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# Effect of organic and inorganic amendments and their combination on phosphorus availability and uptake in grain and straw of various rice genotypes under *Sodic* soils

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### Abstract
Sodic soils have immense productivity potential, if managed through proper technology interventions. Bio-compost is prepared by composting pressmud (a sugar industry byproduct) received from cane juice filtration and spent wash received from distilleries through microbial aerobic decomposition and gypsum received from waste material of mining can be used to reclaim sodic soils and increase nitrogen availability in soils. A field experiments were carried out during *Kharif* seasons 2018 & 2019 at ICAR - Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), Bihar. Our objective was to study the increase phosphorous availability & uptake by rice genotypes under sodic soils. The results obtained from the present investigation revealed that the mean of soil reaction (pH) of all genotypes ranged from 9.10 to 9.23 during 2018 and 9.01 to 9.11 during 2019. The mean of available phosphorous in all genotypes varied from 15.36 to 17.03 kg ha$^{-1}$ in the first year while in the second year it varied from 14.21 to 16.26 kg ha$^{-1}$. The mean phosphorus uptake in grain of the genotypes varied from 10.01 kg ha$^{-1}$ to 15.35 kg ha$^{-1}$ in the first year while in the second year it varied from 10.56 kg ha$^{-1}$ to 15.15 kg ha$^{-1}$ and the phosphorus uptake in straw of the genotypes varied between 2.63 kg ha$^{-1}$ to 3.61 kg ha$^{-1}$ in the first year while in the second year it varied between 2.71 kg ha$^{-1}$ to 3.61 kg ha$^{-1}$.

**Keywords:** Gypsum requirement (GR), gypsum, bio-compost and rice genotypes

### Introduction
Worldwide, approximately 1.2 billion hectare of area is estimated to be salt affected with different levels of salinity and sodicity of soils (Massoud 1974; Ponnamperuma 1984; Tanji 1990 and FAO 2007) [13, 18, 21, 5]. However, India has the largest area under salt affected soils i.e. 6.74 million hectare. In India alone, 1.25 million hectare areas are characterized by coastal salinity, 3.79 million hectare as sodic and 1.71 million hectare area under saline soils. However, in Bihar, the total salt affected soils are spread over 0.15 million hectare area among which 0.11 million hectare area is under alkaline (sodic) soils and 0.047 million hectare area is under saline soils (NRSA and Associates 1996) [15]. Over 6.74 million hectare of the area is estimated to be lost each year to salinity, sodicity and drainage problems (Gupta and Abrol 1990) [7].

In world, 769.9 million tonnes rice have been produced in the year 2018-19 from the total harvested area of 165.93 million hectare with 4.64 t ha$^{-1}$ productivity. As we know that Asia is the biggest rice producer as well as consumer of the world and majority of all rice produce comes from India, China, Japan, Indonesia, Thailand, Burma and Bangladesh while Asian farmers account for 92% of the world's rice production. In the year 2018-19, 169.5 million tonnes rice was produced from 44.49 million hectare in India with 3.81 t ha$^{-1}$ productivity however, 8.3 million tonnes of rice was produced from 3.24 million hectare in Bihar with 2.56 t ha$^{-1}$ productivity (FAO 2018) [4].

Soil salinity is a major abiotic stress limiting plant growth and development. In crops known as glycophyte or salt susceptible [Hasegawa *et al.* 2000; Qadir *et al.* 2007] [9, 19]. It causes yield losses by depressing the uptake of water, and disturbing mineral and normal metabolism. Salt-affected soils are identified by excessive levels of water-soluble salts, especially sodium chloride (NaCl) [Tanji 2002] [22]. NaCl is a small molecule which when ionized by water, produces sodium (Na$^+$) and chloride (Cl$^−$) ions. Excess Na$^+$ in plant cells directly damages membrane systems and organelles, resulting in growth reduction and abnormal development prior to plant death.

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The toxic ions cause ionic and osmotic stress at the cellular level in higher plants, especially in susceptible germplasm [Mansour and Salama 2000; Chinnusamy *et al.* 2005] [12, 2]. Salinity reduces plant growth through osmotic effects and reduces the water uptake, thereby causing a reduction in growth.

