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Influence of Levels of Phosphorus on Yield Components and Yield of Zero Till Maize in Rice-maize (*Zea mays* L.) Sequence

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Influence of levels of phosphorus on yield components and yield of zero till maize in rice-maize (*Zea mays* L.) sequence.
Methodology: Field experiment was conducted during two successive years at College of Agriculture, Rajendranagar, Hyderabad on rice-zero till maize sequence. The experiment was replicated thrice with 5 levels of P_2O_5 in rice and 3 levels of P_2O_5 in maize.
Results: The direct application of 60 kg P_2O_5 ha^{-1} to maize recorded significantly higher value of yield components, grain and stover yield of maize over lower Phosphorus levels. The residual effect

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of 100% and /or 75% RDP (recommended dose of Phosphorus) applied to rice had a greater positive influence on the yield components and yield over lower phosphorus levels. The cumulative effect indicated that application of 100% RDP to both the crops and 75 % RDP to rice and 100% RDP to maize had a positive effect on maize and produced significantly greater yield components and yield over other phosphorus treatments.

Keywords: Maize; phosphorus; yield; yield components; zero till.

1. INTRODUCTION

Maize is the world's most important cereal crop next to rice and wheat with multiple uses as grain (flour, flakes and popcorn), vegetable (sweet corn and baby corn) and as feed (grain and whole plant). Its industrial uses are many like preparation of starch, oil, alcohol, sweeteners and thickening agents [1].

Rice-maize is the predominant cropping system occupying an area of 3.5 m ha in Asia after Rice-rice and rice-wheat cropping system [2]. Rice-maize cropping system is rapidly expanding in south Asia including India due to its potential from *rabi* maize, and its reduced water requirement compared rice-rice system. Diversification of maize could also be a good strategy for adaptation to climate change, as it is more tolerant to high temperatures when compared to wheat. The choice of crops for a given sequence is extremely important due to the impact of particular plants on the physical, chemical and biological soil properties [3]. Timsina and Connor [4] have critically reviewed the soil physical and chemical properties and associated management for alternating wetting and drying environments of Rice-Wheat system that could be well applied to Rice-Maize system as well. One feature of Rice-Maize system is that its difference from Rice-Wheat or Rice-Rice system in nutrient extraction, which would be much greater due to higher yield of maize.

In command areas *rabi* maize sowings are being delayed when farmers resort for conventional land preparation resulting in lower yields, thereby 'late planting' has become a major constraint. These yield reductions due to late planting can be avoided by sowing maize under zero tillage after harvesting of rice crop. Zero tillage is the practice of sowing crops directly in the residues of the previous crop without cultivation, while stubbles are retained and weeds are controlled with herbicide [5]. Zero tillage would reduce the potential for soil erosion and loss of soil organic matter [6]. Besides the soil and water conservation, it also reduces fuel consumption, labour requirement and turnaround time.

Among the various inputs, Phosphorus is considered the costly and key input for root growth. Phosphorus is one of the most limiting nutrients in agricultural cropping systems [7,8,9]. Scheduling fertilizer to cropping systems rather than single crop basis helps its rationalized application and economizing expenses [10,11]. Realistic nutrient drawn (Phosphorus) factors could be derived for each soil and crop growing environment whereby yield could be optimized and profit could be maximized without substantial mining of nutrients from the soil [12]. Application of phosphatic fertilizers to *rabi* season crops and growing *kharif* season crops on residual fertility has been advocated in most of the soils, wheat being a winter crop, responds more to phosphorus application than wet season rice [13]. Efficient utilization of fertilizer Phosphorus, residual and cumulative effects of Phosphorus should be considered while formulating fertilizer use recommendations in different cropping sequences [14]. Research is required to understand the various aspects of Rice-zero tillage maize system that would improve the productivity and sustainability of the system.

Keeping these things in mind the present study was organized to investigate the direct residual and cumulative effect of phosphatic fertilizer application on yield of maize in rice-zero till maize cropping system.

