	1.45	0.42	0.36	2.86	2.73
CD (P=0.05)	517	797	217	180	168	208	3.21	2.94	0.86	0.72	6.0	5.73
<i>Phosphorus levels (P) kg P₂O₅/ha</i>												
0	11 012	11 050	4 938	5 340	6 028	7 010	74.46	78.12	9.76	9.43	70.54	73.76
30	15 448	15 539	6 045	6 686	7 790	8 569	102.58	110.10	16.16	17.21	93.53	96.06
60	17 863	18 322	7 142	7 268	8 689	9 383	128.75	129.20	22.20	22.01	116.66	119.19
90	18 299	19 023	7 244	7 379	8 771	9 472	131.03	135.04	23.40	23.11	122.18	125.74
SEm ±	362	595	132	116	117	146	3.08	3.16	0.98	1.50	2.64	3.83
CD(P=0.05)	731	1128	292	225	237	295	6.17	6.95	2.16	3.34	5.80	8.42

Table 2 Interaction effect of rice crop establishment methods, and irrigation levels on grain yield (kg/ha) of maize

Irrigation levels (I)	Rice crop establishment methods (M)					
	2007-08			2008-09		
	Trans-planted	Aerobic	Mean	Trans-planted	Aerobic	Mean
IW:CPE ratio						
0.8	5 798	6 462	6 130	6 258	6 536	6 396
1.0	6 381	6 728	6 554	6 808	7 072	6 940
Mean	6 139	6 545		6 533	6 803	
		SEm ±	CD	SEm ±	CD	
			(P=0.05)		(P=0.05)	
Between two I means at same or different M		152	307	126	255	
Between two M means at same or different I		114	245	109	262	

Table 3 Interaction effect of irrigation and phosphorus levels on grain yield (kg/ha) of maize

Phosphorus levels (P) (kg P ₂ O ₅ /ha)	Irrigation levels (I), IW: CPE ratio					
	2007-08			2008-09		
	0.8	1.0	Mean	0.8	1.0	Mean
0	4 751	5 125	4 938	4 938	5 734	5 340
30	5 756	6 333	6 045	6 506	6 865	6 686
60	6 934	7 350	7 142	7 058	7 478	7 268
90	7 079	7 408	7 244	7 084	7 674	7 379
Mean	6 130	6 554		6 396	6 940	
		SEm ±	CD	SEm ±	CD	
			(P=0.05)		(P=0.05)	
Between two P means at same or different I		155	311	179	359	
Between two I at same or different P		149	218	179	359	

contribution was low due to less mineralization under zero-tillage conditions (Selles *et al.* 1997).

Nutrient uptake studies

Nitrogen, phosphorus and potassium uptake by *rabi* maize crop was significantly influenced by the preceding rice crop establishment methods, levels of irrigation and phosphorus (Table 1). The N, P and K uptake was significantly higher in aerobic method of rice establishment as compared to transplanted method of rice establishment. The adequate water supply in the plots through irrigation provided at 1.0 IW: CPE resulted in significantly higher nitrogen, phosphorus and potassium uptake over that of irrigations scheduled at 0.8 IW: CPE ratio. Increasing level of phosphorus from 0 to 30 and 60 kg P₂O₅/ha significantly increased the N, P and K uptake during both the years. The N, P and K uptake at 60 kg P₂O₅/ha was comparable over that with 90 kg P₂O₅/ha during both the years. The increased uptake was in accordance with the increased dry matter pattern and grain and stover yields. Hussein (2009) also

reported the significant increase in shoot and grain P content and uptake with increase in P₂O₅ levels from 0 to 30, 60 and 90 kg P₂O₅/ha.

Available soil phosphorus status (kg/ha) after maize harvest

The available phosphorus at the end of each season of rice-maize crop sequence indicated that soil available phosphorus was low in plots with no fertilizer P at the end of second season, even though the *kharif* rice crop was supplied with recommended dose of P (60 kg P₂O₅/ha) than the plots which received phosphorus from 30 to 90 kg P₂O₅/ha.