There are many effective ways for improving salt-affected land, such as leaching, chemical remediation and phytoremediation [Qadir *et al.* 2007; Sharma and Minhas 2005] [19, 20]. The remediation of salt-affected soils using chemical agents, including gypsum ($CaSO_4 \cdot 2H_2O$), pyrite ($FeS_2$), calcite ($CaCO_3$), calcium chloride ($CaCl_2.2H_2O$), and organic matter (farmyard manure, green manure, organic amendment and municipal solid waste), was successful in many cases and has been implemented worldwide, being effective and simple [Sharma and Minhas 2005; Mitchell *et al.* 2000; Hanay *et al.* 2004; Tejada *et al.* 2006] [20, 14, 8, 23]. Gypsum and pyrite are the most effective reclamation agents for sodic soils, but they are expensive and beyond the reach of poor farmers in rainfed lowland areas. But the physical, chemical and biological properties of soils in salt-affected areas can also be improved by the application of organic matter, leading to enhanced plant growth and development [Choudhary *et al.* 2004; Wong *et al.* 2009] [3, 26]. Pressmud, a sugar industry by-product, is readily available in eastern Uttar Pradesh (U.P.) and less expensive compared to gypsum. Biocompost is prepared by composting pressmud received from cane juice filtration and spent wash received from distilleries through microbial aerobic decomposition. It contains nutrients like N, P, K, Zn and big amounts of organic carbon. Calcium replaces $Na^+$ from the cation exchange complex, and about 2% - 3% sulphur converts into sulphuric acid and lowers soil pH.

**Materials and methods**
A field experiments were carried out during 23th June 2018 to 28th November 2018 and 23th June 2019 to 28th November 2019 (two *kharif* seasons). The experiment was conducted at ICAR - Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), Bihar which lies at 85⁰ 40' 19.7" E latitude 25⁰ 59' 06.2" N longitudes with an elevation of 55.00 meter above mean sea level. The experimental site is having hot and humid climate summers and too cold winters with average rainfall of 1344 mm of which 70% received during the monsoon period (mid June - mid September, 2018 and 2019).

**Experimental details**
A field experiment laid out in split plot design with four treatment T₁- Control, T₂- Gypsum @ 100% G.R., T₃- Gypsum @ 50% G.R. + Biocompost @ 2.5 t ha⁻¹, T₄- Biocompost @ 5.0 t ha⁻¹ in main plots and ten genotypes G₁ - Suwasini, G₂ - Rajendra Bhagwati, G₃ - Boro-3, G₄ - Rajendra Neelam, G₅ - CSR-30, G₆ - CSR-36, G₇ - CR-3884-244-8-5-6-1-1, G₈ - CR-2851-SB-1-2-B-1, G₉ - CSR-27, G₁₀ - Pusa-44 in sub plots and replicated in thrice. The main plots and sub plots are permanent plots for both the years (2018 and 2019). During experimentation (2018 and 2019), the plots were kept same for a particular treatment. the experiment site in each plots size was 4.2 m × 2.7 m and spacing in each plot 20 cm × 15 cm. Transplanted rice genotypes were taken with the recommended dose of N: P₂O₅: K₂O @ 120: 60: 40 in the form of urea, diammonium phosphate (DAP) and muriate of

potash (MOP). Fifty per cent of N, and full doses of P₂O₅ and K₂O were applied as basal and the rest fifty per cent of N was applied in two splits at 30 days interval. The study aimed to evaluate the effect of amendments on macronutrient uptake in grain and straw of various rice genotypes.

**Collection and preparation of soil samples**
Representative soil samples from 0-15 cm depth were collected before rice sowing and after rice harvesting stage *Kharif* (2018 and 2019), respectively. Collected soil samples were air dried in shade and grinded with wooden hammer. These grinded samples were then passed through a 2 mm sieve and stored in polyethylene bags with proper labels for further analysis of soil to determine various soil parameters. The pH of soil was measured with the help of a pH meter, maintaining the soil, water ratio of 1:2 as described by Jackson (1967) [10]. Available P was determined by the ascorbic acid procedure using a blue filter (660 mμ) as suggested by Olsen *et al.* (1954) [16].

