Original Research Article

Effect of Gypsum & Bio-compost applications on Relative Water Content in Rice Genotypes under *Sodic* Soil

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. Field experiments were conducted during the June-November of 2018 and 2019 at the ICAR - Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), Bihar. Experiment was laidout in split plot design with four treatments i.e. T_1 - Control, T_2 - Gypsum@100%G.R., T_3 - Gypsum@50%G.R.+Bio-compost @2.5 tha^{-1} and T_4 - Biocompost@5.0 tha^{-1} in main plots and ten rice 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 and G_{10} - Pusa-44 in sub plots and replicated thrice. The promising results reveal that the mean of leaf relative water content at pre-flowering stage in the salt-tolerant genotypes ranged from 69.47 % to 82.20 % during 2018 and 69.52 % to 82.24 % during 2019. The mean of leaf relative water content at grain filling stage in all the genotypes varied between 77.55 % to 85.45 % during 2018 and 75.49 % to 85.16 % during 2019. Soil amendments and genotypes interaction was found significantly in both the years at grain filling stage.

Keywords: Gypsum, Bio-compost, Rice genotypes, Sodic soils, Leaf relative water content.

Introduction

Salinity in soil 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], it causes yield losses by depressing the uptake of water, and disturbing mineral nutrients and normal metabolic activity in plant. Salt-affected soils are identified by excessive levels of water-soluble salts, especially sodium chloride (NaCl) [Tanji 2002]. 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. The toxic ions cause ionic and osmotic stress at the cellular level in higher plants, especially in susceptible germplasm [Mansour and Salama 2000, Chinnusamy 2005]. Salinity reduces plant growth and increase plasmolysis of cells through osmotic pressure and reduces the water uptake, thereby causing a reduction in growth.

Gypsum and pyrite are the most effective reclamation agents for sodic soils and it received from mining so they are expensive and beyond the reach of poor farmers in rainfed lowland areas. Pressmud, a sugar industry by-product, is readily available in Bihar and 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 ion replaces Na ion from the clay particle and replace Na^+ react with SO_4^{2-} then formation of Na_2SO_4. 2% - 3% sulphur converts into sulphuric acid and lowers soil pH. In addition, it contains bioagents like Trichoderma and Azatobacter which protect plants from several fungal pathogens, enhance growth and development through robust root formation, and enhance soil N availability through atmospheric N_2 fixation. Composition of gypsum and biocompost are shown in Table-1 and Table-2, respectively.

Recently released rice varieties in India, including CSR 30, CSR 63, CSR-27, Suwasini, Rajendra Bhagwati, Boro-3, Rajendra Neelam, CR-3884-244-8-5-6-1-1, CR-2851-SB-1-2-B-1 and Pusa-44, have shown great potential for cultivation in sodic/saline soils of Bihar. In addition, Indian rice research institute (IRRI) made considerable progress in developing a Marker Assisted Backcrossing (MABC) system for the major QTL Saltol, associated with salinity tolerance in rice. Through MABC, this locus is now introgressed into three popular varieties (BR11, BRRI dhan 28, and IR64). Trials conducted under field conditions showed that introgression of this QTL significantly improved the salt tolerance of these varieties, and seeds of these three varieties were now ready for testing in farmers' fields. The availability of these salt-tolerant varieties provides a great opportunity for increasing and stabilizing productivity in salt-affected areas. Particularly when combined with best management practices specific for salt-affected areas, salt tolerant rice varieties could become a great opportunity for improving productivity and soil quality of saline and sodic soils. Considering this background, we conducted experiments to evaluate the benefits of combining biocompost, gypsum and salt tolerant varieties together to utilize the sodic soil potential and increase water uptake by rice crop for metabolic activity.

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 Indian Agricultural Research Institute, Sub Regional Station, 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).