2. MATERIALS AND METHODS

The study was conducted during two sequential years with rice and zero tillage maize respectively, during *kharif* and *rabi* seasons in the College farm located at College of Agriculture, Rajendranagar, Hyderabad, Telangana, India (17^0 19' North latitude, 78^0 27' East longitude and 542.6 m above mean sea level). The soil at the experimental site was a well drained sandy clay loam with 61.56 g sand, 15.84 g silt and 22.6 g clay per 100g soil in the surface horizon. Initial soil properties of composite samples taken from 0 to 15 cm soil depth were with 0.63% Organic carbon, 8.33 pH, 0.46 dSm^{-1} electrical conductivity, 187.50 kg ha^{-1} available Nitrogen, 16.96 kg ha^{-1} available Phosphorus and 163.5 kg ha^{-1} available Potassium. The experiment was laid out with 21.6 m^2 (7.2 m X 2.2 m) size plots in randomized block design (two factors) with three replications at five Phosphorus levels to rice viz; F_1: No Phosphorus, F_2: 10 kg P_2O_5 ha^{-1}, F_3: 20 kg P_2O_5 ha^{-1} , F_4: 30 kg P_2O_5 ha^{-1} and F_5: 40 kg P_2O_5 ha^{-1} (recommended dose of phosphorus) and three phosphorus levels to maize viz; P_1: 30 kg P_2O_5 ha^{-1} , P_2: 45 kg P_2O_5 ha^{-1} and P_3: 60 kg P_2O_5 ha^{-1} (recommended dose of phosphorus). The levels of P_2O_5 (kg ha^{-1}) applied to rice and zero tillage maize respectively in different treatments were (T_1: $P_{0\text{-}30}$, T_2:$P_{0\text{-}45}$, T_3: $P_{0\text{-}60}$, T_4: $P_{10\text{-}30}$, T_5: $P_{10\text{-}45}$, T_6: $P_{10\text{-}60}$, T_7: $P_{20\text{-}30}$, T_8: $P_{20\text{-}45}$, T_9: $P_{20\text{-}60}$, T_{10}: $P_{30\text{-}30}$, T_{11}: $P_{30\text{-}45}$, T_{12}: $P_{30\text{-}60}$, T_{13}: $P_{40\text{-}30}$, T_{14}: $P_{40\text{-}45}$ and T_{15}: $P_{40\text{-}60}$).

After completion of puddling 30 days old rice seedlings of MTU 1010 variety were transplanted in the plots during *kharif* season of first year by adopting a spacing of 20 cm x 10 cm at shallow depth of 2-3 cm in leveled plots. Likewise, the rice seedlings during *kharif* season of the succeeding year were also planted in the same plots without disturbing the layout of previous year. The entire quantity of phosphorus according to treatments through single super phosphate and entire potassium (30 kg K_2O ha^{-1}) as Muriate of Potash were incorporated basally into the soil before last puddling. One third of total nitrogen (100 kg ha^{-1}) was applied at transplanting; the remainder of nitrogen in two equal split doses was top dressed uniformly at maximum tillering and at panicle initiation stage of rice. Supplemental irrigation was given with tube well water. A thin film of water was maintained in the plots at the time of transplanting of seedlings. Five centimeter water level was maintained thereafter continuously up to 10days before harvesting. Irrigation was withheld for about 10 days before harvesting. All other recommended agronomic practices were followed uniformly for all the experimental plots of rice.

The Maize hybrid (Super 900M) seeds were dibbled under no-till condition by adopting a spacing of 60 cm between rows and 20 cm between plants within a row during *rabi* season during consecutive years in the same plots without disturbing the layout of previous *kharif* season rice. Thinning was practiced one week after emergence of seedlings thereby the recommended plant population was maintained in the different experimental plots. The entire quantity of P_2O_5 according to treatments through single super phosphate source and the entire recommended dose of Potassium (40 kg K_2O ha^{-1}) as Muriate of Potash were applied in bands at 5 cm away and 5 cm below the seed at the time of sowing. The recommended dose of Nitrogen @120 kg ha^{-1} was applied as Urea in three equal split doses at basal and top dressing at knee high and tasselling stage of the maize crop. Recommended rate of non-selective herbicide (Paraquat @ 1.5 kg a.i.ha^{-1}) was applied to the entire field after harvesting of rice crop to control the existing weeds and to prevent the re-growth of rice stubble. One day after the sowing of maize seeds, pre emergence herbicide (Atrazine) was applied at recommended rate (1 kg a.i. ha^{-1} in 500 liters of water) to the entire field. No irrigation was given after sowing of the crop as there was sufficient residual soil moisture. Subsequent need based irrigations and all other agronomic practices were followed uniformly for all the experimental plots.