**Collection and preparation of grain and straw samples**
Grain and straw samples of rice were collected from each plot at the time of harvesting. Samples were washed with an acidified detergent solution after that rinsed in distilled water and subsequent cleaning was done according to the method suggested by Chapman (1964) [1]. The samples were spread on a filter paper for air drying and afterwards put in paper bags, which were kept in hot air oven at 65°C for 48 hrs for drying. The dried samples were crushed, grinded with the help of Willey heavy duty grinding mill having a stainless steel blade and, then stored in polyethylene bags for the estimation of macro-nutrient contents. Well grinded samples of known weight were digested in diacid mixture prepared by mixing concentrated $HNO_3$ and $HClO_4$ in the ratio of 4:1 observing all relevant precautions as laid down by Piper (1966) [17] for analysis of the nutrients like P. Phosphorous was determined by Vanado-molybdate phosphoric yellow color using Calorimetric method (Jackson 1973) [11].

**Empirical formulae**

$$\text{Macro-nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{dry matter (q ha}^{-1})}{100}$$

**Statistical analysis**
The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) [6] for split plot design. ANOVA was found significant and accordingly results are presented at 5% level of significance (P=0.05).

**Results and discussion**
**Physico-chemical properties of experimental soil**
The soil of the experimental site belongs to order *Entisol*, silt loam in texture at surface containing 10.45% sand, 72.06% silt and 17.49% clay the physico-chemical properties of soil was alkaline pH 9.69 in reaction, electrical conductivity 2.12 dS m⁻¹ and organic carbon 2.6 g kg⁻¹. The soil had the available N, P, K and S was recorded 136.8 kg ha⁻¹, 7.83 kg ha⁻¹, 93.2 kg ha⁻¹ and 3.53 kg ha⁻¹ (Table 1). High pH and low EC of the experimental site might be from excessive accumulation of exchangeable $Na^+$ in the soil particles. This indicates that the soil of the experimental site was sodic

(USDA 1954) [24]. The soil had very low organic carbon content indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic carbon.

Soils in salt-affected landscapes produce less biomass than non-saline soils resulting less in soil organic carbon (Wong *et al.* 2010) [25].

**Table 1:** Physico-chemical properties of experimental soil (0-15 cm depth before start of the experiment)

| Properties | Value |
|---|---|
| **Physical properties** | |
| Sand (%) | 10.45 |
| Silt (%) | 72.06 |
| Clay (%) | 17.49 |
| Textural Class | Silt loam |
| Bulk density(g $cm^{-3}$) | 1.63 |
| Water Holding Capacity (%) | 38.62 |
| Wet Aggregate Stability (%) | 8.45 |
| **Chemical properties** | |
| pH (1:2 Soil: Water) (0 -15 cm depth) | 9.69 |
| EC (dS $m^{-1}$) | 2.12 |
| Organic Carbon (g $kg^{-1}$ soil) | 2.6 |
| Available Nitrogen (kg $ha^{-1}$) | 136.8 |
| Available Phosphorous ($P_2O_5$) (kg $ha^{-1}$) | 7.83 |
| Available Potassium ($K_2O$) (kg $ha^{-1}$) | 93.2 |
| Available Sulphur (kg $ha^{-1}$) | 3.53 |

**Soil reaction (pH)**

Soil reaction (pH) in all the genotypes had non-significant in the first year while in the second year genotypes Boro-3, Rajendra Neelam and Pusa-44 were significantly higher than the all genotypes (Figure 1). The mean of soil reaction (pH) of all genotypes ranged from 9.10 to 9.23 during 2018 and 9.01 to 9.11 during 2019.

All the soil amendments had significantly higher Soil reaction (pH) as compared to the gypsum @ 100% GR treated plot in both the years. Without treated in any amendments had higher

value than the combination of gypsum @ 50% GR and biocompost @ 2.5 t $ha^{-1}$ treated plot and biocompost @ 5.0 t $ha^{-1}$ treated plot. However, biocompost @ 5.0 t $ha^{-1}$ treated plot had higher soil reaction (pH) than the combination of gypsum @ 50% GR and biocompost @ 2.5 t $ha^{-1}$ treated plot in both the years.