A field experiment laid out in split plot design with four treatment T_1- Control, T_2-Gypsum@100% gypsum requirements (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). Initial representative soil samples were analyzed and accordingly gypsum requirement and organic carbon has been calculated for application in soil. Inorganic and organic amendment applied only first year. After incorporation of inorganic and organic amendments in soil, each plot was little irrigated so that gypsum get dissolved and leaching of gypsum from upper layer to lower layer of soil will take place. Then, field was left for 8-10 days for leaching of gypsum before rice transplanting. After 8-10 days for transplanted rice, seedlings of different genotypes i.e. Suwasini, Rajendra Bhagwati, Boro-3, Rajendra Neelam, CSR-30, CSR-36, CR-3884-244-8-5-6-1-1, CR-2851-SB-1-2-B-1, CSR-27, Pusa-44 were raised using a seed rate of 30 kg ha^{-1} and 25 days old seedling were transplanted manually. 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 dose and the rest fifty per cent of N was applied in two splits at 30 days interval.

Gypsum Composition

Calcium percentage in gypsum after analysis is occurring 29.2 % and Sulphur percentage is 18.6%.

Table 1: Biocompost Composition

S.No.	**Properties**	**Value**
1	Moisture Content	38%
2	pH	7.68
3	EC (dS m^{-1})	12
4	Organic Carbon (%)	24.20%
5	Organic Matter (%)	42.11%
6	C : N ratio	13.5%
7	Available Nitrogen (%)	1.80%
8	Available Phosphorous (P2O5) (%)	1.72%
9	Available Potassium (K2O) (%)	1.49%
10	Calcium (%)	3.2%
11	Magnesium (%)	1.1%
12	Available Sulphur (%)	1.3%
13	Available Zn (mg kg-1)	30.89
14	Available Cu (mg kg-1)	14.21
15	Available Fe (mg kg-1)	123.53
16	Available Mn (mg kg-1)	64.29

Leaf relative water content

Fully expanded youngest leaves were selected from different plants. Ten leaves were sampled and weighed immediately to determine the fresh weight (FW) and afterwards they were immersed in distilled water in Petri dishes for 4 hour’s in darkness and then turgid weight (TW) was determined. The leaves were dried in an oven at 68°C for 24 hour and the dry weight (DW) was taken. Afterwards RWC was calculated as by using the methodology which was given by Whetherley *et al*. (1950).

$$\text{Relative Water Content (RWC) (\%)} = \frac{(FW - DW)}{(TW - DW)} \times 100$$

Statistical analysis

The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) 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 the *Entisol* order and charchterized by, silt loam texture at surface containing 10.45% sand, 72.06% silt and 17.49% clay. The physico-chemical properties of soil were alkaline of pH 9.69, with electrical conductivity of 2.12 dS m^{-1} and organic carbon 2.6 g kg^{-1}. The soil available N, P, K and S were 136.8 kg ha^{-1}, 7.83 kg ha^{-1}, 93.2 kg ha^{-1} and 3.53 kg ha^{-1}, respectively (Table 2). 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). The soil had very low organic carbon content indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic carbon. Salt-affected soils produce less biomass than non-saline soils resulting less in soil organic carbon (Wong *et al.* 2010).

Table 2: Physico-chemical properties of experimental soil (0-15 cm depth before starting 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

Plant water status at pre-flowering stage

It was observed that all genotypes had significantly higher RWC than the Pusa-44 and Rajendra Bhagwati in both years (Table 3). The mean leaf relative water content at pre-flowering stage in all the genotypes ranged from 69.47 % to 82.20 % during 2018 and 69.52 % to 82.24 % during 2019. All the soil amendments plots had significantly higher leaf relative water content at pre-flowering stage as compared to the control plot in the first year while in the second year it was significantly higher than the control plot and biocompost @

5.0 t ha^{-1} applications. The combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} had higher value than the other two amendments. However, gypsum @ 100% GR application had higher leaf relative water content at pre-flowering stage than the biocompost @ 5.0 t ha^{-1} application in both years.

Leaf relative water content at pre-flowering stage ranged from 64.86 % to 86.61 % in the first year while in the second year it ranged from 66.83 % to 87.01 %. Amendment and genotype interaction was non-significant during 2018 and 2019.

It might be due to increase in osmotic pressure of cytoplasm which is accompanied by the synthesis of osmolytes which ultimately enhanced water flow into plant organs. Ca^{2+} helps in removal of excess sodium ion and biocompost increase water holding capacity.

Table 3: The influence of organic and inorganic amendments and their combination on leaf relative water content (RWC) (%) at pre-flowering stage in different rice genotypes.