The grain and stover yield of maize were quantified separately from samples collected in a 10.56 m^2 area and converted to kg ha^{-1}. Grain yields were adjusted to a moisture content of 0.14 kg moisture kg^{-1} grain.

2.1 Analysis of Variance (ANOVA)

Analysis of variance was carried out for each character separately as per standard statistical procedure for two factor randomized block design as suggested by the Panse and Sukhatme [15]. Wherever the treatment differences were found significant critical differences were worked out at five % probability level (P=0.05) and treatment differences that were non-significant were denoted by 'NS'.

3. RESULTS AND DISCUSSION

The data on yield attributes of maize as influenced by different phosphorus levels to rice and maize in rice-maize cropping system is presented in Table 1, 2 and 3.

3.1 Yield Components

The positive role of phosphorus on the yield components of maize was also distinct. Application of 100% RDP (60 kg P_2O_5 ha^{-1}) directly to maize recorded significantly superior yield components viz., cob girth, cob length, number of grain rows cob^{-1}, number of grains cob^{-1}, test weight, grain weight cob^{-1}, cob weight and shelling per cent. Application of 100% RDP (60 kg P_2O_5 ha^{-1}) recorded significantly higher cob girth (13.85 and 13.79 cm), cob length (12.63 and 12.41 cm) and number of grain rows cob^{-1} (15.19 and 14.85) respectively during first year and second year over 50 and 75% RDP. It increased number of grains cob^{-1} by 48 and 25 over 75% RDP and by 79 and 57 over 50 % RDP, in corresponding years. The increase in test weight was 3.77 and 10.62 per cent in first year and 4.59 and 11.39 per cent in second year over 75 and 50% RDP, respectively. The grain weight cob^{-1}, cob weight and shelling percent also followed same trend. The application of 100% RDP increased the grain weight cob^{-1} by 9.38 and 9.78 per cent over 75% RDP and by 16.67 and 23.17 per cent over 50% RDP in respective years. These better and enhanced yield components resulted in higher shelling percent (72.41 and 71.77) with 100% RDP over lower levels.

The residual effect of preceding season applied phosphorus @ 75%RDP (30 kg P_2O_5 ha^{-1}) to rice, recorded significantly superior yield components of maize over lower P levels; however it was found at par with 100% RDP(40 kg P_2O_5 ha^{-1}) to rice. Higher cob girth (13.61 and 13.77 cm), cob length (12.27 and 12.03 cm) and number of grain rows cob^{-1}(15.05 and 14.29) of maize during two consecutive years was

Table 1. Cob girth, cob length and number of seed rows cob^{-1} of maize as influenced by levels of Phosphorus to rice-maize cropping system

Treatments	Cob girth (cm)		Cob length (cm)		Number of seed rows cob^{-1}	
	I Year	II Year	I Year	II Year	I Year	II Year
***kharif-rabi* (Rice-maize)**						
0-30	11.47	12.38	9.67	10.80	13.20	13.53
0-45	12.23	13.17	10.44	11.47	13.97	14.15
0-60	13.37	13.63	12.00	11.80	14.45	14.58
10-30	12.83	12.73	10.27	10.90	14.07	13.53
10-45	12.90	13.23	11.00	11.77	14.70	14.18
10-60	13.57	13.53	12.40	12.03	14.95	14.60
20-30	12.87	12.94	11.77	11.33	14.90	13.46
20-45	13.17	13.33	12.00	11.90	15.17	14.24
20-60	13.67	13.60	12.57	12.27	15.72	14.63
30-30	13.23	13.47	11.80	10.87	14.87	13.40
30-45	13.30	13.87	12.00	12.13	15.10	14.37
30-60	14.30	13.97	13.00	13.10	15.18	15.09
40-30	13.23	13.67	11.70	11.13	14.97	13.26
40-45	13.43	13.70	12.17	12.37	14.83	14.53
40-60	14.37	14.20	13.17	12.83	15.65	15.35
SE(m) ±	0.11	0.08	0.20	0.13	0.20	0.13
C.D.(P = 0.05)	0.33	0.24	0.59	0.39	N.S.	0.39
Residual (*Kharif*)						
F_1: No Phosphorus	12.36	13.06	10.70	11.36	13.87	14.09
F_2:25% RDP (10 kg P_2O_5 ha^{-1})	13.10	13.17	11.23	11.57	14.57	14.10
F_3:50% RDP (20 kg P_2O_5 ha^{-1})	13.23	13.29	12.11	11.83	15.26	14.11
F_4:75% RDP (30 kg P_2O_5 ha^{-1})	13.61	13.77	12.27	12.03	15.05	14.29
F_5:100% RD (40 kg P_2O_5 ha^{-1})	13.68	13.86	12.35	12.11	15.15	14.38
SE(m) ±	0.05	0.05	0.09	0.08	0.12	0.08
C.D. (P = 0.05)	0.15	0.14	0.26	0.22	0.34	0.22
Direct (*Rabi*)						
P_1:50% RDP (30 kg P_2O_5 ha^{-1})	12.73	13.04	11.04	11.01	14.40	13.44
P_2:75% RDP (45 kg P_2O_5 ha^{-1})	13.01	13.46	11.52	11.93	14.75	14.30
P_3:100% RDP (60 kg P_2O_5 ha^{-1})	13.85	13.79	12.63	12.41	15.19	14.85
S.Em.±	0.07	0.04	0.12	0.06	0.09	0.06
C.D. (P = 0.05)	0.19	0.11	0.34	0.17	0.26	0.17

