



ISSN (E): 2277- 7695

ISSN (P): 2349-8242

NAAS Rating: 5.23

TPI 2022; 11(2): 1365-1370

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www.thepharmajournal.com

Received: 07-11-2021

Accepted: 17-12-2021

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Effect of gypsum & bio-compost applications on potassium availability and uptake in rice genotypes under *Sodic* soil

Suraj Mali and Sanjay Tiwari

Abstract

Sodic soils have immense productivity potential, if managed through proper technology interventions. Bio-compost and gypsum can be used to reclaim sodic soils decreased soil pH. A field experiments were carried out during June–November of 2018 & 2019 at ICAR - Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), Bihar. Our objective was to study the increase potassium availability & uptake in rice genotypes under sodic soils. Experiment was laidout in split plot design with four treatments i.e. T₁ - Control, T₂ - Gypsum@100%G.R., T₃ - Gypsum@50%G.R.+Bio-compost @2.5 tha⁻¹ and T₄ - Biocompost@5.0 tha⁻¹ in main plots and ten rice 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 and G₁₀ - Pusa-44 in sub plots and replicated thrice. 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 potassium in all genotypes varied from 116.92 kg ha⁻¹ to 123.82 kg ha⁻¹ in the first year while in the second year it varied from 113.34 kg ha⁻¹ to 123.50 kg ha⁻¹. The potassium uptake in grain of the genotypes varied between 7.28 kg ha⁻¹ to 12.21 kg ha⁻¹ in the first year while in the second year it varied between 7.16 kg ha⁻¹ to 10.88 kg ha⁻¹. The potassium uptake in straw of the genotypes ranged from 54.13 kg ha⁻¹ to 71.92 kg ha⁻¹ in the first year while in the second year it ranged from 53.53 kg ha⁻¹ to 72.57 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; Ponnampereuma 1984; Tanji 1990 and FAO 2007) [13, 17, 20, 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, 18]. 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] [21]. 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] ^[18, 19]. The remediation of salt-affected soils using chemical agents, including gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), pyrite (FeS_2), calcite (CaCO_3), calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$), 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] ^[19, 14, 8, 22]. 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, 25]. 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 85° 40' 19.7" E latitude 25° 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 K was estimated with 1N NH₄OAc (pH 7.0) reagent using flame photometer (Jackson 1967) ^[10].

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 HNO₃ and HClO₄ in the ratio of 4:1 observing all relevant precautions as laid down by Piper (1966) ^[16] for analysis of the nutrients like K. Potassium was determined by Flame photometer method (Jackson 1973) ^[11].

Empirical formulae

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

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) [23]. 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) [24].

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 ₂ O ₅) (kg ha ⁻¹)	7.83
Available Potassium (K ₂ O) (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.

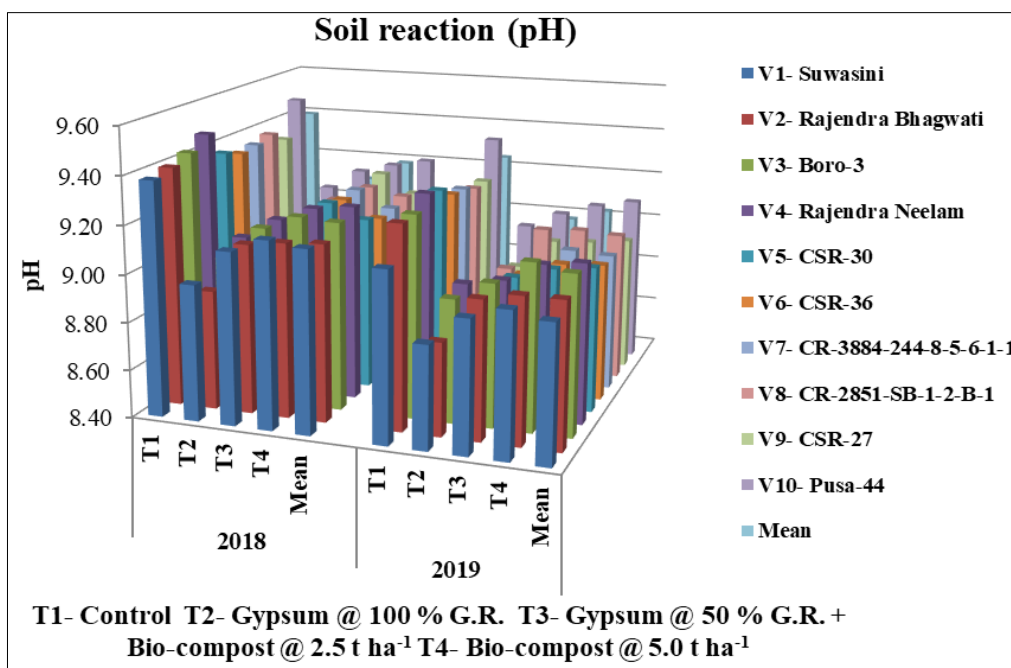


Fig 1: The influence of organic and inorganic amendments and their combination on soil reaction (pH - 1:2 Soil: Water) after harvest of rice crop

