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Influence of organic and inorganic amendments and their combination on micro nutrient (Zn, Cu, Fe, Mn and Boron) uptake in grain and straw of various rice genotypes under *Sodic* soils of Bihar

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Abstract

A field experiments were carried out during two *Kharif* seasons 23th June 2018 to 28th November 2018 and 23th June 2019 to 28th November 2019 at ICAR - Indian Agricultural Research Institute, Sub Regional Station and front of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar. A field experiment laid out in split plot design with four treatment T_1 - Control, T_2 - Gypsum @ 100% G.R., T_3 - Gypsum @ 50% G.R. + Biocompost @ 2.5 t ha^{-1}, T_4 - Biocompost @ 5.0 t ha^{-1} in main plots and ten genotypes G_1 - Suwasini, G_2 - Rajendra Bhagwati, G_3 - Boro-3, G_4 - Rajendra Neelam, G_5 - CSR-30, G_6 - CSR-36, G_7 - CR-3884-244-8-5-6-1-1, G_8 - CR-2851-SB-1-2-B-1, G_9 - CSR-27, G_{10} - Pusa-44 in sub plots and replicated in thrice. Our objective was to study how the effect of amendments on micro nutrient uptake in various rice genotypes. The experimental site has hot and humid summers and too cold winters and soil belong to order *Entisol,* silt loam in texture at surface containing 10.45% sand, 72.06% silt and 17.49% clay the soil was alkaline pH 9.69 in reaction, electrical conductivity 2.12 dS m^{-1} and organic carbon 2.6 g kg^{-1}. Application the recommended dose of N: P_2O_5: K_2O @ 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 P_2O_5 and K_2O were applied as basal and the rest fifty per cent of N was applied in two splits at 30 days interval and application of inorganic and organic amendment separately in treatment T_2 (Gypsum @100% G.R. in 2.5 kg $plots^{-1}$) and T_4 (Biocompost @ 5.0 t ha^{-1} in 5 kg $plots^{-1}$) and both inorganic and organic combined application in treatment T_3 (Gypsum @50% G.R. in 1.25 kg $plots^{-1}$ + Biocompost @ 2.5 t ha^{-1} in 2.5 kg $plots^{-1}$). The same treatment is applied on the same plots. The treatment was applied in 2018-19. The organic soil amendments *viz*., biocompost were provided by Magadh Sugar & Energy Limited Unit - Hasanpur Sugar Mills, Samastipur (Bihar). The results obtained from the present investigation revealed that the Zn and Cu uptake in grain had significantly higher in the genotypes CSR-27 followed by CSR-36 and CR-3884-244-8-5-6-1-1 and combination of gypsum @ 50% G.R. and bio-compost @ 2.5 t ha^{-1} application had significantly higher followed by gypsum @ 100% G.R. application and Fe, Mn and Boron uptake in grain and Zn, Cu, Fe Mn and Boron uptake in straw had significantly higher in the genotypes CSR-36 followed by CSR-27 and CR-3884-244-8-5-6-1-1 and combination of gypsum @ 50% G.R. and bio-compost @ 2.5 t ha^{-1} application had significantly higher than the control treatment, respectively.

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) [20, 26, 32, 8]. 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) [23]. 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) [12]. Moreover, economic loss is about 9% of the global value resulting from salt related land degradation (Ghassemi *et al.* 1995) [10].

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) [7].

Salt affected soils are having major abiotic stress which adversely affect the growth and productivity, especially that of rice, by more than 50% world-wide (Mahajan and Tutejan 2005; Nishimura *et al.* 2011 and Hazman *et al.* 2016) [19, 22, 14], particularly in developing countries (Zhou *et al.* 2007; Shobbar *et al.* 2010) [38, 30]. Salinity/sodicity stresses decrease water uptake ability of plants thereby reducing plant growth by inhibiting cell division and accelerating cell death (Munns 2002) [21]. Several physiological pathways like photosynthesis, respiration and unbalanced nutrient uptake, accumulation of toxic ions, oxidative and osmotic stresses, nitrogen fixation and carbohydrate metabolism have been observed to be affected by high salinity/sodicity (Chen *et al.* 2008; Wang *et al.* 2012 and Singh *et al.* 2018) [4, 34, 31]. Excess Na^+ in plant cells directly damages membrane systems and organelles, which results in plant growth reduction and abnormal development prior to plant death (Davenport *et al.* 2005; Quintero *et al.* 2007) [5, 27]. Photosynthesis, the foremost metabolic process regulating crop production is severely affected by salinity/sodicity by reduction of in stomatal conductance (Yusuf *et al.* 2010) [36]. Thus, reduction in stomatal conductance also lower transpiration rate by stomatal closure and increase plant survival ability by restricting water reserves in the root zone (Zhang and Kirkham 1995) [37]. Consequently, exchange of water vapour and CO_2 through stomata also become limited due to stomatal closure resulting in increased leaf turgidity (Chaves *et al.* 2009; Farooq *et al.* 2009) [3,9]. Besides, sodium is absorbed by roots and translocated to shoots mainly through xylem (Deinlein *et al.* 2014) [6]. Above to this, osmotic stress leads to degradation in chlorophyll pigments (Jnandabhiram and Sailen Prasad 2012) [15]. It has been observed that salinity/sodicity induced movement of salt into root is associated with transpiration flux, which is found obligatory in maintenance of plant water status. It has also been observed that unregulated transpiration causes ion toxicity in plant aerial parts and high ionic concentration disturbs ion homeostasis, cell membrane functions and interferes with internal solute balance. Excessive Na^+ accumulation during salt stress, competitively inhibits K^+ uptake and disrupts K^+/Na^+ ratio of cells and reduced the uptake of mineral nutrients (Ma *et al.* 2014; Kaya *et al.* 2001) [18, 16]. The negative interactions between salinity/sodicity and mineral nutrition of plants decreased the nutrient use efficiency at different growth stages, phenotypic character and grain yield component (Parida and Das 2005; Rao *et al.* 2008; Reddy *et al.* 2014; Beakal *et al.* 2016) [24, 28, 29, 1].

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 and front of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar which lies at 85^0 40' 19.7" E latitude 25^0 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 T_1- Control, T_2- Gypsum @ 100% G.R., T_3- Gypsum @ 50% G.R. + Biocompost @ 2.5 t ha^{-1}, T_4- Biocompost @ 5.0 t ha^{-1} in main plots and ten genotypes G_1 - Suwasini, G_2 - Rajendra Bhagwati, G_3 - Boro-3, G_4 - Rajendra Neelam, G_5 - CSR-30, G_6 - CSR-36, G_7 - CR-3884-244-8-5-6-1-1, G_8 - CR-2851-SB-1-2-B-1, G_9 - CSR-27, G_{10} - 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: P_2O_5: K_2O @ 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 P_2O_5 and K_2O 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 micro nutrient uptake in grain and straw of various rice genotypes.

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) [2]. 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 micro 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) [25] for analysis of the nutrients like Zn, Cu, Fe, Mn and Boron. Nutrients were estimated following the methods given below.

Zn, Cu, Fe and Mn were determined by diacid digest method using Atomic absorption spectrophotometer (Lindsay and Norvell 1978) [17] and Boron was determined by Turbidimetric determination using spectrophotometer and carmine reagent (Hatcher and Wilcox 1950) [13].

Statistical analysis

The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) [11] for split plot design. ANOVA was found significant and accordingly results are presented at 5% level of significance (P=0.05).

