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Phosphorus uptake and phosphorus use efficiency of high zinc rice genotypes of clay soil under different levels of fertility

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Abstract

Phosphorus (P) is necessary by crop plants for many physiological and biochemical functions. Consciousness of phosphorus uptake and its use by crop plants is essential for management of this essential nutrient. A field experiment was conducted during Kharif season, 2013 at the Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidhyalaya, Raipur (C.G), to determine P uptake and use efficiency of high zinc containing rice genotypes in lowland clay soil order belongs to the Vertisols. Plant samples were collected at maturity stage. Rice (*Oryza sativa* L.) is one of the most important staple food crops for approximately half of the global world. The experiment was carried out in split-plot design with three replications having four fertility levels in main plots and twelve varieties in sub plots. The highest total phosphorus uptake was recorded by R-1033-968-1(ABL) (G2), followed by the genotype R-RF-31(ABL) (G1) that was statistically at par with Chandrahasini (G12) and significantly the lowest phosphorus uptake was obtained by SWARNA×MOROBRAKEN-23 (G3). Phosphorus uptake increased with increasing fertilizer application from low to high fertility level. Application of high fertility level produced higher phosphorus uptake (18.645kg ha⁻¹) followed by medium fertility level (17.249kg ha⁻¹) low in lower fertility level (15.110kg ha⁻¹) and lowest (11.081 ha⁻¹) in control. Phosphorus use efficiency ranged from 17.80 to 36.70 90 per cent with overall mean value of 27.00 per cent. The genotype R-1033-968-1(ABL) was recorded maximum PUE and the lowest by Improve Chitimitulya. The doses of phosphorus application affected P use efficiency. It was higher in case of low fertility level than that of medium and high fertility level.

Keywords: Phosphorus use efficiency, p uptake, NPK, *Oryza sativa* L., vertisols, zinc rice

Introduction

Rice (*Oryza sativa* L.) is a very important staple food crop in the world. Rice plant belongs to the family Gramineae. Total rice crop area was 42.56 million hectares and production was 115.60 million tonnes (Anonymous, 2018-19a) [2]. Phosphorus play important role in the plant metabolism, structure, and reproduction that cannot be performed by any other element. The concentration of phosphorus in plants usually is lower than the concentration of nitrogen, potassium, or calcium. Except for nitrogen, unsatisfactory plant growth is regularly observed due to a shortage of phosphorus than to a shortage of any other element. Phosphorus is intimately associated with all life processes and it is a vital constituent of every living cell. The results showed that tiller number, fertile tiller, total grain, 1000-grain weight and yield increased significantly with phosphorus fertilizer. Adequate P rates for maximum grain yield varied from genotype to genotype. The objectives of this study were to quantify phosphorus (P) uptake and use efficiency in cultivars of different species of high zinc containing rice genotype under different phosphorus fertility levels.

Materials and Methods

Twelve genotypes of Rice (*Oryza sativa* L.) having high Zn containing genotypes were selected to study PUE, the experiment was conducted at Indira Gandhi Agricultural University, during *kharif* 2013 Raipur, Chhattisgarh. The soil of the experimental field comes under the order of *Vertisols* and identified as Arang II series. It is clayey in texture, dark brown to black in color, neutral to alkaline in reaction due to presence of lime concretion in lower horizon. The experiment was carried out in split-plot design with three replications having four

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fertility levels (00, 30, 50 and 70 kg P ha⁻¹) in main plots and twelve varieties R-RF-31 (ABL) (G-1), R-1033-968-1(ABL) (G-2), SWARNA×MOROBRAKEN-23 (G-3), SWARNA×MOROBRAKEN-21 (G-4), Bas 1×IR681444 (G-5), IR 681444×HMT (G-6), IR 94297 (G-7), IR 94033 (G-8), IR 681444-2B-2-2-3-1-127 (G-9), IR 83286-22-1-2-7-1(G-10),

Improve Chitmutalya (G-11) and Chandrahasini (G-12), in sub plots. Full doses of P were applied as basal. Data was recorded at maturity viz., number of effective tillers per meter square, grain test weight and straw yield quintals per ha. Phosphorus, use efficiency was calculated by using the following formula.

$$\text{PUE (\%)} = \frac{\text{Uptake from treated plot (kg ha}^{-1}\text{)} - \text{Uptake from control plot (kg ha}^{-1}\text{)}}{\text{Total nutrient applied}} \times 100$$

The data was analyzed using OPSTAT.