Available Potassium in soil

Most of the genotypes were significantly higher available potassium as compared to the salt tolerant genotypes: CSR-30 (Salt tolerant Basmati), CSR-27, CSR-36, CR-3884-244-8-5-

6-1-1 and CR-2851-SB-1-2-B-1 during 2018 and 2019. The mean of available potassium in all genotypes varied from 116.92 kg ha⁻¹ to 123.82 kg ha⁻¹ in the first year while in the second year it varied from 113.34 kg ha⁻¹ to 123.50 kg ha⁻¹

(Figure 2). Available potassium in all the soil amendments had significantly higher than the without treated in any amendments. Biocompost @ 5.0 t ha⁻¹ treated plot had higher value than the other two amendments. However, the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha⁻¹ treated plot had higher available potassium than the gypsum @ 100% GR treated plot in both the years. Available potassium varied between 100.73 kg ha⁻¹ to 140.53 kg ha⁻¹ during 2018 and 95.00 kg ha⁻¹ to 141.67 kg ha⁻¹. The interaction between genotypes and soil amendments was

significant in both the years. Without application of any amendment all the varieties were found superior of CSR-27 during 2018 and CR-2851-SB-1-2-B-1 during 2019. The variation of available potassium in gypsum, gypsum in combination with biocompost and biocompost treated soils among the different genotypes were between 108.87 to 121.63 kg ha⁻¹, 116.70 to 133.10 kg ha⁻¹ and 127.43 to 140.53 kg ha⁻¹ in the first year while in the second year it was varied between 102.33 to 125.00 kg ha⁻¹, 115.33 to 133.33 kg ha⁻¹ and 125.33 to 141.67 kg ha⁻¹.