Emperical formulae

$$\text{Micro nutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient content (mg kg}^{-1}\text{)} \times \text{dry matter (q ha}^{-1}\text{)}}{10^6} \times 10^5$$

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} and available micro nutrient (Zn, Cu, Fe, Mn and Boron) was recorded 0.31 mg kg^{-1}, 2.44 mg kg^{-1}, 13.78 mg kg^{-1}, 4.06 mg kg^{-1} and 8.56 mg kg^{-1}, respectively (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) [33]. 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) [35].

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
Available Zn (mg kg^{-1})	0.31
Available Cu (mg kg^{-1})	2.44
Available Fe (mg kg^{-1})	13.78
Available Mn (mg kg^{-1})	4.06
Available B (mg kg^{-1})	8.56

Zinc (Zn) uptake in grain and straw

Grain

All the genotypes had significantly higher Zn uptake in grain than varietal check Pusa-44, Rajendra Neelam and CR-2851-SB-1-2-B-1 in the first year while in the second year all genotypes had significantly higher than the varietal check Pusa-44 and Rajendra Neelam shown in Table 2. The Zn uptake in grain of the genotypes varied between 51.74 g ha^{-1} to 86.54 g ha^{-1} during 2018 and 49.46 g ha^{-1} to 80.71 g ha^{-1} during 2019. During both the years the minimum and maximum values were obtained in Rajendra Neelam and CSR-27, respectively. All the soil amendments had significantly higher Zn 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 Zn uptake in grain than the gypsum application. The interaction between genotype and soil amendment was non-significant in both the years. Zn uptake in grain varied between 38.90 g ha^{-1} to 99.79 g ha^{-1} during 2018 and 40.50 g ha^{-1} to 90.48 g ha^{-1}, respectively during 2019.

Pooled mean of all genotypes had significantly higher than the varietal check Pusa-44 and Rajendra Neelam. The mean of among the different genotypes, Zn uptake in grain varied from 50.60 g ha^{-1} in Pusa-44 to 83.62 g ha^{-1} in CSR-27. Similar values were observed among CSR-27, CSR-36, CR-3884-244-8-5-6-1-1 and Suwasini. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Zn uptake in grain (77.57 g ha^{-1}) than the other two amendments. However, bio-compost application had higher Zn uptake in grain than the gypsum application. The interaction between genotype and soil amendment was non-significant. Zn uptake in grain varied between 39.70 g ha^{-1} to 95.13 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-27 genotypes had highest value. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Straw

Zn uptake in straw in most of the genotypes was significantly higher than the Pusa-44, Rajendra Bhagwati and CR-2851-SB-1-2-B-1 in the first year while in the second year it was significantly higher in all genotypes than the Pusa-44, Rajendra Bhagwati, CR-2851-SB-1-2-B-1 and Rajendra Neelam. The Zn uptake in straw of the genotypes varied from 76.10 g ha^{-1} to 128.15 g ha^{-1} during 2018 and 83.55 g ha^{-1} to 122.18 g ha^{-1} during 2019 (Table 3). All the soil amendments had significantly higher Zn uptake in straw as compared to the control plot. The treatment having combination of gypsum @ 50% GR and bio-compost @ 2.5 t ha^{-1} had higher value than the other two amendments. However, bio-compost @ 5.0 t ha^{-1} application had higher Zn uptake in straw than the gypsum @ 100% GR application during 2018 and 2019. Zn uptake in straw varied between 67.59 g ha^{-1} to 160.90 g ha^{-1} during 2018 and 68.70 g ha^{-1} to 155.14 g ha^{-1} during 2019. Amendment and genotype interaction was non-significant in both the years.

Pooled mean of all genotypes had significantly higher than the varietal check Pusa-44 and Rajendra Bhagwati. The mean of among the different genotypes, Zn uptake in straw varied from 79.82 g ha^{-1} in Pusa-44 to 125.16 g ha^{-1} in CSR-36. Similar values were observed among CSR-36, CSR-27, CR-3884-244-8-5-6-1-1 and CSR-30. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Zn uptake in straw (119.66 g ha^{-1}) than the other two amendments. However, bio-compost application had higher Zn uptake in straw than the gypsum application. The interaction between genotype and soil amendment was significant. Zn uptake in straw varied between 68.14 g ha^{-1} to 158.02 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. The response of gypsum, bio-compost and their combination varied from 79.30 to 114.47 g ha^{-1}, 78.79 to 138.32 g ha^{-1} and 93.06 to 158.02 g ha^{-1}. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Table 2: The influence of organic and inorganic amendments and their combination on Zn uptake (g ha^{-1}) in grain of different rice genotypes.

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	60.85	77.65	82.72	78.81	75.01	55.32	70.10	80.34	73.47	69.81	58.09	73.87		81.53	76.14		72.41
G_2	53.96	62.01	66.47	70.00	63.11	53.24	59.93	68.29	66.56	62.01	53.60	60.97		67.38	68.28		62.56
G_3	45.94	68.19	75.19	71.62	65.24	44.44	72.61	81.59	68.85	66.87	45.19	70.40		78.39	70.24		66.06
G_4	43.86	59.20	60.62	57.83	55.38	45.22	62.00	65.68	52.72	56.41	44.54	60.60		63.15	55.28		55.89
G_5	45.98	74.00	85.67	74.61	70.07	50.64	66.42	76.32	70.78	66.04	48.31	70.21		80.99	72.70		68.05
G_6	61.78	80.75	97.42	92.08	83.01	58.66	86.53	90.05	85.83	80.27	60.22	83.64		93.73	88.96		81.64
G_7	55.12	80.34	86.61	80.96	75.76	52.64	79.92	87.05	82.11	75.43	53.88	80.13		86.83	81.53		75.59
G_8	44.25	64.03	71.65	63.08	60.75	46.44	61.91	74.68	57.79	60.21	45.35	62.97		73.16	60.44		60.48
G_9	67.55	89.21	99.79	89.61	86.54	66.40	83.33	90.48	82.61	80.71	66.98	86.27		95.13	86.11		83.62
G_{10}	38.90	54.46	57.61	55.97	51.74	40.50	50.41	53.25	53.66	49.46	39.70	52.43		55.43	54.82		50.60
Mean	51.82	70.98	78.38	73.46		51.35	69.32	76.77	69.44		51.59	70.15		77.57	71.45		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	9.499	9.723	NS	NS		8.791	7.057	NS	NS		NS	5.651	NS	5.944	NS	NS	NS
SE(m) ±	2.693	3.442	8.515	7.063		2.492	2.498	7.880	5.355		1.604	1.834	2.594	2.126	3.007	4.253	6.014

Table 3: The influence of organic and inorganic amendments and their combination on Zn uptake (g ha^{-1}) in straw of different rice genotypes.