Table 1: Some chemical properties of the soil used for the study.

Parameter	Rating/value	Parameter	Rating/value
EC (dSm ⁻¹)	0.18	Available Zn (ppm)	1.89
Soil pH	8.03	Available Fe (ppm)	6.56
Organic Matter %	0.58	Available Mn (ppm)	6.33
CEC (c mol (p+) Kg ⁻¹)	36.32	Available Cu (ppm)	2.51
Available nitrogen (Kg ha ⁻¹)	238.3	Texture	Clay
Available Phosphorous (Kg ha ⁻¹)	14.2		
Available Potash (Kg ha ⁻¹)	459.2		

Result and Discussion

Yield attributes

The Number of effective tillers (Table 2), test weight (Table 3), grain yield (Table 4) and straw yield (Table 5) were significantly varied under different genotypes and fertility levels. The average effective tillers were significantly higher with R-1033-968-1(ABL) followed by R-RF-31(ABL), IR 94297. The mean effective tillers of 156 /m² were recorded by improved Chitmutalya, which was significantly lower than all other genotypes. The average test weight was significantly higher in R-RF-31(ABL) followed by R-1033-968-1(ABL), IR 94297. The test weight of 18.13 gram was recorded by Improve Chitmutalya, which was significantly lower than all other genotypes except IR 681444×HMT. The average grain yield was significantly higher in R-1033-968-1(ABL) followed by R-RF-31(ABL), followed by IR 94297. The grain yield of 30.09 q ha⁻¹ was recorded by Improve Chitmutalya, which was significantly lower than all other genotypes, except (SWARNA×MOROBRAKEN-23). The average straw yield was accumulated significantly higher in R-RF-31(ABL) followed by R-1033-968-1(ABL), IR 94033. The straw yield of 43.33 q ha⁻¹ was recorded by BAS 1×IR681444 which was significantly lower than all other genotypes, except SWARNA×MOROBRAKEN-21, IR 681444-2B-2-2-3-1-127 and Improve Chitmutalya. Fertility levels were also significantly influenced the effective tillers, test weight, grain and straw yield of different rice genotypes as shown in the Table 2, Table 3, Table 4 and Table 5 respectively. Significantly highest effective tillers, test weight, grain and straw yield of 230 m², 25.26 gram, 53.89 q ha⁻¹ and 61.87 q ha⁻¹ were recorded under high soil fertility level (F3) followed by medium soil fertility level (F2) with 222 m², 24.19 gram. While in case of grain and straw yields were at par with medium fertility level (51.11 q ha⁻¹) and (57.91 q ha⁻¹) (F2). Control soil fertility level (F0) recorded significantly lowest effective tillers, test weight, grain and straw yield of rice respectively, 165 m², 22.32 gram, 31.38 q ha⁻¹ and 34.54 q ha⁻¹. Different rice genotypes have responded to the graded dose of fertilizer application created from low to high fertility level. Similar findings were also reported by Tabar *et al.* (2012) [9]. Test weight of rice genotypes increased with increasing levels of fertilizer application was also reported by

Tabar *et al.* (2012) [9] and Ahmad *et al.* (2005) [3]. Similar results for grain yield also reported by Uddin *et al.* (2013) [10], Fageria *et al.* (2011) [5], Metwally *et al.* (2011) [6] and Awan *et al.* (2011) [3], who reported increase in paddy yield of rice as the rates of N increased. Genotypes had significant effect on the growth and yield attributes and among them, R-1033-968-1(ABL) recorded the higher growth and yield attributes i.e. total tiller, effective tiller and their combined effect resulted the maximum rice yield. Superiority of R-1033-968-1(ABL) over other varieties may also seems to be on account of higher root and shoot growth, leaf area index and efficient translocation of metabolites towards grain formation.