The interaction between genotype and soil amendment was non-significant in both the years. Soil reaction (pH) ranged from 8.86 to 9.48 in the first year while in the second year it was ranged from 8.79 to 9.35.
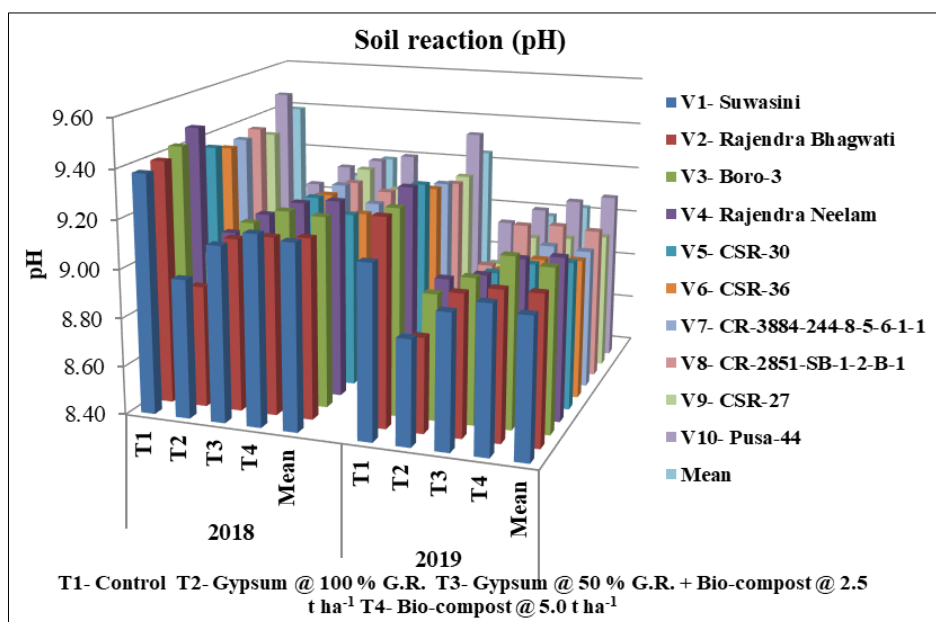


**Fig 1:** The influence of organic and inorganic amendments and their combination on soil reaction (pH - 1:2 Soil: Water) after harvest of rice crop

**Available Phosphorous in soil**

All the genotypes had non-significant during 2018 while Rajendra Neelam, Rajendra Bhagwati and Suwasini significantly higher than the all genotypes during 2019 shown in Figure 2. The mean of available phosphorous in all genotypes varied from 15.36 to 17.03 kg $ha^{-1}$ in the first year

while in the second year it varied from 14.21 to 16.26 kg $ha^{-1}$. All the soil amendments had significantly higher available phosphorous than the control plot. Biocompost @ 5.0 t $ha^{-1}$ applications had higher value than the other two amendments application. However, the combination of gypsum @ 50% GR and biocompost @ 2.5 t $ha^{-1}$ applications had higher available

phosphorous than the gypsum @ 100% GR applications in both the years. The interaction between genotype and soil amendment was non-significant in both the years. Available phosphorous ranged between 10.61 to 19.57 kg ha$^{-1}$ during 2018 and 9.21 to 19.37 kg ha$^{-1}$ during 2019.

This might be due to the mineralization of organic phosphorous and the dissolution of the slightly soluble phosphorous compounds as the soil pH declines activates some of the previously unavailable phosphorous in the soil become available.
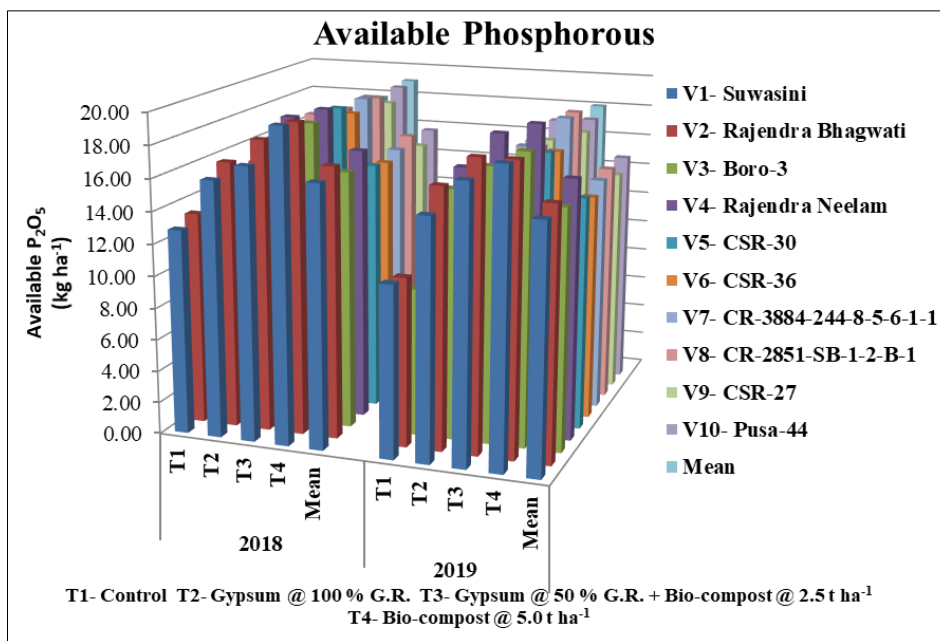