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	74.40	100.22	108.33	101.83	96.20	80.50	96.75	104.64	94.21	94.03	77.45	98.49		106.48	98.02		95.11
G_2	71.81	83.92	98.84	81.14	83.93	74.72	85.23	98.93	91.49	87.59	73.26	84.58		98.89	86.32		85.76
G_3	70.85	95.22	109.52	92.89	92.12	75.65	102.22	117.31	92.51	96.92	73.25	98.72		113.42	92.70		94.52
G_4	77.28	91.83	105.44	87.07	90.41	75.45	90.04	109.99	99.54	93.76	76.36	90.93		107.71	93.30		92.08
G_5	80.84	100.75	143.19	113.99	109.69	81.03	103.54	125.77	101.56	102.98	80.94	102.15		134.48	107.78		106.34
G_6	92.01	117.93	160.90	141.75	128.15	87.66	111.02	155.14	134.90	122.18	89.83	114.47		158.02	138.32		125.16
G_7	80.98	109.71	136.64	109.67	109.25	85.11	111.51	142.12	118.69	114.36	83.05	110.61		139.38	114.18		111.81
G_8	72.91	83.98	97.58	87.41	85.47	80.52	90.58	105.45	85.22	90.44	76.72	87.28		101.51	86.31		87.96
G_9	91.41	109.19	146.25	118.05	116.23	86.96	108.57	141.09	115.26	112.97	89.18	108.88		143.67	116.66		114.60
G_{10}	67.59	76.59	86.41	73.81	76.10	68.70	82.02	99.70	83.77	83.55	68.14	79.30		93.06	78.79		79.82
Mean	78.01	96.93	119.31	100.76		79.63	98.15	120.01	101.72		78.82	97.54		119.66	101.24		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	11.074	9.399	NS	NS		7.787	10.372	NS	NS		NS	5.911	NS	6.926	NS	13.851	NS
SE(m) ±	3.139	3.327	9.927	7.050		2.207	3.672	6.980	7.308		1.088	1.919	2.714	2.477	3.503	4.955	7.007

Cu uptake in grain and straw

Grain

Cu uptake in grain of all the genotypes had significantly higher than the varietal check, Pusa-44 and Rajendra Bhagwati in the first year while in the second year it was significantly higher in all genotypes than the varietal check, Pusa-44 revealed in Table 4. The Cu uptake in grain of the genotypes ranged from 4.08 g ha^{-1} to 9.05 g ha^{-1} in the first year while in the second year it ranged from 3.68 g ha^{-1} to 7.37 g ha^{-1}. Cu uptake in grain of the different amendments had significantly higher than the control plot in both the years. The combination of gypsum and bio-compost had higher value than the other two amendments. However, bio-compost application had higher Cu uptake in grain than the gypsum application. Cu uptake in grain ranged from 2.78 g ha^{-1} to 10.99 g ha^{-1} in the first year while in the second year it ranged from 3.00 g ha^{-1} to 8.57 g ha^{-1}. Amendment and genotype interaction was non-significant in both the years.

Pooled mean of all the genotypes had significantly higher than the varietal check, Pusa-44. The mean of among the different genotypes, Cu uptake in grain varied from 3.88 g ha^{-1} in Pusa-44 to 8.08 g ha^{-1} in CSR-27. Similar values were observed among CSR-27, CSR-36, CR-3884-244-8-5-6-1-1 and CSR-30. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Cu uptake in grain (7.06 g ha^{-1}) than the other two amendments. However, bio-compost application had higher Cu uptake in grain than the gypsum application. The interaction between genotype and soil amendment was significant. Cu uptake in grain varied between 2.99 g ha^{-1} to 9.75 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-27 genotypes had highest value. The response of gypsum, bio-compost and their combination varied from 3.88 to 8.72 g ha^{-1}, 4.39 to 8.80 g ha^{-1} and 4.26 to 9.75 g ha^{-1}. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Straw

Cu uptake in straw of the all genotypes had significantly higher than the Pusa-44 and CR-2851-SB-1-2-B-1 during 2018 and Pusa-44 and Rajendra Bhagwati during 2019 (Table 5). The Cu uptake in straw of the genotypes varied between 23.35 g ha^{-1} to 40.40 g ha^{-1} in the first year while in the second year it varied between 22.84 g ha^{-1} to 35.96 g ha^{-1}. During both the years the maximum value were obtained in CSR-36. All the soil amendments had significantly higher Cu uptake in straw as compared to the without application in any amendment. The treatment having combination of gypsum @ 50% GR and bio-compost @ 2.5 t ha^{-1} had higher value than the other two amendments. However, bio-compost @ 5.0 t ha^{-1} applications had higher Cu uptake in straw than the gypsum @ 100% GR application during 2018 and gypsum @ 100% GR application had higher Cu uptake in straw than the bio-compost @ 5.0 t ha^{-1} application during 2019. Soil amendments and genotypes interaction was non-significant in both the years. Cu uptake in straw varied between 18.66 g ha^{-1} to 47.98 g ha^{-1} during 2018 and 18.65 g ha^{-1} to 42.17 g ha^{-1}, respectively during 2019.

Table 4: The influence of organic and inorganic amendments and their combination on Cu uptake (g ha^{-1}) in grain of different rice genotypes.

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	4.10	6.22	6.84	6.98	6.04	3.56	5.38	6.06	6.45	5.36	3.83	5.80		6.45	6.71		5.70
G_2	4.25	5.13	4.91	5.73	5.01	3.78	4.19	5.79	5.53	4.82	4.01	4.66		5.35	5.63		4.91
G_3	2.78	6.44	7.14	6.94	5.83	3.22	4.90	6.49	5.98	5.15	3.00	5.67		6.81	6.46		5.49
G_4	3.27	6.34	6.62	6.27	5.63	3.41	6.34	6.04	5.41	5.30	3.34	6.34		6.33	5.84		5.46
G_5	3.85	7.81	9.13	8.21	7.25	3.26	6.53	6.88	5.96	5.66	3.55	7.17		8.01	7.08		6.45
G_6	5.14	8.87	9.97	9.49	8.37	4.70	8.57	8.36	7.86	7.37	4.92	8.72		9.16	8.68		7.87
G_7	3.23	7.48	9.13	8.67	7.13	4.05	6.18	7.84	7.52	6.40	3.64	6.83		8.48	8.09		6.76
G_8	3.15	5.90	6.34	5.63	5.26	3.54	4.31	5.65	5.27	4.69	3.34	5.11		5.99	5.45		4.97
G_9	5.50	9.48	10.99	10.23	9.05	4.68	7.90	8.51	7.37	7.12	5.09	8.69		9.75	8.80		8.08
G_{10}	2.98	4.15	4.53	4.66	4.08	3.00	3.61	3.99	4.12	3.68	2.99	3.88		4.26	4.39		3.88
Mean	3.83	6.78	7.56	7.28		3.72	5.79	6.56	6.15		3.77	6.29		7.06	6.71		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	1.172	0.992	NS	NS		1.085	0.909	NS	NS		NS	0.697	NS	0.666	NS	1.331	NS
SE(m) ±	0.332	0351	1.051	0.744		0.307	0.322	0.972	0.684		0.201	0.226	0.320	0.238	0.337	0.476	0.673

Table 5: The influence of organic and inorganic amendments and their combination on Cu uptake (g ha^{-1}) in straw of different rice genotypes.