Effect of rice genotypes and fertility levels on total phosphorus uptake (kg/ha)

The effects of rice genotypes and fertility levels on total phosphorus uptake was found to be significant (Table 6.) The average total phosphorus uptake was observed significantly higher in R-1033-968-1(ABL) (G2) as compared to those of other genotypes in the order of R-RF-31(ABL) (G1), Chandrahasini (G12), BAS 1×IR681444 (G5), IR 681444×HMT (G6), IR 681444-2B-2-2-3-1-127 (G9), IR 94297 (G7), IR 83286-22-1-2-7-1 (G10), IR 94033 (G8), Improve Chitmutalya (G11), SWARNA×MOROBRAKEN-21 (G4). The phosphorus uptake of 11.57 kg ha⁻¹ was recorded by SWARNA×MOROBRAKEN-23 (G3), which was significantly lower than all other genotypes. Fertility levels were also significantly influenced the phosphorus uptake of different rice genotypes as shown in the Table 6. Significantly the highest phosphorus uptake of 18.64 kg ha⁻¹ was recorded under high soil fertility level (F3) followed by medium soil fertility level (17.24 kg ha⁻¹) (F2). Control soil fertility level (F0) recorded significantly the lowest phosphorus uptake (11.08 kg ha⁻¹). P uptake increased with increasing fertilizer application from low to high fertility level. The phosphorus uptake being a function of biomass production, it was significantly increased due to increase in grain and straw yields along with their concentration in plant and with increasing P application levels in soil. Plants absorb proportionately more nitrogen and phosphorus from the pool of available with higher dose of application. Patel *et al.*, 1997 and Bharde *et al.* (2003) [7, 4] also reported the synergistic

effect of N in availability of P and K. Interaction between rice genotypes and fertility levels was found to be non-significant. Similar findings were also reported by *et al.* (2009) and Singh *et al.* (2010)^[8].

Phosphorus use efficiency as influenced by rice genotypes and fertility levels

Table 7. Showed the average phosphorus use efficiency ranged from 17.80 to 36.70 per cent with overall mean value of 27.00 per cent. The highest average PUE was recorded by R-1033-968-1(ABL) (G2) followed by IR 681444-2B-2-2-3-1-127

(G9), followed by SWARNA×MOROBRAKEN-23 (G3), R-RF-31(ABL) (G2), followed by IR 94297 (G7), IR 83286-22-1-2-7-1 (G10) and the lowest PUE was recorded by Improve Chitimutalya. Low fertility level exhibited higher phosphorus use efficiency (0.305 per cent) than that of medium (0.275 per cent) and high fertility level (0.229 per cent). Under low fertility level the genotype R-1033-968-1(ABL) recorded higher phosphorus use efficiency and the lowest was recorded by Improve Chitimutalya. The doses of P application affected phosphorus use efficiency. It was higher in case of low fertility level than that of medium and higher fertility level.

Table 2: Effective tillers m²

S.N.	Rice genotype	Fertility levels (kg P ha ⁻¹)				Mean
		00	30	50	70	
1	R-RF-31(ABL)	184	240	245	265	236
2	R-1033-968-1(ABL)	224	254	263	275	251
3	SWARNA×MOROBRAKEN-23	140	175	210	217	185
4	SWARNA×MOROBRAKEN-21	142	187	208	214	188
5	Bas 1×IR681444	182	226	235	240	221
6	IR 681444×HMT	163	182	200	210	189
7	IR 94297	170	218	245	266	225
8	IR 94033	154	182	210	208	188
9	IR 681444-2B-2-2-3-1-120	161	196	224	232	203
10	IR 83286-22-1-2-7-1	170	184	219	233	201
11	Improved Chitimutalya	142	149	163	170	156
12	Chandahasini	152	189	240	233	204
	MEAN	165 ^D	198 ^C	222 ^B	230 ^A	204

CD at 5% for, F**= 5.02, G**=6.66

Table 3: Test weight (1000 grain weight (g).