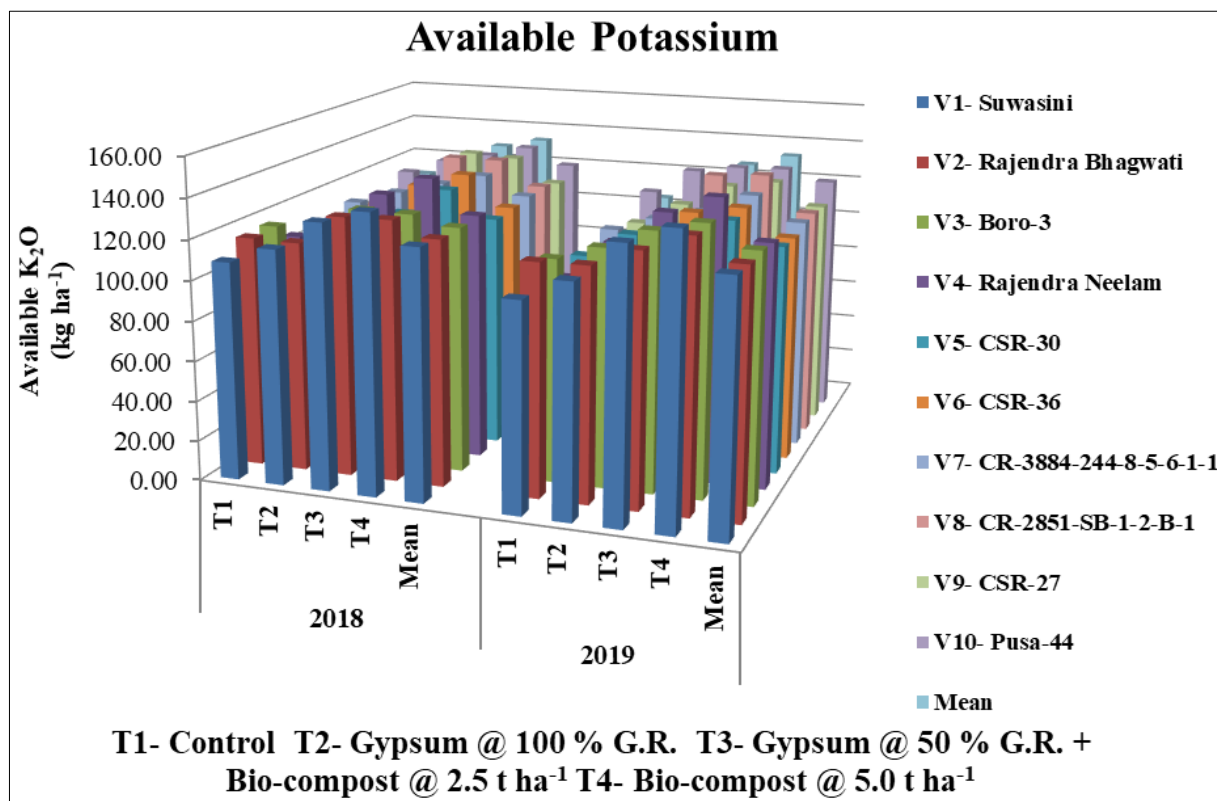


Fig 2: The influence of organic and inorganic amendments and their combination on Available Potassium (kg ha⁻¹) after harvest of rice crop

Potassium uptake in grain

Potassium uptake in grain in most of the genotypes were significantly higher than the varietal check Pusa-44, Rajendra Neelam and Rajendra Bhagwati in the first year while in the second year all the genotypes were found significantly higher than the varietal check Pusa-44 (Figure 3). The potassium uptake in grain of the genotypes varied between 7.28 kg ha⁻¹ to 12.21 kg ha⁻¹ in the first year while in the second year it varied between 7.16 kg ha⁻¹ to 10.88 kg ha⁻¹. All the soil amendments had significantly higher potassium uptake in grain as compared to the control. The combination of gypsum

and bio-compost had higher value than the other two amendments in both the years. However, bio-compost application had higher potassium uptake in grain than the gypsum application in the first year and gypsum application had higher potassium uptake in grain than the bio-compost application in the second year. Soil amendments and genotypes interaction was non-significant in both the years. Potassium uptake in grain varied between 5.19 kg ha⁻¹ to 13.79 kg ha⁻¹ in the first year while in the second year it varied between 6.02 kg ha⁻¹ to 12.82 kg ha⁻¹.

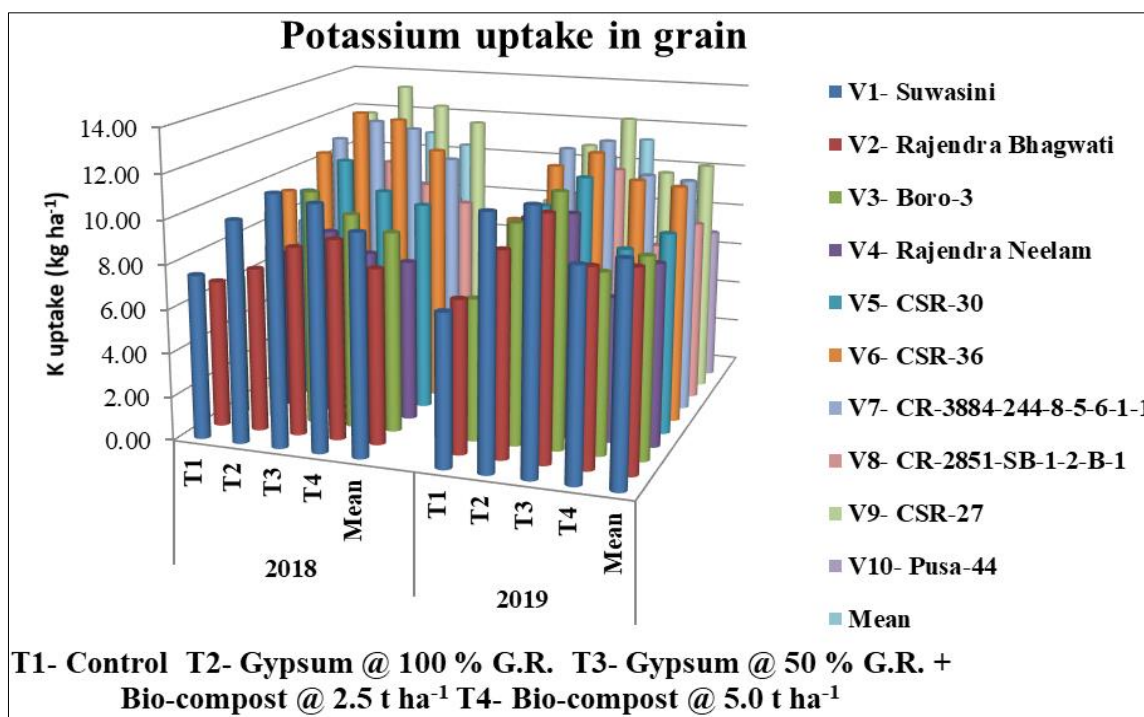


Fig 3: The influence of organic and inorganic amendments and their combination on Potassium uptake (kg ha^{-1}) in grain of different rice genotypes