Table 2. Number of seeds cob^{-1} and test weight of maize as influenced by levels of Phosphorus to rice-maize cropping system

Treatments	Number of seeds cob^{-1}		Test weight (g)	
	I Year	II Year	I Year	II Year
***kharif-rabi* (Rice-maize)**				
0-30	265	259	23.02	22.49
0-45	330	289	24.34	23.78
0-60	363	327	24.73	24.34
10-30	285	280	23.70	23.15
10-45	320	323	24.65	24.09
10-60	366	352	26.23	25.83
20-30	306	295	23.75	23.24
20-45	356	354	24.78	24.21
20-60	377	364	26.37	25.96
30-30	345	346	23.79	23.24
30-45	349	361	25.86	25.27
30-60	415	385	26.60	26.19
40-30	350	353	23.89	23.34
40-45	351	363	26.32	25.69
40-60	426	388	26.77	26.35
SE(m) ±	9	7	0.17	0.17
C.D. (P = 0.05)	27	20	0.52	0.50
Residual (*Kharif*)				
F_1:No Phosphorus	319	292	24.03	23.54
F_2:25% RDP (10 kg P_2O_5 ha^{-1})	324	318	24.86	24.36
F_3:50% RDP (20 kg P_2O_5 ha^{-1})	346	337	24.97	24.47
F_4:75% RDP (30 kg P_2O_5 ha^{-1})	370	364	25.42	24.90
F_5:100% RDP (40 kg P_2O_5 ha^{-1})	376	368	25.66	25.13
SE(m) ±	5	4	0.10	0.10
C.D. (P = 0.05)	16	11	0.30	0.29
Direct (*Rabi*)				
P_1:50% RDP (30 kg P_2O_5 ha^{-1})	310	306	23.63	23.10
P_2:75% RDP (45 kg P_2O_5 ha^{-1})	341	338	25.19	24.60
P_3:100% RDP (60 kg P_2O_5 ha^{-1})	389	363	26.14	25.73
S.Em.±	4	3	0.08	0.08
C.D. (P = 0.05)	12	9	0.23	0.22

observed with 75% RDP application to rice. Similarly, application of 75%RDP increased number of grains cob^{-1} (24, 46 and 51 in first year) and (27, 46 and 72 in second year) over 50, 25% RDP and no phosphorus, respectively.

The interaction effect of P levels to rice and maize showed that with addition of 100% RDP (60 kg P_2O_5 ha^{-1}) to maize through P_{40-60} treatment recorded significantly superior cob girth, cob length, number of grain rows cob^{-1} and number of grains cob^{-1} over rest of the treatment combinations except P_{30-60} treatment in both years. It also recorded significantly higher test weight over rest of the treatment combinations; however, it was found at par with P_{20-60}, P_{30-60} in both years in addition to P_{40-45} in first year. The grain weight cob^{-1} and cob weight with P_{40-60} were significantly higher in both years over the rest of the treatment combinations except P_{30-60} treatment.