S.N.	Rice genotype	Fertility levels (kg P ha ⁻¹)				Mean
		00	30	50	70	
1	R-RF-31(ABL)	26.24	27.61	28.43	29.40	27.92
2	R-1033-968-1(ABL)	26.53	27.00	27.57	28.97	27.51
3	SWARNA×MOROBRAKEN-23	21.51	23.65	23.60	24.50	23.31
4	SWARNA×MOROBRAKEN-21	22.94	23.12	23.46	24.08	23.40
5	Bas 1×IR681444	22.08	24.06	25.32	25.87	24.33
6	IR 681444×HMT	17.98	18.98	19.67	19.76	19.09
7	IR 94297	23.57	24.59	26.35	27.83	25.58
8	IR 94033	22.71	24.28	24.08	25.53	24.15
9	IR 681444-2B-2-2-3-1-120	22.16	23.83	24.93	25.40	24.08
10	IR 83286-22-1-2-7-1	22.87	23.05	24.38	26.18	24.11
11	Improve Chitimutalya	16.39	17.48	18.84	19.82	18.13
12	Chandahasini	22.91	22.61	23.63	25.71	23.71
	MEAN	22.32 ^D	23.35 ^C	24.19 ^B	25.26 ^A	23.78

CD at 5% for, F**= 0.55, G**=0.93

Table 4: Grain yield q ha⁻¹

S.N.	Rice genotype	Fertility levels (kg P ha ⁻¹)				Mean
		00	30	50	70	
1.	R-RF-31(ABL)	33.87	49.46	62.80	64.04	52.54
2.	R-1033-968-1(ABL)	38.49	56.71	64.58	68.36	57.03
3.	SWARNA×MOROBRAKEN-23	21.82	30.09	36.05	38.67	31.66
4.	SWARNA×MOROBRAKEN-21	29.55	42.22	48.31	50.67	42.69
5.	Bas 1×IR681444	32.98	45.60	57.07	57.60	48.3
6.	IR 681444×HMT	32.22	43.56	50.13	50.58	44.12
7.	IR 94297	36.18	50.22	56.93	58.36	50.42
8.	IR 94033	27.11	41.87	45.95	45.29	40.05
9.	IR 681444-2B-2-2-3-1-127	29.29	45.95	55.91	59.87	47.75
10.	IR 83286-22-1-2-7-1	32.80	43.78	50.22	61.65	47.11
11.	Improve Chitimutalya	23.78	30.14	32.40	34.04	30.09
12.	Chandahasini	38.49	43.02	53.02	57.60	48.03
	MEAN	31.38 ^D	43.55 ^C	51.11 ^{AB}	53.89 ^A	44.98

CD at 5% for, F**= 4.86, G**=3.42

Table 5: Straw yield q ha¹

S.N.	Rice genotype	Fertility levels (kg P ha ⁻¹)				Mean
		00	30	50	70	
1	R-RF-31(ABL)	43.52	65.75	84.79	84.93	69.75
2	R-1033-968-1(ABL)	46.50	68.37	77.71	81.05	68.41
3	SWARNA×MOROBRAKEN-23	35.46	48.93	55.72	63.68	50.95
4	SWARNA×MOROBRAKEN-21	29.76	42.48	49.65	52.40	43.57
5	Bas 1×IR681444	28.85	40.68	51.62	52.17	43.33
6	IR 681444×HMT	32.53	47.96	55.92	56.76	48.29
7	IR 94297	34.14	47.81	55.54	59.88	49.34
8	IR 94033	34.24	55.57	57.07	60.78	51.92
9	IR 681444-2B-2-2-3-1-127	26.40	42.47	50.46	57.67	44.25
10	IR 83286-22-1-2-7-1	31.51	44.55	51.24	62.71	47.50
11	Improve Chitimutalya	35.38	46.19	49.58	52.72	45.97
12	Chandahasini	36.24	44.66	55.65	57.73	48.57
	MEAN	34.54 ^D	49.62 ^C	57.91 ^{AB}	61.87 ^A	50.99