Each increased level of P from 0 to 30, 60 and 90 kg P₂O₅/ha irrespective of the season increased the available phosphorus in the soil. The soil had higher available phosphorus (24.7 kg P/ha and 27.77 kg P/ha) at the end of 2nd year in plots where fertilizer was applied to both rice (60 kg P₂O₅/ha) and maize (90 kg P₂O₅/ha) as sequence to rice crop during *kharif* and *rabi* seasons in both the methods of rice-maize system. Addition of P to both rice and maize increased the quantity of available P and also resulted in buildup of soil P at higher levels at the end of rice-maize crop sequence (Table 3). Hussein (2009) also reported soil available phosphorus increased significantly with increased rate of 'P' application, the increase in extractable 'P' in soil was about 144, 219 and 324% for rates 30, 60 and 90 kg P₂O₅/ha, respectively relative to the control treatment.

PHOSPHORUS FERTILIZER USE EFFICIENCY

Apparent phosphorus recovery (%)

The percent P recovery was higher under transplanted method of establishment (19.79 and 18.16%) than under aerobic method of establishment (17.72 and 16.22%) during 2007-08 and 2008-09, respectively. Similar trend of higher P recovery (%) was observed in maize plots irrigated at 1.0 IW: CPE (18.63 and 20.38%) as compared to 0.8 IW: CPE (15.74 and 17.13%) during 2007-08 and 2008-09,

Table 4 Available soil phosphorus status (kg/ha) at end of rice-maize system

P ₂ O ₅ levels (kg/ha)		After end of rice-maize system	
<i>Kharif</i> transplanted rice	<i>Rabi</i> maize	2007-08	2008-09
60	0	16.12	16.96
60	30	19.28	22.42
60	60	21.02	23.19
60	90	22.18	24.70
<i>Kharif</i> aerobic rice	<i>Rabi</i> maize		
60	0	15.89	17.78
60	30	20.12	22.76
60	60	22.60	25.79
60	90	23.12	27.77

respectively. There was decrease in apparent phosphorus recovery with increase in P levels from 30 to 60 and 90 kg P₂O₅/ha. At lower level of P (30 kg P₂O₅/ha) higher apparent recovery (20.38 and 22.14%) was observed as compared to higher levels of P (60 and 90 kg P₂O₅/ha) (Table 4).

Phosphorus use efficiency (kg grain/kg of P₂O₅)

The P use efficiency in terms of kg grain/kg P₂O₅ applied also varied with preceding rice crop establishment methods, levels of irrigation and phosphorus. The higher P-use efficiency was recorded by aerobic method of establishment as compared to transplanted method of rice

establishment during both the years. Irrigation at IW : CPE ratio of 1.0 resulted in higher P-use efficiency than with irrigation at IW:CPE ratio of 0.8. There was significant decrease in P use efficiency with increase in P₂O₅ levels from 30 to 60 and 90 kg/ha (53.91 to 24.95 and 57.17 to 25.61 kg grain kg/P₂O₅ 1st and 2nd years respectively) (Table 5). These findings of higher phosphorus use efficiency, phosphorus recovery efficiency and utilization at lower P levels than at higher levels are in agreement with the findings of Hussein (2009).

Phosphorus balance

The balance sheet of available soil P at the end of two years as influenced by the levels of phosphorus fertilization in rice-maize crop sequence indicated that initially the soil had 15.39 kg available P/ha. The maize crop removed greater quantity of P from the soil with increase in the rate of P from 30 to 60 and 90 kg P₂O₅/ha. The uptake of P by maize crop was much higher than the rice crop. Depletion of available soil P was maximum when phosphorus was applied to rice during *khariif* and without phosphorus application to maize during *rabi* and also when rice crop was applied higher dose of phosphorus (60 kg P₂O₅/ha) and the second maize crop was fertilized with lower dose (30 kg P₂O₅/ha). However, maximum accumulation of phosphorus was noticed when two crops were fertilized with 60 kg P₂O₅/ha for both rice and maize and also 60 kg P₂O₅/ha to rice during *khariif* and 90 kg P₂O₅/ha to maize during *rabi* (Table 6).

Maximum depletion of -3.35 kg P/ha with transplanted rice-maize system and -2.53 kg P/ha with aerobic rice-maize system was observed when phosphorus applied to rice only and no phosphorus applied to maize and -3.74 and -5.16 kg P/ha when lower dose of 30 kg P₂O₅/ha was applied to maize with a normal dose of 60 kg P₂O₅/ha for rice crop under two methods respectively. Maximum

Table 5 Influence of crop establishment methods of rice, irrigation and phosphorus levels on apparent P recovery (%) and P-use efficiency (kg grain/kg P₂O₅)