Rice genotypes	2018					2019				
	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	
G_1	66.29	75.69	78.27	74.18	**73.61**	68.36	76.82	76.45	72.88	**73.63**
G_2	66.77	72.59	75.09	72.89	**71.84**	70.18	73.77	73.20	69.07	**71.55**
G_3	68.57	75.68	79.10	73.51	**74.22**	70.26	78.10	76.64	73.63	**74.65**
G_4	70.81	72.80	75.84	73.45	**73.23**	72.50	74.22	73.19	71.14	**72.76**
G_5	70.37	75.11	78.53	73.84	**74.46**	73.43	76.38	78.19	72.50	**75.12**
G_6	74.35	77.68	81.64	77.31	**77.75**	73.00	81.60	78.10	75.69	**77.10**
G_7	71.81	76.94	80.33	74.69	**75.94**	73.84	78.65	77.77	75.62	**76.47**
G_8	70.78	75.21	80.23	75.33	**75.39**	69.47	76.73	76.45	72.32	**73.75**
G_9	76.11	86.61	84.85	81.25	**82.20**	74.35	84.69	87.01	82.93	**82.24**
G_{10}	64.86	69.83	72.73	70.46	**69.47**	67.40	72.54	71.30	66.83	**69.52**
Mean	**70.07**	**75.81**	**78.66**	**74.69**		**71.28**	**77.35**	**76.83**	**73.26**	
	T	**G**	**T×G**	**G×T**		**T**	**G**	**T×G**	**G×T**	
CD (P = 0.05)	3.308	2.938	NS	NS		3.269	3.525	NS	NS	
SE(m) ±	0.938	1.040	2.965	2.184		0.927	1.248	2.931	2.542	

Plant water status at grain filling stage

Leaf relative water content at grain filling stage in most of the genotypes were significantly higher than the varietal check Pusa-44 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 (Table 4). The mean of leaf relative water content at grain filling stage in all the genotypes varied between 77.55 % to 85.45 % during 2018 and 75.49 % to 85.16 % during 2019. All the soil amendments plots had significantly higher leaf relative water content at grain filling stage as compared to the control plot in the first year while in the second year it was significantly higher than the control plot and biocompost @ 5.0 t ha^{-1} applications. The combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} had higher value than the other two amendments. However, gypsum @ 100% GR application had higher leaf relative water content at grain filling stage than the biocompost @ 5.0 t ha^{-1} application.

Soil amendments and genotypes interaction was significant in both the years. Leaf relative water content at grain filling stage varied from 68.68 % to 86.53 % in the first year while in the second year it varied from 65.50 % to 87.29 %. Without application of any amendment all the varieties were found superior to Pusa-44 and Rajendra Neelam in both the years. The response of gypsum, biocompost and their combination varied between 78.80 % to 86.53 %, 76.36 % to 85.52 % and 81.09 % to 86.43 % in the first year, respectively; while in the second year it was varied between 80.76 % to 85.57 %, 72.04 % to 84.70 % and 79.21 % to 87.29 %, respectively.

The high salt concentration in the root zone, which causes osmotic stress, restricts water absorption by the plants and causes cellular dehydration, seems to be primarily responsible for decrease in RWC. Furthermore sodicity induced membrane damage and caused RWC reduction in leaves. Salt stressed plants exhibit damage of lipid membranes which often results in increased cell permeability and electrolyte leakage from cells. Almost similar results were also reported by Singh *et al.* (2015); Kumar *et al.* (2016) and Taffouo *et al.* (2017).

Table 4: The influence of organic and inorganic amendments and their combination on leaf relative water content (RWC) (%) at grain filling stage in different rice genotypes.