CD at 5% for, F**= 4.92, G**=3.56

Table 6: Effect of rice genotypes and fertility levels on total phosphorus uptake (kg/ha).

S.N.	Rice genotype	Symbol	Fertility levels				Mean
			Control	Low	Medium	High	
1	R-RF-31(ABL)	G-1	13.50	18.04	20.69	21.97	18.55 ^b
2	R-1033-968-1(ABL)	G-2	15.84	21.26	23.95	25.45	21.62 ^a
3	SWARNA×MOROBRAKEN-23	G-3	7.50	10.88	13.00	14.91	11.57 ^g
4	SWARNA×MOROBRAKEN-21	G-4	7.80	11.59	13.60	15.01	12.00 ^g
5	Bas 1×IR681444	G-5	12.76	17.08	19.35	21.00	17.55 ^{bc}
6	IR 681444×HMT	G-6	11.81	15.80	17.58	18.75	15.98 ^c
7	IR 94297	G-7	9.48	13.94	16.32	17.10	14.21 ^e
8	IR 94033	G-8	9.56	13.37	14.84	16.10	13.47 ^e
9	IR 681444-2B-2-2-3-1-127	G-9	11.22	15.08	17.34	19.21	15.71 ^{cd}
10	IR 83286-22-1-2-7-1	G-10	9.50	13.20	15.46	17.37	13.88 ^e
11	Improve Chitimutalya	G-11	10.10	13.15	14.63	15.22	13.28 ^{ef}
12	Chandahasini	G-12	13.87	17.89	20.19	21.59	18.39 ^b
	MEAN		11.08 ^D	15.11 ^C	17.24 ^B	18.64 ^A	15.52

CD at 5% for, F**= 1.12, G**=1.15, Interaction (FG**)- NS

Table 7: Phosphorus use efficiency (%)

S.N.	Rice genotype	Symbol	Fertility levels			Mean
			Low	Medium	High	
1	R-RF-31(ABL)	G-1	0.347	0.299	0.229	0.292 ^{bc}
2	R-1033-968-1(ABL)	G-2	0.414	0.372	0.315	0.367 ^a
3	SWARNA×MOROBRAKEN-23	G-3	0.328	0.306	0.262	0.299 ^{bc}
4	SWARNA×MOROBRAKEN-21	G-4	0.29	0.282	0.236	0.269 ^{cd}
5	Bas 1×IR681444	G-5	0.302	0.282	0.223	0.269 ^{cd}
6	IR 681444×HMT	G-6	0.305	0.265	0.227	0.266 ^{cd}
7	IR 94297	G-7	0.341	0.282	0.223	0.282 ^{bc}
8	IR 94033	G-8	0.237	0.211	0.158	0.202 ^{de}
9	IR 681444-2B-2-2-3-1-120	G-9	0.37	0.359	0.313	0.348 ^{ab}
10	IR 83286-22-1-2-7-1	G-10	0.301	0.278	0.257	0.279 ^{bc}
11	Improve Chitimutalya	G-11	0.21	0.177	0.149	0.178 ^e
12	Chandahasini	G-12	0.22	0.192	0.152	0.188 ^e
	Mean		0.305	0.275	0.229	0.270

CD at 5% for, F**= 0.56, G**=0.080, Interaction (FG**)- NS

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