Treatment	Apparent P recovery (%)		P-use efficiency (kg grain/kg P ₂ O ₅)	
	2007-08	2008-09	2007-08	2008-09
<i>Main plots</i>				
<i>Crop establishment methods (M)</i>				
Transplanted rice	18.16	19.79	34.94	38.23
Aerobic rice	16.22	17.72	41.13	41.83
<i>Sub-plots</i>				
<i>Irrigation levels(I), IW : CPE ratio</i>				
0.8	15.74	17.13	36.19	39.00
1.0	18.63	20.38	39.88	41.05
<i>Phosphorus levels(P), kg P₂O₅/ha</i>				
0				
30	20.38	22.14	53.91	57.17
60	16.70	18.74	35.26	37.31
90	14.50	15.40	24.95	25.61

Data not analyzed statistically

Table 6 Balance sheet of phosphorus fertilization in rice-maize system

	P applied (kg/ha)				Total P initial + fertilizer applied (kg/ha)	Removal by crops (P kg/ha)				Total P (kg/ha)	Actual balance of P at the end of 4 th season	Total plant and soil P (kg/ha)	Net gain/ loss (kg/ha) (6-13)
	2007-08		2008-09			2007-08		2008-09					
	K	R	K	R		K	R	K	R				
1	2	3	4	5	6	7	8	9	10	11	12	13	14
<i>Transplanted rice (Initial soil P)</i>													
15.39	25.8	0	25.8	0	66.99	16.58	9.60	17.28	9.92	53.38	16.96	70.34	-3.35
15.39	25.8	12.9	25.8	12.9	92.79	16.58	15.99	17.28	16.68	66.53	22.42	88.95	-3.74
15.39	25.8	25.8	25.8	25.8	118.59	16.58	20.62	17.28	21.71	76.19	23.19	99.38	+19.11
15.39	25.8	38.7	25.8	38.7	144.29	16.58	23.78	17.28	24.84	82.48	24.70	107.18	+37.11
<i>Aerobic rice</i>													
15.39	25.8	0	25.8	0	66.99	15.62	9.94	16.12	10.06	51.74	17.78	69.52	-2.53
15.39	25.8	12.9	25.8	12.9	92.79	15.62	16.17	16.12	16.86	64.77	22.76	87.53	-5.16
15.39	25.8	25.8	25.8	25.8	118.59	15.62	21.81	16.12	22.24	75.79	25.79	101.58	+16.91
15.39	25.8	38.7	25.8	38.7	144.29	15.62	25.04	16.12	25.86	82.64	27.77	110.41	+33.88

accumulation was observed with transplanted rice-maize system (37.11 kg P/ha) than aerobic rice-maize system (33.88 kg P/ha) plots which received 60 kg P₂O₅/ha to rice and 90 kg P₂O₅/ha to maize in rice –maize crop sequence. However, the aerobic rice–maize sequence depleted more of 2.2 to 3.2 kg P/ha than transplanted-maize sequence.

Hassan (1999) found that higher ‘P’ rates and its repeated application every year results in higher ‘P’ build up in soil. Wet land rice crop utilize both soil P and applied P efficiently than any upland crop. Field submergence enhances the release of soil P and make, it available to the rice crop. The sequence crop of maize under irrigated dry conditions respond well to applied P since the availability of soil P is low. Katyal *et al.* (2000) mentioned that the capacity of crops to utilize fertilizer and native soil phosphorus vary greatly since P applied to soil is not lost out of soil. Available ‘P’ in the soil was maximum where P applied @90 kg/ha being 30% more than initial value of ‘P’ and 7% more when P was applied to both *kharif* and *rabi* crops.

Yield–input relationship

The relation between grain yield of maize and different phosphorus levels was established by least square technique. The estimated relationship indicated that the second polynomial equation (quadratic) performed well in both the years (Fig 1 and 2) as well as on pooled basis (Fig 3). The fitted equation is as follows:

2007-08	$Y = 4905.363 + 46.968 P - 0.2654 P^2$
	$R^2 = 0.831^*$
2008-09	$Y = 5357.76 + 53.112 P - 0.3424 P^2$
	$R^2 = 0.998^*$
Pooled	$Y = 5131.56 + 51.035 P - 0.298 P^2$
	$R^2 = 0.999^*$

The coefficient of determination (R^2) for the production function was 0.83, 0.99 and 0.99 during 2007-08, 2008-09 and on pooled basis, respectively. The regression pertaining to linear and quadratic functions are highly significant. Further, the regression for the linear term P was positive in all the cases suggesting that grain yield increased linearly