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	21.96	25.39	27.91	28.55	25.95	23.34	28.54	28.92	24.33	26.28	22.65	26.96		28.42	26.44		26.12
G_2	19.50	27.10	29.47	29.59	26.42	20.10	26.06	26.58	24.16	24.23	19.80	26.58		28.02	26.87		25.32
G_3	21.67	28.22	30.22	31.20	27.83	21.72	29.95	30.10	26.17	26.99	21.69	29.09		30.16	28.69		27.41
G_4	23.02	27.34	30.82	29.25	27.61	21.76	27.25	29.31	24.94	25.82	22.39	27.29		30.06	27.10		26.71
G_5	25.11	34.99	37.18	34.17	32.86	24.62	30.89	33.75	27.76	29.26	24.86	32.94		35.47	30.97		31.06
G_6	31.57	40.45	47.98	41.58	40.40	29.04	36.20	42.17	36.41	35.96	30.31	38.33		45.08	38.99		38.18
G_7	25.40	35.55	42.41	34.11	34.37	26.93	34.11	38.37	33.90	33.33	26.16	34.83		40.39	34.00		33.85
G_8	21.42	24.59	26.34	29.76	25.53	21.02	26.50	28.75	26.17	25.61	21.22	25.54		27.54	27.96		25.57
G_9	32.58	38.81	41.12	35.19	36.93	26.93	33.03	37.77	29.98	31.93	29.75	35.92		39.44	32.58		34.42
G_{10}	18.66	21.00	26.71	27.04	23.35	18.65	23.03	26.04	23.64	22.84	18.65	22.01		26.37	25.34		23.09
Mean	24.09	30.34	34.02	32.04		23.41	29.56	32.18	27.75		23.75	29.95		33.10	29.89		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	1.690	2.595	NS	NS		2.486	2.310	NS	NS		NS	1.313	1.857	1.719	2.431	3.438	NS
SE(m) ±	0.479	0.918	1.515	1.807		0.705	0.818	2.229	1.704		0.612	0.426	0.603	0.615	0.869	1.230	1.739

Pooled mean of all the genotypes had significantly higher than the varietal check, Pusa-44. The mean of among the different genotypes, Cu uptake in straw varied from 23.09 g ha^{-1} in Pusa-44 to 38.18 g ha^{-1} in CSR-36. Similar values were observed among CSR-36, CSR-27, CR-3884-244-8-5-6-1-1 and CSR-30. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Cu uptake in straw (33.10 g ha^{-1}) than the other two amendments. However, gypsum application had higher Cu uptake in straw than the bio-compost application. The interaction between genotype and soil amendment was significant. Cu uptake in straw varied between 18.65 g ha^{-1} to 45.08 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. The response of gypsum, bio-compost and their combination varied from 22.01 to 38.33 g ha^{-1}, 25.34 to 38.99 g ha^{-1} and 26.37 to 45.08 g ha^{-1}. Year effect was non-significant. Interaction between soil amendments with year was significant and genotypes with year were significant. Interaction between genotypes, soil amendments and year was non-significant.

Iron (Fe) uptake in grain and straw

Grain

All the genotypes had significantly higher Fe uptake in grain than Pusa-44 and Rajendra Neelam in the first year while in the second year it was significantly higher in all genotypes than the Pusa-44 and CR-2851-SB-1-2-B-1 shown in Table 6. The Fe uptake in grain of the genotypes varied between 178.76 g ha^{-1} to 286.72 g ha^{-1} during 2018 and 176.98 g ha^{-1} to 281.85 g ha^{-1} during 2019. The minimum and maximum values were obtained in Pusa-44 and CSR-36. All the soil amendments had significantly higher Fe uptake in grain as compared to the without application in any amendments. The combination of gypsum and bio-compost had higher value than the other two amendments. However, bio-compost application had higher Fe uptake in grain than the gypsum application during 2018 and gypsum application had higher Fe uptake in grain than the bio-compost application during 2019. Soil amendments and genotypes interaction was non-significant in both the years. Fe uptake in grain varied between 140.81 g ha^{-1} to 325.91 g ha^{-1} during 2018 and 144.59 g ha^{-1} to 309.28 g ha^{-1}, respectively during 2019.

Pooled mean of all the genotypes had significantly higher Fe uptake in grain as compared to the Pusa-44. The mean of among the different genotypes, Fe uptake in grain varied from 177.87 g ha^{-1} in Pusa-44 to 284.29 g ha^{-1} in CSR-36. Similar values were observed among CSR-36, CSR-27 and CR-3884-244-8-5-6-1-1. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Fe uptake in grain (275.58 g ha^{-1}) than the other two amendments. However, bio-compost application had higher Fe uptake in grain than the gypsum application. Soil amendments and genotypes interaction was non-significant. Fe uptake in grain varied between 145.12 g ha^{-1} to 316.27 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Table 6: The influence of organic and inorganic amendments and their combination on Fe uptake (g ha^{-1}) in grain of different rice genotypes.

<table>
<tr><th rowspan="3">Rice genotypes</th><th colspan="5">2018</th><th colspan="5">2019</th><th colspan="7">Pooled mean of 2018 and 2019</th></tr>
<tr><th colspan="4">Organic and inorganic amendments</th><th rowspan="2">Mean</th><th colspan="4">Organic and inorganic amendments</th><th rowspan="2">Mean</th><th colspan="6">Organic and inorganic amendments</th><th rowspan="2">Mean</th></tr>
<tr><th>T_1</th><th>T_2</th><th>T_3</th><th>T_4</th><th>T_1</th><th>T_2</th><th>T_3</th><th>T_4</th><th>T_1</th><th colspan="2">T_2</th><th>T_3</th><th colspan="2">T4</th></tr>
<tr><td>G_1</td><td>190.86</td><td>255.80</td><td>283.54</td><td>271.49</td><td>250.42</td><td>212.33</td><td>258.20</td><td>285.25</td><td>258.85</td><td>253.66</td><td>201.59</td><td colspan="2">257.00</td><td>284.40</td><td colspan="2">265.17</td><td>252.04</td></tr>
<tr><td>G_2</td><td>180.80</td><td>237.02</td><td>256.11</td><td>254.46</td><td>232.10</td><td>184.54</td><td>202.77</td><td>271.68</td><td>240.61</td><td>224.90</td><td>182.67</td><td colspan="2">219.90</td><td>263.89</td><td colspan="2">247.53</td><td>228.50</td></tr>
<tr><td>G_3</td><td>150.91</td><td>239.48</td><td>274.60</td><td>264.68</td><td>232.42</td><td>189.73</td><td>266.44</td><td>295.39</td><td>222.44</td><td>243.50</td><td>170.32</td><td colspan="2">252.96</td><td>285.00</td><td colspan="2">243.56</td><td>237.96</td></tr>
<tr><td>G_4</td><td>145.26</td><td>199.94</td><td>232.67</td><td>220.17</td><td>199.51</td><td>176.31</td><td>252.28</td><td>251.92</td><td>211.07</td><td>222.90</td><td>160.79</td><td colspan="2">226.11</td><td>242.29</td><td colspan="2">215.62</td><td>211.20</td></tr>
<tr><td>G_5</td><td>140.81</td><td>256.18</td><td>292.18</td><td>259.53</td><td>237.18</td><td>149.44</td><td>252.46</td><td>273.61</td><td>231.71</td><td>226.81</td><td>145.12</td><td colspan="2">254.32</td><td>282.90</td><td colspan="2">245.62</td><td>231.99</td></tr>
<tr><td>G_6</td><td>232.58</td><td>281.20</td><td>325.91</td><td>307.20</td><td>286.72</td><td>238.60</td><td>293.49</td><td>306.64</td><td>288.66</td><td>281.85</td><td>235.59</td><td colspan="2">287.35</td><td>316.27</td><td colspan="2">297.93</td><td>284.29</td></tr>
<tr><td>G_7</td><td>215.65</td><td>298.47</td><td>314.63</td><td>286.89</td><td>278.91</td><td>183.46</td><td>302.62</td><td>309.28</td><td>293.97</td><td>272.33</td><td>199.55</td><td colspan="2">300.55</td><td>311.96</td><td colspan="2">290.43</td><td>275.62</td></tr>
<tr><td>G_8</td><td>163.25</td><td>236.77</td><td>266.18</td><td>229.70</td><td>223.98</td><td>144.59</td><td>201.59</td><td>263.63</td><td>217.85</td><td>206.92</td><td>153.92</td><td colspan="2">219.18</td><td>264.91</td><td colspan="2">223.77</td><td>215.45</td></tr>
<tr><td>G_9</td><td>245.34</td><td>286.87</td><td>319.22</td><td>292.76</td><td>286.05</td><td>222.17</td><td>283.60</td><td>307.63</td><td>284.66</td><td>274.52</td><td>233.75</td><td colspan="2">285.24</td><td>313.43</td><td colspan="2">288.71</td><td>280.28</td></tr>
<tr><td>G_{10}</td><td>147.43</td><td>192.01</td><td>193.82</td><td>181.76</td><td>178.76</td><td>151.58</td><td>173.94</td><td>187.71</td><td>194.67</td><td>176.98</td><td>149.50</td><td colspan="2">182.97</td><td>190.77</td><td colspan="2">188.22</td><td>177.87</td></tr>
<tr><td>Mean</td><td>181.29</td><td>248.37</td><td>275.89</td><td>256.86</td><td></td><td>185.28</td><td>248.74</td><td>275.27</td><td>244.45</td><td></td><td>183.28</td><td colspan="2">248.56</td><td>275.58</td><td colspan="2">250.66</td><td></td></tr>
<tr><td></td><td>T</td><td>G</td><td>T×G</td><td>G×T</td><td></td><td>T</td><td>G</td><td>T×G</td><td>G×T</td><td></td><td>Y</td><td>T</td><td>Y×T</td><td>G</td><td>Y×G</td><td>T×G</td><td>Y×T×G</td></tr>
<tr><td>CD (P = 0.05)</td><td>28.619</td><td>29.398</td><td>NS</td><td>NS</td><td></td><td>33.158</td><td>33.714</td><td>NS</td><td>NS</td><td></td><td>NS</td><td>19.125</td><td>NS</td><td>22.132</td><td>NS</td><td>NS</td><td>NS</td></tr>
<tr><td>SE(m) ±</td><td>8.113</td><td>10.406</td><td>25.654</td><td>21.346</td><td></td><td>9.399</td><td>11.934</td><td>29.723</td><td>24.516</td><td></td><td>8.779</td><td>6.208</td><td>8.779</td><td>7.917</td><td>11.196</td><td>15.833</td><td>22.392</td></tr>
</table>

