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 Vishwavidyalaya, 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) and lowest (11.081 kg ha⁻¹) in control. Phosphorus use efficiency ranged from 17.80 to 36.70 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 Chitimutalya.

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). 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...
fertility levels (00, 30, 50 and 70 kg P ha\(^{-1}\)) in main plots and twelve varieties R-3F-31 (ABL) (G-1), R-1033-968-1(ABL) (G-2), SWARNA×MOROBRAKEN-23 (G-3), SWARNA×MOROBRAKEN-21 (G-4), BAS 1xIR681444 (G-5), IR 681444xHMT (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 Chitimutalya (G-11) and Chandrahhasini (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 Phosphorus (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 m\(^{-1}\) were recorded by improved Chitimutalya, 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 Chitimutalya, 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 Chitimutalya, 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 1xIR681444 which was significantly lower than all other genotypes, except SWARNA×MOROBRAKEN-21, IR 681444-2B-2-2-3-1-127 and Improve Chitimutalya. 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 m\(^{2}\), 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 m\(^{2}\), 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 m\(^{2}\), 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) [9] and Awan et al. (2011) [5], 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), Chandrahhasini (G12), BAS 1xIR681444 (G5), IR 681444xHMT (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 Chitimutalya (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. Patle et al., 1997 and Bharde et al. (2003) [7, 4] also reported the synergistic
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 SWARNAxMOROBRAKEN-23 (G3), RRF-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.

| S.N. | Rice genotype         | Fertility levels (kg P ha⁻¹) | Mean |
|------|-----------------------|-----------------------------|------|
| 1    | R-RF-31(ABL)          | 184                         | 240  |
| 2    | R-1033-968-1(ABL)     | 224                         | 254  |
| 3    | SWARNAxMOROBRAKEN-23 | 140                         | 175  |
| 4    | SWARNAxMOROBRAKEN-21 | 142                         | 187  |
| 5    | Bas 1xIR681444        | 182                         | 226  |
| 6    | IR 681444xHMT         | 163                         | 182  |
| 7    | IR 94297              | 170                         | 218  |
| 8    | IR 94033              | 154                         | 182  |
| 9    | IR 681444-2B-2-2-3-1-120 | 161              | 196  |
| 10   | IR 83286-22-1-2-7-1   | 170                         | 184  |
| 11   | Improved Chitimutalya | 142                         | 149  |
| 12   | Chandrahasini         | 152                         | 189  |
| MEAN |                      | 165                         | 198  |

$CD_{a} 5\%$ 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 |
|------|-----------------------|-----------------------------|------|
| 1    | R-RF-31(ABL)          | 26.24                       | 27.61 |
| 2    | R-1033-968-1(ABL)     | 26.53                       | 27.00 |
| 3    | SWARNAxMOROBRAKEN-23 | 21.51                       | 23.65 |
| 4    | SWARNAxMOROBRAKEN-21 | 22.94                       | 23.12 |
| 5    | Bas 1xIR681444        | 22.08                       | 24.06 |
| 6    | IR 681444xHMT         | 17.98                       | 18.98 |
| 7    | IR 94297              | 23.57                       | 24.59 |
| 8    | IR 94033              | 22.71                       | 24.28 |
| 9    | IR 681444-2B-2-2-3-1-120 | 22.16              | 23.83 |
| 10   | IR 83286-22-1-2-7-1   | 22.87                       | 23.05 |
| 11   | Improved Chitimutalya | 16.39                       | 17.48 |
| 12   | Chandrahasini         | 22.91                       | 22.61 |
| MEAN |                      | 22.32                      | 23.35 |

$CD_{a} 5\%$ 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 |
|------|-----------------------|-----------------------------|------|
| 1    | R-RF-31(ABL)          | 33.87                       | 49.46 |
| 2    | R-1033-968-1(ABL)     | 38.49                       | 56.71 |
| 3    | SWARNAxMOROBRAKEN-23 | 21.82                       | 30.09 |
| 4    | SWARNAxMOROBRAKEN-21 | 29.55                       | 42.22 |
| 5    | Bas 1xIR681444        | 32.98                       | 45.60 |
| 6    | IR 681444xHMT         | 32.22                       | 43.56 |
| 7    | IR 94297              | 36.18                       | 50.22 |
| 8    | IR 94033              | 27.11                       | 41.87 |
| 9    | IR 681444-2B-2-2-3-1-127 | 29.29            | 45.95 |
| 10   | IR 83286-22-1-2-7-1   | 32.80                       | 43.78 |
| 11   | Improved Chitimutalya | 23.78                       | 30.14 |
| 12   | Chandrahasini         | 38.49                       | 43.02 |
| MEAN |                      | 31.38                      | 43.55 |