The increase in yield components with increased phosphorus levels might be attributed to the higher uptake of nutrients and their effective utilization in the metabolic activities of plant parts thereby better growth and development. The cumulative effect of both previous season applied (residual) P and current season (direct) applied phosphorus through P_{40-60} and P_{30-60} treatments was significantly superior to other combinations of 'P' levels in the system. This was probably the consequence of better root proliferation, elongation and growth at higher levels of P (P_{40-60} and P_{30-60}) which enabled the crop to tap the nutrients and moisture in relatively higher quantities from larger soil volume. The increased LAI at higher Phosphorus level might have led to more carbohydrate formation and its translocation to reproductive parts resulting in maximum test weight and grain weight cob^{-1} of maize. These results are in accordance with the findings of Narang et al. [16], Narang and Singh [17], Arya and Singh [18] and Suryavanshi et al. [19].

3.2 Yield

The data on grain yield of maize as influenced by different phosphorus levels to rice and maize in rice-maize cropping system is presented in Table 4.

Maize responded to phosphorus application and recorded the highest grain yield of 5144 and 5198 kg ha^{-1} by direct application of 100% RDP (60 kg P_2O_5 ha^{-1}) as against 4830 and 4836 kg ha^{-1} with 75% RDP and 4436 and 4447 kg ha^{-1} with 50% RDP during first and second years, respectively. The increase in grain yield by application of 100% RDP was by 15.96 and 16.89 % over 50% RDP and 6.50 and 7.49 % over 75% RDP in the first and second years, respectively. Similarly, it produced a significantly higher stover yield of 7324 and 7234 kg ha^{-1} respectively in two years.

The residual effect of 75% RDP (30 kg P_2O_5 ha^{-1}) applied to a previous crop of rice was significant in increasing the grain and stover yield of maize over lower levels of phosphorus; however it was found at par with 100% RDP(40 kg P_2O_5 ha^{-1}). It increased the grain yield by 231 and 306 kg ha^{-1} over 50% RDP; and by 245 and 321 kg ha^{-1} over 25% RDP; and 352 and 462 kg ha^{-1} over no phosphorus in consecutive years, respectively.

Table 3. Grain weight cob^{-1}, cob weight and shelling % of maize as influenced by levels of Phosphorus to rice-maize cropping system

Treatments	Grain weight cob^{-1} (g)		Cob weight (g)		Shelling %	
	I Year	II Year	I Year	II Year	I Year	II Year
***kharif-rabi* (Rice-maize)**						
0-30	80	74	116	109	68.94	67.97
0-45	84	84	122	121	69.28	69.83
0-60	96	95	133	133	72.09	71.37
10-30	87	77	127	113	69.05	68.22
10-45	96	90	139	129	69.24	70.13
10-60	102	99	142	139	72.12	71.24
20-30	86	78	125	114	69.06	68.43
20-45	96	91	139	130	69.36	70.20
20-60	106	99	147	138	72.40	71.85
30-30	98	89	142	129	69.04	69.08
30-45	102	97	148	139	69.11	69.91
30-60	110	105	152	146	72.59	72.10
40-30	99	93	144	135	69.14	69.12
40-45	103	97	147	137	70.10	70.75
40-60	112	106	153	146	72.85	72.29
SE(m) ±	2	2	2	2	1.19	1.60
C.D. (P = 0.05)	5	N.S.	5	6	N.S.	N.S.
Residual (*Kharif*)						
F_1:No Phosphorus	87	85	124	121	70.11	69.72
F_2:25% RDP (10 kg P_2O_5 ha^{-1})	95	89	136	127	70.14	69.87
F_3:50% RDP (20 kg P_2O_5 ha^{-1})	96	89	137	127	70.27	70.16
F_4:75% RDP (30 kg P_2O_5 ha^{-1})	103	97	147	138	70.25	70.36
F_5:100% RDP (40 kg P_2O_5 ha^{-1})	105	99	148	140	70.70	70.72
SE(m) ±	1	1	1	1	0.69	0.92
C.D. (P = 0.05)	2	3	3	3	N.S.	N.S.
Direct (*Rabi*)						
P_1:50% RDP (30 kg P_2O_5 ha^{-1})	90	82	131	120	69.05	68.56
P_2:75% RDP (45 kg P_2O_5 ha^{-1})	96	92	139	131	69.42	70.17
P_3:100% RDP (60 kg P_2O_5 ha^{-1})	105	101	145	141	72.41	71.77
S.Em.±	1	1	1	1	0.53	0.72
C.D. (P = 0.05)	3	2	2	3	1.54	2.07

Table 4. Grain and stover yield and harvest index (HI) of Maize as influenced by levels of Phosphorus to rice-maize cropping system