**Fig 2:** The influence of organic and inorganic amendments and their combination on Available Phosphorous (kg ha$^{-1}$) after harvest of rice crop

**Phosphorous uptake in grain**
Most of the genotypes were significantly higher phosphorus uptake in grain as compared to the varietal check Pusa-44, Rajendra Neelam, Rajendra Bhagwati and CR-2851-SB-1-2-B-1 in the first year while in the second year all the genotypes significantly higher than the varietal check, Pusa-44 and Rajendra Bhagwati found in Figure 3. The mean phosphorus uptake in grain of the genotypes varied from 10.01 kg ha$^{-1}$ to 15.35 kg ha$^{-1}$ in the first year while in the second year it varied from 10.56 kg ha$^{-1}$ to 15.15 kg ha$^{-1}$. All the soil amendments had significantly higher phosphorus uptake in

grain as compared to the control plot. The combination of gypsum and bio-compost had higher value than the other two amendments.
However, bio-compost application had higher phosphorus uptake in grain than the gypsum application in the first year and gypsum application had higher phosphorus uptake in grain than the bio-compost application in the second year. Soil amendments and genotypes interaction was non-significant in both the years. Phosphorus uptake in grain varied from 7.54 kg ha$^{-1}$ to 17.65 kg ha$^{-1}$ in the first year while in the second year it varied from 8.53 kg ha$^{-1}$ to 17.64 kg ha$^{-1}$.
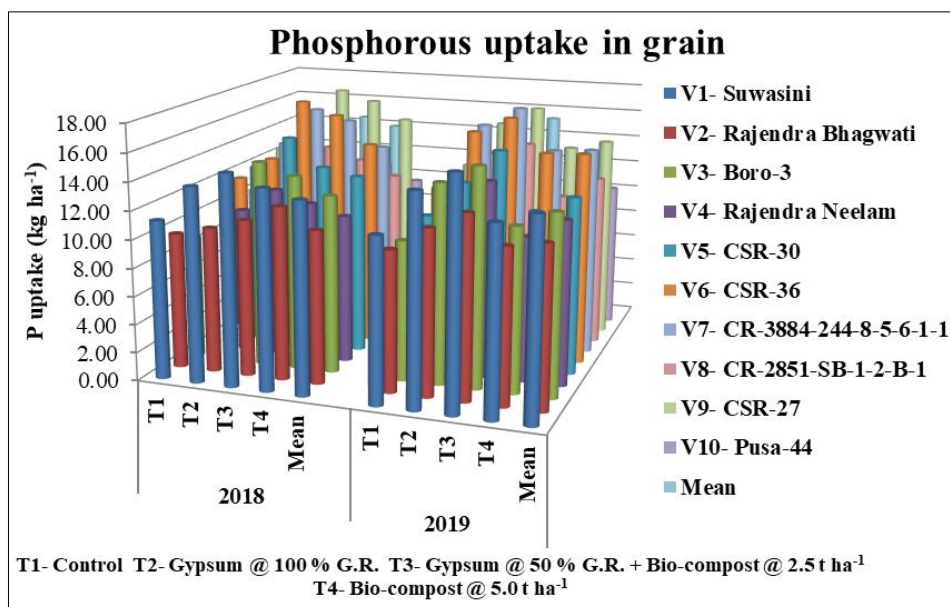


**Fig 3:** The influence of organic and inorganic amendments and their combination on Phosphorous uptake (kg ha$^{-1}$) in grain of different rice genotypes