$CD_{a} 5\%$ for, $F^{**}= 4.86, G^{**}=3.42$
### Table 5: Straw yield q ha⁻¹

| S.N. | Rice genotype       | Fertility levels (kg P ha⁻¹) | Mean |
|------|---------------------|------------------------------|------|
|      |                     | 0.00 | 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 1xIR681444      | 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 | 45.55 | 51.24 | 62.71 | 47.30 |
| 11   | Improve Chitumitalya | 35.38 | 46.19 | 49.58 | 52.72 | 45.97 |
| 12   | Chandrasaini        | 36.24 | 46.66 | 55.65 | 57.73 | 48.57 |

CD 精益求, 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 | Control | Low | Medium | High | Mean |
|------|---------------------|--------|---------|-----|--------|------|------|
| 1    | R-RF-31(ABL)       | G-1    | 13.50   | 20.06 | 21.97 | 18.55 |
| 2    | R-1033-968-1(ABL)  | G-2    | 15.84   | 21.26 | 23.95 | 25.45 | 21.62 |
| 3    | SWARNA×MOROBRAKEN-23 | G-3   | 7.50    | 10.88 | 13.00 | 14.91 | 11.57 |
| 4    | SWARNA×MOROBRAKEN-21 | G-4   | 7.80    | 11.59 | 13.60 | 15.01 | 12.00 |
| 5    | Bas 1xIR681444     | G-5    | 12.76   | 17.84 | 19.35 | 21.00 | 17.55 |
| 6    | IR 681444×HMT      | G-6    | 11.81   | 15.80 | 17.58 | 18.75 | 15.98 |
| 7    | IR 94297           | G-7    | 9.48    | 13.94 | 16.32 | 17.10 | 14.21 |
| 8    | IR 94033           | G-8    | 9.56    | 13.37 | 14.84 | 16.10 | 13.47 |
| 9    | IR 681444-2B-2-2-3-1-127 | G-9   | 11.22   | 15.08 | 17.34 | 19.21 | 15.71 |
| 10   | IR 83286-22-1-2-7-1 | G-10  | 9.50    | 13.20 | 15.46 | 17.37 | 13.88 |
| 11   | Improve Chitumitalya | G-11  | 10.10   | 13.15 | 14.63 | 15.22 | 13.28 |
| 12   | Chandrasaini       | G-12   | 13.87   | 17.89 | 20.19 | 21.59 | 18.39 |

CD метрі F**= 1.12, G**=1.15, Interaction (FG**)- NS

### Table 7: Phosphorus use efficiency (%)

| S.N. | Rice genotype      | Symbol | Low | Medium | High | Mean |
|------|---------------------|--------|-----|--------|------|------|
| 1    | R-RF-31(ABL)       | G-1    | 0.347 | 0.299 | 0.229 | 0.292 |
| 2    | R-1033-968-1(ABL)  | G-2    | 0.414 | 0.372 | 0.315 | 0.367 |
| 3    | SWARNA×MOROBRAKEN-23 | G-3   | 0.328 | 0.306 | 0.262 | 0.299 |
| 4    | SWARNA×MOROBRAKEN-21 | G-4   | 0.29  | 0.282 | 0.236 | 0.269 |
| 5    | Bas 1xIR681444     | G-5    | 0.302 | 0.282 | 0.223 | 0.269 |
| 6    | IR 681444×HMT      | G-6    | 0.305 | 0.265 | 0.227 | 0.266 |
| 7    | IR 94297           | G-7    | 0.341 | 0.282 | 0.223 | 0.282 |
| 8    | IR 94033           | G-8    | 0.237 | 0.211 | 0.158 | 0.202 |
| 9    | IR 681444-2B-2-2-3-1-127 | G-9   | 0.37  | 0.359 | 0.313 | 0.348 |
| 10   | IR 83286-22-1-2-7-1 | G-10  | 0.301 | 0.278 | 0.257 | 0.279 |
| 11   | Improve Chitumitalya | G-11  | 0.21  | 0.177 | 0.149 | 0.178 |
| 12   | Chandrasaini       | G-12   | 0.22  | 0.192 | 0.152 | 0.188 |

Mean | 0.305 | 0.275 | 0.229 | 0.270 |

CD метрі F**= 0.56, G**=0.80, Interaction (FG**)- NS

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