Table 7: The influence of organic and inorganic amendments and their combination on Fe uptake (g ha^{-1}) in straw of different rice genotypes.

<table>
<tr><th rowspan="3">Rice genotypes</th><th colspan="5">2018</th><th colspan="5">2019</th><th colspan="7">Pooled mean of 2018 and 2019</th></tr>
<tr><th colspan="4">Organic and inorganic amendments</th><th rowspan="2">Mean</th><th colspan="4">Organic and inorganic amendments</th><th rowspan="2">Mean</th><th colspan="6">Organic and inorganic amendments</th><th rowspan="2">Mean</th></tr>
<tr><th>T_1</th><th>T_2</th><th>T_3</th><th>T_4</th><th>T_1</th><th>T_2</th><th>T_3</th><th>T_4</th><th>T_1</th><th colspan="2">T_2</th><th>T_3</th><th colspan="2">T4</th></tr>
<tr><td>G_1</td><td>368.40</td><td>416.25</td><td>440.96</td><td>454.58</td><td>420.05</td><td>369.72</td><td>432.88</td><td>458.66</td><td>405.63</td><td>416.72</td><td>369.06</td><td colspan="2">424.56</td><td>449.81</td><td colspan="2">430.11</td><td>418.39</td></tr>
<tr><td>G_2</td><td>344.12</td><td>365.18</td><td>384.72</td><td>371.50</td><td>366.38</td><td>346.94</td><td>372.72</td><td>386.74</td><td>373.93</td><td>370.08</td><td>345.53</td><td colspan="2">368.95</td><td>385.73</td><td colspan="2">372.72</td><td>368.23</td></tr>
<tr><td>G_3</td><td>364.84</td><td>440.09</td><td>491.61</td><td>432.40</td><td>432.24</td><td>362.97</td><td>455.12</td><td>510.98</td><td>381.64</td><td>427.68</td><td>363.90</td><td colspan="2">447.61</td><td>501.29</td><td colspan="2">407.02</td><td>429.96</td></tr>
<tr><td>G_4</td><td>341.17</td><td>408.77</td><td>458.81</td><td>420.85</td><td>407.40</td><td>362.73</td><td>422.93</td><td>436.32</td><td>398.31</td><td>405.07</td><td>351.95</td><td colspan="2">415.85</td><td>447.57</td><td colspan="2">409.58</td><td>406.24</td></tr>
<tr><td>G_5</td><td>380.09</td><td>504.55</td><td>519.43</td><td>490.19</td><td>473.57</td><td>388.83</td><td>517.18</td><td>510.36</td><td>449.61</td><td>466.50</td><td>384.46</td><td colspan="2">510.87</td><td>514.90</td><td colspan="2">469.90</td><td>470.03</td></tr>
<tr><td>G_6</td><td>434.51</td><td>559.18</td><td>652.37</td><td>561.60</td><td>551.92</td><td>435.39</td><td>557.10</td><td>641.23</td><td>520.77</td><td>538.62</td><td>434.95</td><td colspan="2">558.14</td><td>646.80</td><td colspan="2">541.18</td><td>545.27</td></tr>
<tr><td>G_7</td><td>409.14</td><td>555.63</td><td>610.24</td><td>536.44</td><td>527.86</td><td>409.89</td><td>581.07</td><td>580.29</td><td>511.37</td><td>520.66</td><td>409.51</td><td colspan="2">568.35</td><td>595.27</td><td colspan="2">523.90</td><td>524.26</td></tr>
<tr><td>G_8</td><td>368.88</td><td>427.74</td><td>444.07</td><td>420.87</td><td>415.39</td><td>363.74</td><td>409.46</td><td>442.15</td><td>384.01</td><td>399.84</td><td>366.31</td><td colspan="2">418.60</td><td>443.11</td><td colspan="2">402.44</td><td>407.62</td></tr>
<tr><td>G_9</td><td>435.83</td><td>516.32</td><td>561.47</td><td>471.77</td><td>496.35</td><td>427.57</td><td>527.18</td><td>538.96</td><td>442.30</td><td>484.00</td><td>431.70</td><td colspan="2">521.75</td><td>550.22</td><td colspan="2">457.04</td><td>490.18</td></tr>
<tr><td>G_{10}</td><td>346.22</td><td>371.32</td><td>430.10</td><td>392.40</td><td>385.01</td><td>350.91</td><td>376.63</td><td>431.72</td><td>385.63</td><td>386.22</td><td>348.57</td><td colspan="2">373.98</td><td>430.91</td><td colspan="2">389.01</td><td>385.62</td></tr>
<tr><td>Mean</td><td>379.32</td><td>456.50</td><td>499.38</td><td>455.26</td><td></td><td>381.87</td><td>465.23</td><td>493.74</td><td>425.32</td><td></td><td>380.59</td><td colspan="2">460.87</td><td>496.56</td><td colspan="2">440.29</td><td></td></tr>
<tr><td></td><td>T</td><td>G</td><td>T×G</td><td>G×T</td><td></td><td>T</td><td>G</td><td>T×G</td><td>G×T</td><td></td><td>Y</td><td>T</td><td>Y×T</td><td>G</td><td>Y×G</td><td>T×G</td><td>Y×T×G</td></tr>
<tr><td>CD (P = 0.05)</td><td>24.272</td><td>27.983</td><td>57.611</td><td>58.202</td><td></td><td>24.783</td><td>30.971</td><td>NS</td><td>NS</td><td></td><td>NS</td><td>15.148</td><td>NS</td><td>20.652</td><td>NS</td><td>41.305</td><td>NS</td></tr>
<tr><td>SE(m) ±</td><td>6.880</td><td>9.905</td><td>21.758</td><td>20.013</td><td></td><td>7.025</td><td>10.963</td><td>22.215</td><td>21.955</td><td></td><td>2.467</td><td>4.917</td><td>6.954</td><td>7.387</td><td>10.447</td><td>14.775</td><td>20.895</td></tr>
</table>