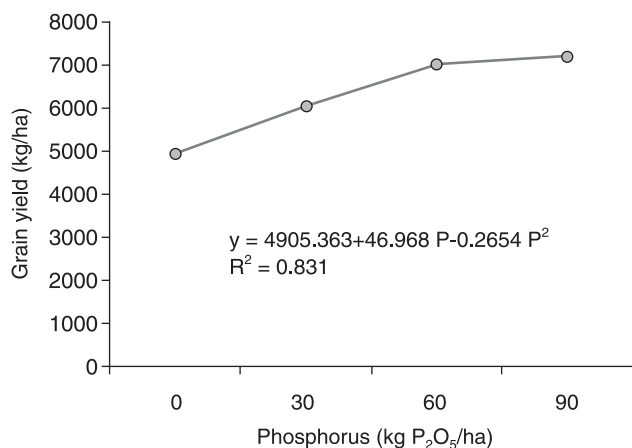


Fig 1 Response of maize grain yield to phosphorus application during 2007-08

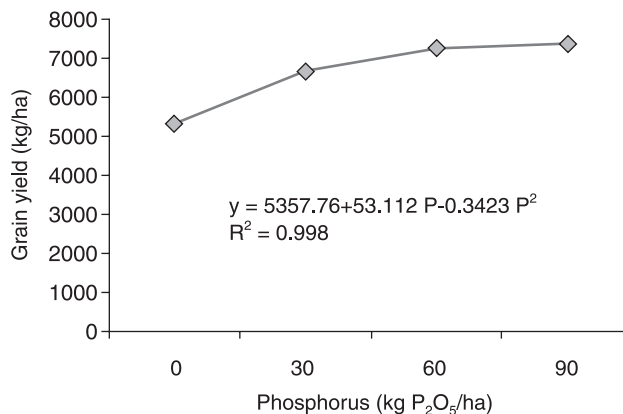


Fig 2 Response of maize grain yield to phosphorus application during 2008-09

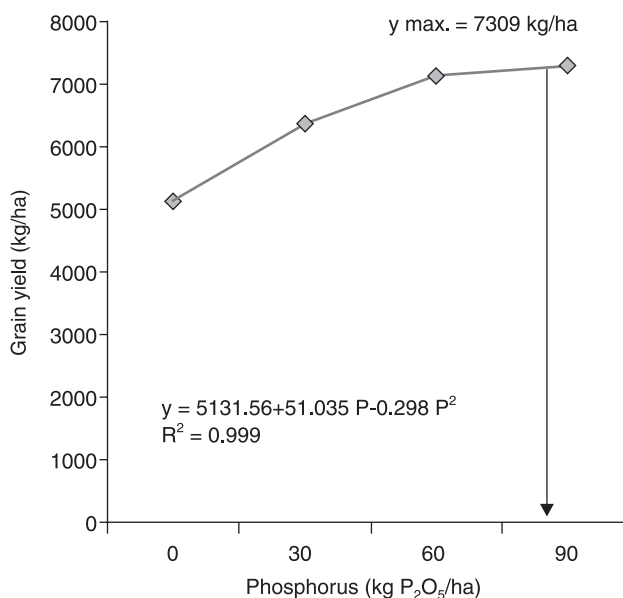


Fig 3 Response of maize grain yield to phosphorus application on pooled basis

from initial increments of this input. But, the negative second power regression coefficient (P^2) suggested that the grain yield increased at diminishing rate at higher levels of phosphorus. The predicted yield potential was 7 295 kg/ha with an input of 92.8 kg P₂O₅/ha in 2007-08 and was 7 417 kg/ha with an input of 77.5 kg P₂O₅/ha in 2008-09 and 7 309 kg/ha with an input level of 85.4 kg P₂O₅/ha on pooled basis. However, as per fitted equation, the economic yield was 7 288 kg/ha with an input level of 87.8 kg P₂O₅/ha in 2007-08 and was 7 412 kg/ha with an input level of 73.7 kg P₂O₅/ha in 2008-09 and 7 303 kg/ha with an input level of 80.7 kg P₂O₅/ha on pooled basis.

Maize crop grown after aerobic rice was more productive and profitable than that grown after transplanted rice with higher phosphorus use efficiency. Scheduling of irrigation at IW: CPE of 1.0 to maize crop and phosphorus application @60 kg P₂O₅/ha each for both rice and maize crops evidenced maximum accumulation of available soil phosphorus in rice-maize cropping sequence.

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