Potassium uptake in straw

The salt tolerant genotypes CSR-36, CR-3884-244-8-5-6-1-1, CSR-27 and CSR-30 were significantly higher than the all genotypes in both the years. The potassium uptake in straw of the genotypes ranged from 54.13 kg ha^{-1} to 71.92 kg ha^{-1} in the first year while in the second year it ranged from 53.53 kg ha^{-1} to 72.57 kg ha^{-1} (Figure 4). All the soil amendments had significantly higher potassium uptake in straw as compared to the control plot. The combination of gypsum and bio-compost had higher value than the other two amendments. However,

gypsum application had higher potassium uptake in straw than the bio-compost application in both the years. The interaction between genotypes and soil amendments was non-significant in both the years. Potassium uptake in straw ranged from 41.28 kg ha^{-1} to 87.10 kg ha^{-1} in the first year while in the second year it ranged from 41.44 kg ha^{-1} to 90.16 kg ha^{-1} . It might be due to improve the favourable pH range and bio-compost break down due to increase availability of potassium in soil for uptake by genotypes.

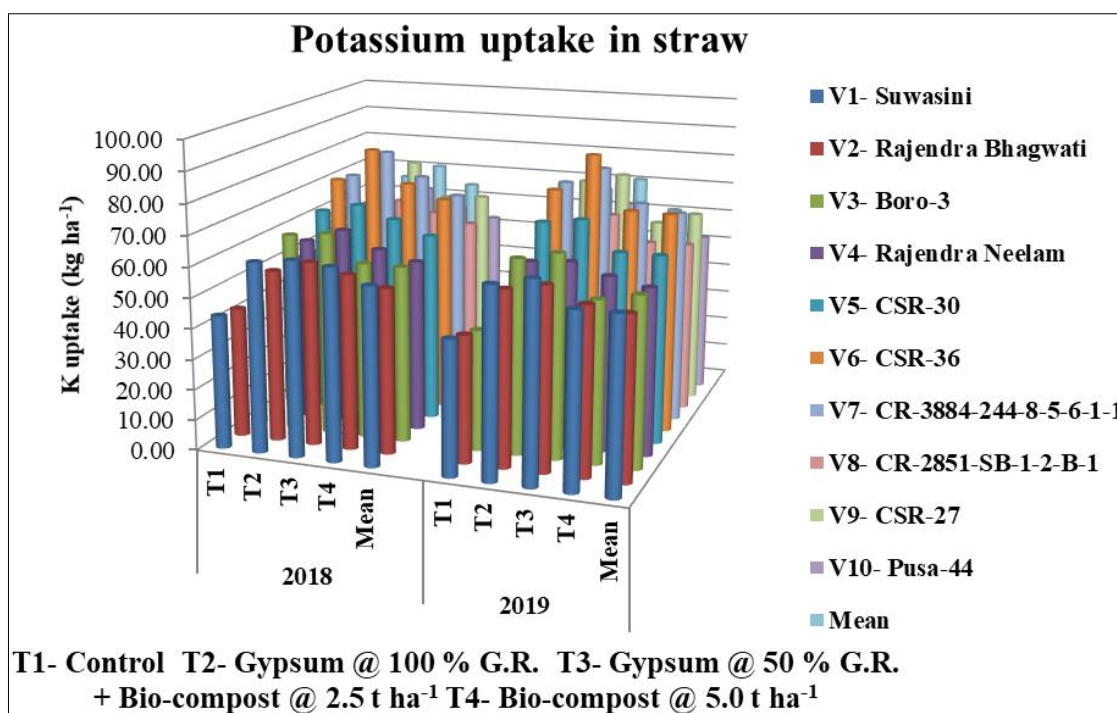


Fig 4: The influence of organic and inorganic amendments and their combination on Potassium uptake (kg ha^{-1}) in straw of different rice genotypes

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. Available potassium in all the soil amendments had significantly higher than the without treated in any amendments. Biocompost @ 5.0 t ha⁻¹ treated plot had higher value than the other two amendments. However, the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha⁻¹ treated plot had higher available potassium than the gypsum @ 100% GR treated plot in both years.

Potassium uptake in grain in most of the genotypes were significantly higher than varietal check Pusa-44, Rajendra Neelam and Rajendra Bhagwati in the first year while in the second year all the genotypes were found significantly higher than varietal check Pusa-44. Potassium uptake in straw in salt tolerant genotypes CSR-36, CR-3884-244-8-5-6-1-1, CSR-27 and CSR-30 were significantly higher than all genotypes in both years.

Acknowledgement

The authors are thankful to the support of the Professor Dr. Ranjan Laik in Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar, to conduct the field experiment in the ICAR - Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), Bihar of the Department and providing the necessary facilities and financial support to carry out the work smoothly.

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