Straw

All the genotypes were significantly higher than the Rajendra Bhagwati and varietal check, Pusa-44 in the first year while in the second year it was significantly higher in all genotypes than the Rajendra Bhagwati, varietal check, Pusa-44 and CR-2851-SB-1-2-B-1 (Table 7). The Fe uptake in straw of the genotypes ranged from 366.38 g ha^{-1} to 551.92 g ha^{-1} during 2018 and 370.08 g ha^{-1} to 538.62 g ha^{-1} during 2019. All the soil amendments had significantly higher Fe uptake in straw as compared to the control plot. The treatment having combination of gypsum @ 50% GR and bio-compost @ 2.5 t ha^{-1} had higher value than the other two amendments. However, gypsum @ 100% GR application had higher Fe uptake in straw than the bio-compost @ 5.0 t ha^{-1} application in both the years. The interaction between genotype and soil amendment was significant in the first year, while it was non-significant in the second year. Fe uptake in straw ranged from 341.17 g ha^{-1} to 652.37g ha^{-1} in the first year while in the second year it ranged from 346.94 g ha^{-1} to 641.23 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. The variation of Fe uptake in straw in control plot, gypsum, gypsum in combination with bio-compost and bio-compost treated soils among the different genotypes were between 341.17 to 435.83 g ha^{-1}, 365.18 to 559.18 g ha^{-1}, 384.72 to 652.37 g ha^{-1} and 371.50 to 561.60 g ha^{-1}, respectively during 2018.

Pooled mean of all the genotypes had significantly higher Fe uptake in straw as compared to the Rajendra Bhagwati and Pusa-44. The mean of among the different genotypes, Fe uptake in straw varied from 368.23 g ha^{-1} in Rajendra Bhagwati to 545.27 g ha^{-1} in CSR-36. Similar values were observed among CSR-36, CSR-27, CSR-30 and CR-3884-244-8-5-6-1-1. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Fe uptake in straw (496.56 g ha^{-1}) than the other two amendments. However, gypsum application had higher Fe uptake in straw than the bio-compost application. Soil amendments and genotypes interaction was significant. Fe uptake in straw varied between 345.53 g ha^{-1} to 646.80 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. The response of gypsum, bio-compost and their combination varied from 368.95 to 568.35 g ha^{-1}, 372.72 to 541.18 g ha^{-1} and 385.73 to 646.80 g ha^{-1}. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

It might be due to improve the favourable pH range and bio-compost break down due to increase availability of Fe in soil for uptake by genotypes.

Manganese (Mn) uptake in grain and straw

Grain

All the genotypes had significantly higher Mn uptake in grain than varietal check Pusa-44 in the first year while in the second year all genotypes had significantly higher than the varietal check Pusa-44, Rajendra Neelam and CR-2851-SB-1-2-B-1 shown in Table 8. The Mn uptake in grain of the all genotypes ranged from 25.63 g ha^{-1} to 42.64 g ha^{-1} in the first year while in the second year it ranged from 26.67 g ha^{-1} to 40.03 g ha^{-1}. Mn uptake in grain of the different amendments had significantly higher than the control plot in both the years. 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 Mn uptake in grain than the gypsum application in the first year and gypsum application had higher Mn uptake in grain than the bio-compost application in the second year. The interaction between genotypes and soil amendments was non-significant in both the years. Mn uptake in grain ranged from 16.14 g ha^{-1} to 50.35 g ha^{-1} in the first year while in the second year it ranged from 21.16 g ha^{-1} to 48.26 g ha^{-1}.

Pooled mean of all the genotypes had significantly higher Mn uptake in grain as compared to the Pusa-44. The mean of among the different genotypes, Mn uptake in grain varied from 26.14 g ha^{-1} in Pusa-44 to 41.01 g ha^{-1} in CSR-36. Similar values were observed among CSR-36, CSR-27 and CR-3884-244-8-5-6-1-1. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Mn uptake in grain (40.27 g ha^{-1}) than the other two amendments. However, bio-compost application had higher Mn uptake in grain than the gypsum application. Soil amendments and genotypes interaction was non-significant. Mn uptake in grain varied between 18.65 g ha^{-1} to 49.01 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-27 genotypes had highest value. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Straw

The Mn uptake in straw of the genotypes ranged from 247.30 g ha^{-1} to 345.82 g ha^{-1} in the first year while in the second year it ranged from 258.19 g ha^{-1} to 362.88 g ha^{-1}. All the genotypes were significantly higher than the Rajendra Bhagwati, Pusa-44 and CR-2851-SB-1-2-B-1 during 2018 and Rajendra Neelam, Pusa-44, Rajendra Bhagwati, CR-2851-SB-1-2-B-1 and Suwasini during 2019 (Table 9). All the soil amendments had significantly higher Mn uptake in straw as compared to the control plot. The treatment having combination of gypsum @ 50% GR and bio-compost @ 2.5 t ha^{-1} had higher value than the other two amendments. However, gypsum @ 100% GR application had higher Mn uptake in straw than the bio-compost @ 5.0 t ha^{-1} application in both the years. The interaction between genotype and soil amendment was significant in the first year, while it was non-significant in the second year. Mn uptake in straw ranged from 200.15 g ha^{-1} to 408.71 g ha^{-1} in the first year while in the second year it ranged from 213.22 g ha^{-1} to 443.89 g ha^{-1}. All the soil amendments and genotypes interaction was significantly higher than the control plot in genotypes: CSR-30, Rajendra Neelam, Boro-3, Pusa-44, Rajendra Bhagwati, CR-2851-SB-1-2-B-1 and Suwasini in the first year. The response of Mn uptake in straw in gypsum, gypsum in combination with bio-compost and bio-compost treated soils among the different genotypes ranged from 247.38 to 348.07 g ha^{-1}, 256.96 to 408.71 g ha^{-1} and 249.93 to 352.35 g ha^{-1}, respectively during 2018.

Table 8: The influence of organic and inorganic amendments and their combination on Mn uptake (g ha^{-1}) in grain of different rice genotypes.