**Phosphorous uptake in straw**
The phosphorus uptake in straw of the genotypes varied between 2.63 kg ha⁻¹ to 3.61 kg ha⁻¹ in the first year while in the second year it varied between 2.71 kg ha⁻¹ to 3.61 kg ha⁻¹ (Figure 4). The genotypes CSR-36, CR-3884-244-8-5-6-1-1 and CSR-27 were significantly higher than the all genotypes in both the years. During both the years the maximum and minimum value was obtained in Rajendra Bhagwati and CSR-36, respectively. The soil amendments varied between 2.25 kg ha⁻¹ to 3.14 kg ha⁻¹ during 2018 and 2.31 kg ha⁻¹ to 3.51 kg ha⁻¹ during 2019. All the soil amendments had significantly higher phosphorus uptake in straw as compared to the control plot. The combination of gypsum and bio-compost had higher value than the other two amendments in both the years. However, gypsum application had higher phosphorus uptake in straw than the bio-compost application during 2018 and 2019. Soil amendments and genotypes interaction was non-significant in both the years. Phosphorus uptake in straw varied between 1.95 kg ha⁻¹ to 4.34 kg ha⁻¹ during 2018 and 2.14 kg ha⁻¹ to 4.46 kg ha⁻¹, respectively during 2019. It might be due to improve the favourable pH range and availability of phosphorous in soil for uptake.
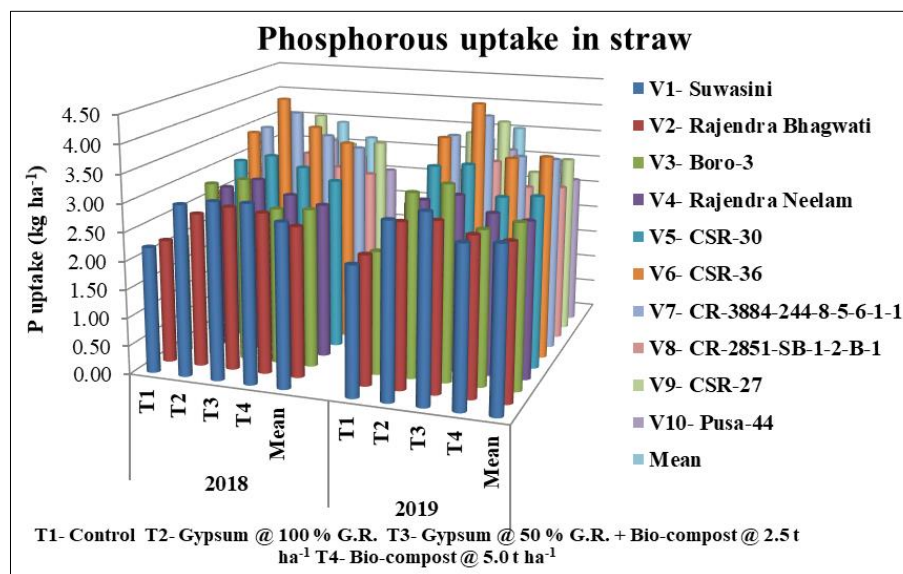


**Fig 4:** The influence of organic and inorganic amendments and their combination on Phosphorous uptake (kg ha⁻¹) in straw of different rice genotypes

**Conclusion**
All the soil amendments had significantly higher Soil reaction (pH) as compared to the gypsum @ 100% GR treated plot in both the years. Without treated in any amendments had higher value than the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha⁻¹ treated plot and biocompost @ 5.0 t ha⁻¹ treated plot. All the soil amendments had significantly higher available phosphorous than the control plot. Biocompost @ 5.0 t ha⁻¹ applications had higher value than the other two amendments application.
Most of the genotypes were significantly higher phosphorus uptake in grain as compared to the varietal check Pusa-44, Rajendra Neelam, Rajendra Bhagwati and CR-2851-SB-1-2-B-1 in the first year while in the second year all the genotypes significantly higher than the varietal check, Pusa-44 and Rajendra Bhagwati. The genotypes CSR-36, CR-3884-244-8-5-6-1-1 and CSR-27 were significantly higher phosphorous uptake in straw than the all genotypes in both the years. During both the years the maximum and minimum value was obtained in Rajendra Bhagwati and CSR-36, respectively.

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