Treatments	Grain yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Harvest index(%)	
	I Year	II Year	I Year	II Year	I Year	II Year
***kharif-rabi* (Rice-maize)**						
0-30	4056	3961	5955	5670	40.52	41.10
0-45	4677	4678	6822	6726	40.68	41.02
0-60	5022	5072	7259	7090	40.90	41.72
10-30	4280	4286	6322	6180	40.37	40.95
10-45	4726	4727	6926	6784	40.56	41.07
10-60	5071	5120	7202	7109	41.32	41.87
20-30	4290	4295	6375	6291	40.22	40.51
20-45	4752	4755	6904	6768	40.78	41.26
20-60	5076	5128	7267	7174	41.11	41.66
30-30	4704	4819	6824	6584	40.81	42.27
30-45	4894	5005	7038	6896	41.01	42.04
30-60	5213	5272	7328	7285	41.57	41.98
40-30	4850	4872	6869	6633	41.40	42.34
40-45	5103	5013	7248	6906	41.32	42.06
40-60	5339	5398	7565	7512	41.37	41.81
SE(m) ±	72	92	102	108	0.41	0.44
C.D.(P = 0.05)	210	267	295	314	N.S.	N.S.
Residual (*Kharif*)						
F_1:No Phosphorus	4585	4570	6679	6495	40.70	41.28
F_2:25% RDP (10 kg P_2O_5 ha^{-1})	4692	4711	6817	6691	40.75	41.29
F_3:50% RDP (20 kg P_2O_5 ha^{-1})	4706	4726	6849	6744	40.70	41.15
F_4:75% RDP (30 kg P_2O_5 ha^{-1})	4937	5032	7063	6922	41.13	42.10
F_5:100% RDP (40 kg P_2O_5 ha^{-1})	5097	5094	7227	7017	41.36	42.07
SE(m) ±	42	53	59	63	0.24	0.26
C.D.(P = 0.05)	121	154	170	181	N.S.	N.S
Direct (*Rabi*)						
P_1:50% RDP (30 kg P_2O_5 ha^{-1})	4436	4447	6469	6272	40.66	41.43
P_2:75% RDP (45 kg P_2O_5 ha^{-1})	4830	4836	6988	6816	40.87	41.49
P_3:100% RDP (60 kg P_2O_5 ha^{-1})	5144	5198	7324	7234	41.25	41.81
S.Em.±	32	41	46	48	0.18	0.20
C.D.(P = 0.05)	94	120	132	140	N.S.	N.S.

Similarly stover yield with 100% RDP application was improved by 2.64 and 3.12 % over 50% RDP; 3.45 and 3.61% over 25% RDP and by 6.57 and 5.75 % over no phosphorus treatment in both years, respectively.

The interaction effect of P levels in rice-maize sequence showed that application of 100% RDP to maize (60 kg P_2O_5 ha^{-1}) through P_{40-60} treatment maximized the grain production (5340 and 5400 kg ha^{-1}) over application of 50% RDP (P_{0-30}, P_{10-30}, P_{20-30}, P_{30-30} and P_{40-30}) and 75% RDP (P_{0-45}, P_{10-45}, P_{20-45}, P_{30-45} and P_{40-45}) and P_{0-60}, P_{10-60} and P_{20-60} treatment combinations. However, it was found at par with the grain yield obtained by the P_{30-60} treatment (5210 and 5270 kg ha^{-1}) in both years, respectively. Similarly, stover yield also followed same trend in both years. This indicated that the maize crop can be conveniently grown in plots which received 75% RDP to rice (30 kg P_2O_5 ha^{-1}) in the previous season, thereby saving 10 kg P_2O_5 ha^{-1} per annum in this system.

Similar kind of response was observed in wheat following wet season rice by many researchers [20] and [21]. Gill and Meelu [14] stated that upland crop (wheat) after rice, responds to higher P application because of reduced 'P' availability due to moisture regime and low temperature during winter season. The increase in grain and stover yield of maize with increased phosphorus levels has been reported by several workers [18,22,23,24,25,26].

4. CONCLUSION

The sustainable application of 30 kg P_2O_5 ha^{-1} (75% RDP) to rice and 60 kg P_2O_5 ha^{-1} (RDP) to maize in rice-zero till maize crop sequence save 10 kg P_2O_5 ha^{-1} $annum^{-1}$.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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