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	30.19	38.68	41.58	40.81	37.82	25.49	37.83	36.75	36.05	34.03	27.84	38.26		39.17	38.43		35.93
G_2	28.21	31.08	35.73	41.69	34.18	26.84	33.98	33.20	36.19	32.55	27.53	32.53		34.46	38.94		33.37
G_3	23.04	37.31	38.17	42.98	35.38	24.50	32.59	40.90	33.76	32.94	23.77	34.95		39.53	38.37		34.16
G_4	21.49	36.27	37.19	35.79	32.69	22.35	36.17	36.39	27.02	30.48	21.92	36.22		36.79	31.40		31.58
G_5	24.87	38.43	48.07	44.27	38.91	26.13	33.16	41.32	33.41	33.51	25.50	35.80		44.69	38.84		36.21
G_6	33.03	40.31	49.01	45.59	41.99	32.40	48.26	43.14	36.32	40.03	32.71	44.29		46.08	40.95		41.01
G_7	23.87	46.86	49.66	44.54	41.23	27.34	43.01	44.78	43.01	39.54	25.61	44.93		47.22	43.78		40.39
G_8	20.96	35.71	38.34	35.26	32.57	23.09	33.48	32.62	31.75	30.24	22.02	34.59		35.48	33.50		31.40
G_9	33.38	40.21	50.35	46.61	42.64	31.32	38.21	47.66	39.37	39.14	32.35	39.21		49.01	42.99		40.89
G_{10}	16.14	28.35	29.64	28.37	25.63	21.16	26.47	30.95	28.08	26.67	18.65	27.41		30.29	28.22		26.14
Mean	25.52	37.32	41.77	40.59		26.06	36.32	38.77	34.50		25.79	36.82		40.27	37.54		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	4.844	3.874	NS	NS		6.086	4.155	NS	NS		NS	3.396	NS	2.811	NS	NS	NS
SE(m) ±	1.373	1.371	4.342	2.942		1.725	1.471	5.456	3.281		0.702	1.102	1.559	1.005	1.422	2.011	2.844

Table 9: The influence of organic and inorganic amendments and their combination on Mn uptake (g ha^{-1}) in straw of different rice genotypes.

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	238.75	292.44	287.71	295.60	278.63	249.66	280.80	300.99	305.35	284.20	244.20	286.62		294.35	300.48		281.41
G_2	234.93	247.38	256.96	249.93	247.30	243.33	267.24	262.73	271.75	261.26	239.13	257.31		259.84	260.84		254.28
G_3	231.63	288.03	308.79	269.66	274.53	257.25	317.76	332.01	278.69	296.43	244.44	302.89		320.40	274.18		285.48
G_4	228.50	278.34	295.55	278.35	270.19	226.15	262.40	280.17	264.04	258.19	227.33	270.37		287.86	271.19		264.19
G_5	200.15	311.74	325.57	302.34	284.95	252.23	317.06	335.80	307.34	303.11	226.19	314.40		330.68	304.84		294.03
G_6	275.72	348.07	407.13	352.35	345.82	273.83	386.12	443.89	347.69	362.88	274.77	367.10		425.51	350.02		354.35
G_7	253.91	338.66	408.71	334.60	333.97	259.34	334.40	374.31	331.52	324.89	256.62	336.53		391.51	333.06		329.43
G_8	237.22	270.01	275.98	269.86	263.27	227.15	301.05	293.02	255.21	269.11	232.18	285.53		284.50	262.54		266.19
G_9	286.41	340.57	356.30	298.15	320.36	272.50	337.20	339.85	335.95	321.38	279.45	338.88		348.08	317.05		320.87
G_{10}	233.13	247.42	282.26	257.08	254.97	213.22	292.99	287.47	249.46	260.79	223.18	270.21		284.86	253.27		257.88
Mean	242.04	296.27	320.50	290.79		247.47	309.70	325.02	294.70		244.75	302.98		322.76	292.75		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	14.389	18.968	38.813	38.663		21.193	31.541	NS	NS		NS	11.182	NS	18.211	NS	36.421	NS
SE(m) ±	4.079	6.714	12.899	13.376		6.007	11.165	18.997	22.019		2.338	3.630	5.133	6.514	9.212	13.028	18.424

Pooled mean of all the genotypes had significantly higher Mn uptake in straw as compared to the Rajendra Bhagwati, Pusa-44, Rajendra Neelam and CR-2851-SB-1-2-B-1. The mean of among the different genotypes, Mn uptake in straw varied from 254.28 g ha^{-1} in Rajendra Bhagwati to 354.35 g ha^{-1} in CSR-36. Similar values were observed among CSR-36, CSR-27 and CR-3884-244-8-5-6-1-1. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher Mn uptake in straw (322.76 g ha^{-1}) than the other two amendments. However, gypsum application had higher Mn uptake in straw than the bio-compost application. Soil amendments and genotypes interaction was significant. Mn uptake in straw varied between 223.18 g ha^{-1} to 425.51 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Boron uptake in grain and straw

Grain

Boron uptake in grain of the all genotypes had significantly higher than the Pusa-44, Rajendra Neelam and CR-2851-SB-1-2-B-1 in both the years (Table 10). The boron uptake in grain of the all genotypes varied from 24.54 g ha^{-1} to 49.83 g ha^{-1} in the first year while in the second year it varied from 27.20 g ha^{-1} to 47.22 g ha^{-1}. Boron uptake in grain of the different amendments had significantly higher than the gypsum application and without application of any amendments. The combination of gypsum and bio-compost had higher value than the bio-compost amendments in both the years. The interaction between genotype and soil amendment was non-significant in the first year, while it was significant in the second year. Boron uptake in grain ranged from 20.29 g ha^{-1} to 59.84 g ha^{-1} in the first year while in the second year it ranged from 24.37 g ha^{-1} to 54.39 g ha^{-1}. Under the different amendments boron uptake in grain was lowest in Pusa-44 in the second year. The response of boron uptake in grain in control plot, gypsum, gypsum in combination with bio-compost and bio-compost treated soils among the different genotypes were between 25.78 to 40.34 g ha^{-1}, 24.37 to 52.14 g ha^{-1}, 30.20 to 52.74 g ha^{-1} and 28.43 to 54.39 g ha^{-1}, respectively during 2019.

Pooled mean of all the genotypes had significantly higher boron uptake in grain as compared to the Pusa-44. The mean of among the different genotypes, boron uptake in grain varied from 25.87 g ha^{-1} in Pusa-44 to 48.52 g ha^{-1} in CSR-36. Similar values were observed among CSR-36 and CSR-27. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher boron uptake in grain (43.52 g ha^{-1}) than the other two amendments. However, bio-compost application had higher boron uptake in grain than the gypsum application. Soil amendments and genotypes interaction was significant. Boron uptake in grain varied between 23.04 g ha^{-1} to 56.29 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Straw

It was observed that all salt tolerant genotypes were significantly higher than the Suwasini, Rajendra Bhagwati, Rajendra Neelam and varietal check in both the years shown in Table 11. The boron uptake in straw of the genotypes varied from 73.79 g ha^{-1} to 113.39 g ha^{-1} in the first year while in the second year it varied from 76.17 g ha^{-1} to 110.96 g ha^{-1}. Boron uptake in straw of the different amendments had significantly higher than the gypsum application and control plot during 2018 and all the soil amendments had significantly higher boron uptake in straw as compared to the control plot during 2019. The treatment having combination of gypsum @ 50% GR and bio-compost @ 2.5 t ha^{-1} had higher value than the other two amendments. However, bio-compost @ 5.0 t ha^{-1} application had higher boron uptake in straw than the gypsum @ 100% GR application in both the years. Boron uptake in straw varied from 63.80 g ha^{-1} to 140.40 g ha^{-1} during 2018 and 69.72 g ha^{-1} to 140.56 g ha^{-1} during 2019. Soil amendment and genotype interaction was significant in both the years. Without application of any amendment all the varieties were found superior of Rajendra Neelam. The variation in boron uptake in straw in control plot, gypsum, gypsum in combination with bio-compost and bio-compost treated soils among the different genotypes varied between 63.80 to 95.23 g ha^{-1}, 69.70 to 96.39 g ha^{-1}, 79.39 to 140.40 g ha^{-1} and 75.39 to 126.35 g ha^{-1} in the first year while in the second year it was varied between 69.72 to

92.19 g ha^{-1}, 70.11 to 96.66 g ha^{-1}, 81.88 to 140.56 g ha^{-1} and 78.47 to 126.68 g ha^{-1}.

Pooled mean of all the genotypes had significantly higher boron uptake in straw as compared to the Suwasini, Rajendra Neelam, Pusa-44 and Rajendra Bhagwati. The mean of among the different genotypes, boron uptake in straw varied from 74.98 g ha^{-1} in Suwasini to 112.18 g ha^{-1} in CSR-36. Similar values were observed among CSR-36, CR-3884-244-8-5-6-1-1 and CSR-27. All the soil amendments had significantly higher values as compared to control plot. The combination of gypsum and bio-compost had higher boron uptake in straw (101.45 g ha^{-1}) than the other two amendments. However, bio-compost application had higher boron uptake in straw than the gypsum application. Soil amendments and genotypes interaction was significant. Boron uptake in straw varied between 66.76 g ha^{-1} to 140.48 g ha^{-1}. Combination of gypsum and bio-compost treatment and CSR-36 genotypes had highest value. The response of gypsum, bio-compost and their combination varied from 70.14 to 96.37 g ha^{-1}, 77.61 to 122.40 g ha^{-1} and 81.11 to 140.48 g ha^{-1}. Year effect was non-significant. Interaction between soil amendments with year was non-significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments and year was non-significant.

Table 10: The influence of organic and inorganic amendments and their combination on Boron uptake (g ha^{-1}) in grain of different rice genotypes.

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	40.44	37.82	52.61	48.31	44.80	36.98	33.70	51.23	33.94	38.96	38.71	35.76		51.92	41.12		41.88
G_2	34.02	30.24	38.23	44.34	36.71	35.41	29.14	37.37	38.67	35.15	34.71	29.69		37.80	41.51		35.93
G_3	27.79	32.18	47.11	48.35	38.86	35.06	28.05	45.39	40.61	37.28	31.43	30.12		46.25	44.48		38.07
G_4	24.35	24.76	32.05	31.20	28.09	27.17	28.57	34.23	31.10	30.27	25.76	26.66		33.14	31.15		29.18
G_5	34.17	36.72	51.20	47.96	42.51	37.14	36.59	48.37	42.49	41.15	35.65	36.65		49.78	45.22		41.83
G_6	41.32	42.36	59.84	55.79	49.83	37.10	44.64	52.74	54.39	47.22	39.21	43.50		56.29	55.09		48.52
G_7	33.74	41.49	49.51	46.60	42.84	35.17	43.46	49.87	44.99	43.37	34.46	42.47		49.69	45.80		43.11
G_8	25.29	27.55	30.70	29.93	28.37	29.21	29.08	34.59	26.27	29.79	27.25	28.32		32.65	28.10		29.08
G_9	41.11	39.61	55.91	50.76	46.85	40.34	52.14	42.71	46.27	45.37	40.72	45.87		49.31	48.52		46.11
G_{10}	20.29	24.34	26.47	27.06	24.54	25.78	24.37	30.20	28.43	27.20	23.04	24.36		28.33	27.75		25.87
Mean	32.25	33.71	44.36	43.03		33.94	34.97	42.67	38.72		33.09	34.34		43.52	40.87		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	4.091	3.990	NS	NS		5.944	4.592	9.709	10.496		NS	3.151	NS	3.010	NS	6.020	NS
SE(m) ±	1.160	1.412	3.668	2.920		1.685	1.625	5.328	3.514		0.780	1.023	1.446	1.077	1.523	2.153	3.045

Table 11: The influence of organic and inorganic amendments and their combination on Boron uptake (g ha^{-1}) in straw of different rice genotypes

Rice genotypes	2018					2019					Pooled mean of 2018 and 2019						
	Organic and inorganic amendments				Mean	Organic and inorganic amendments				Mean	Organic and inorganic amendments						Mean
	T_1	T_2	T_3	T_4		T_1	T_2	T_3	T_4		T_1	T_2		T_3	T4		
G_1	65.38	69.96	79.39	80.43	73.79	70.29	73.09	82.83	78.47	76.17	67.84	71.52		81.11	79.45		74.98
G_2	74.31	70.17	82.02	83.70	77.55	70.72	70.11	81.88	85.36	77.02	72.52	70.14		81.95	84.53		77.29
G_3	78.35	75.72	97.56	85.44	84.27	74.95	86.12	98.11	84.20	85.85	76.65	80.92		97.84	84.82		85.06
G_4	63.80	71.21	84.43	82.84	75.57	69.72	77.61	82.01	83.96	78.33	66.76	74.41		83.22	83.40		76.95
G_5	78.37	96.39	112.33	101.42	97.13	79.15	96.35	107.42	104.70	96.91	78.76	96.37		109.87	103.06		97.02
G_6	94.66	92.16	140.40	126.35	113.39	91.91	95.82	140.56	115.54	110.96	93.29	93.99		140.48	120.94		112.18
G_7	78.31	90.02	125.18	118.13	102.91	82.27	96.40	126.20	126.68	107.89	80.29	93.21		125.69	122.40		105.40
G_8	76.93	84.28	87.57	83.93	83.18	78.61	83.65	94.06	83.95	85.07	77.77	83.97		90.82	83.94		84.13
G_9	95.23	89.98	116.40	96.11	99.43	92.19	96.66	114.99	101.98	101.46	93.71	93.32		115.69	99.05		100.44
G_{10}	68.76	69.70	83.36	75.39	74.30	74.19	71.00	92.21	79.83	79.31	71.47	70.35		87.78	77.61		76.80
Mean	77.41	80.96	100.86	93.37		78.40	84.68	102.03	94.47		77.91	82.82		101.45	93.92		
	T	G	T×G	G×T		T	G	T×G	G×T		Y	T	Y×T	G	Y×G	T×G	Y×T×G
CD (P = 0.05)	6.080	6.776	13.976	14.177		5.618	6.513	13.405	13.534		NS	3.616	NS	4.650	NS	9.301	NS
SE(m) ±	1.723	2.399	5.450	4.867		1.593	2.305	5.036	4.655		1.288	1.174	1.660	1.663	2.352	3.327	4.705

Conclusion

Zn and Cu uptake in grain had significantly higher in the genotypes CSR-27 followed by CSR-36 and CR-3884-244-8-5-6-1-1 and combination of gypsum @ 50% G.R. and bio-compost @ 2.5 t ha^{-1} application had significantly higher followed by gypsum @ 100% G.R. application and Fe, Mn and Boron uptake in grain and Zn, Cu, Fe Mn and Boron uptake in straw had significantly higher in the genotypes CSR-36 followed by CSR-27 and CR-3884-244-8-5-6-1-1 and combination of gypsum @ 50% G.R. and bio-compost @ 2.5 t ha^{-1} application had significantly higher than the control treatment, respectively.

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