Rice genotypes	2018					2019				
	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	
G_1	78.86	82.90	84.50	80.66	**81.73**	78.90	84.37	87.29	81.77	**83.08**
G_2	78.59	78.80	81.09	80.51	**79.75**	78.59	80.76	79.21	78.63	**79.30**
G_3	80.74	81.39	86.43	82.43	**82.75**	80.80	83.51	86.50	81.27	**83.02**
G_4	70.44	83.92	85.14	83.08	**80.65**	71.78	83.90	85.34	81.99	**80.75**
G_5	81.22	83.92	84.78	83.13	**83.26**	81.93	84.37	85.70	83.61	**83.90**
G_6	80.56	84.76	85.83	84.19	**83.83**	83.64	84.42	87.29	83.10	**84.61**
G_7	82.04	84.70	85.37	84.94	**84.26**	82.29	85.20	84.95	84.02	**84.12**
G_8	82.35	83.34	84.81	83.91	**83.60**	80.70	84.60	84.91	83.11	**83.33**
G_9	83.87	86.53	85.86	85.52	**85.45**	83.83	85.57	86.55	84.70	**85.16**
G_{10}	68.68	79.21	85.96	76.36	**77.55**	65.50	83.02	81.41	72.04	**75.49**
Mean	**78.74**	**82.95**	**84.98**	**82.47**		**78.80**	**83.97**	**84.92**	**81.42**	
	T	**G**	**T×G**	**G×T**		**T**	**G**	**T×G**	**G×T**	
CD (P = 0.05)	1.781	2.322	4.753	4.740		3.038	2.924	6.082	6.301	
SE(m) ±	0.505	0.822	1.596	1.639		0.861	1.035	2.723	2.144	

CONCLUSION

Relative water content at pre-flowering stage and grain filling stage was significantly higher in genotypes CSR-27 followed by CSR-36 and CR-3884-244-8-5-6-1-1 Moreover, combination of gypsum @ 50% G.R. and biocompost @ 2.5 t ha^{-1} application had significantly higher RWC followed by gypsum application @ 100% G.R..

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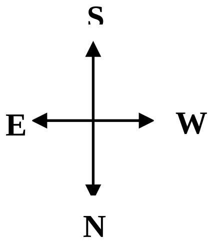
Layout of the experiment (Split Plot Design)



EAST

SOUTH

R_1	T_3	T_4	T_2	T_1
	G_4	G_7	G_7	G_3
	IRRIGATION CHANNEL			
	G_3	G_8	G_1	G_6
	G_{10}	G_3	G_4	G_7
	IRRIGATION CHANNEL			
	G_9	G_{10}	G_9	G_1
	G_1	G_5	G_6	G_{10}
	IRRIGATION CHANNEL			
	G_2	G_6	G_5	G_8
	G_5	G_2	G_2	G_4
	IRRIGATION CHANNEL			
	G_7	G_1	G_{10}	G_2
	G_8	G_4	G_3	G_9
	IRRIGATION CHANNEL			
	G_6	G_9	G_8	G_5
R_2	T_4	T_1	T_3	T_2
	G_9	G_6	G_3	G_4
	IRRIGATION CHANNEL			
	G_8	G_4	G_4	G_{10}
	G_3	G_{10}	G_7	G_7
	IRRIGATION CHANNEL			
	G_2	G_1	G_6	G_3
	G_7	G_9	G_{10}	G_6
	IRRIGATION CHANNEL			
	G_{10}	G_7	G_9	G_5
	G_4	G_3	G_8	G_2
	IRRIGATION CHANNEL			
	G_5	G_5	G_5	G_9
	G_1	G_8	G_2	G_1
	IRRIGATION CHANNEL			
	G_6	G_2	G_1	G_8
R_3	T_1	T_2	T_4	T_3
	G_7	G_5	G_4	G_9
	IRRIGATION CHANNEL			
	G_5	G_3	G_7	G_6
	G_1	G_9	G_3	G_1
	IRRIGATION CHANNEL			
	G_6	G_7	G_8	G_{10}
	G_{10}	G_2	G_5	G_5
	IRRIGATION CHANNEL			
	G_4	G_6	G_{10}	G_3
	G_8	G_1	G_9	G_8
	IRRIGATION CHANNEL			
	G_9	G_4	G_1	G_4
	G_3	G_{10}	G_6	G_2
	IRRIGATION CHANNEL			
	G_2	G_8	G_2	G_7

NORTH

IRRIGATION CHANNEL

WEST

Figure 1: Relative water content measurement.

Figure 2: Pre-flowering stage or rice genotypes.

Figure 3: Grain filling stage or rice genotypes.

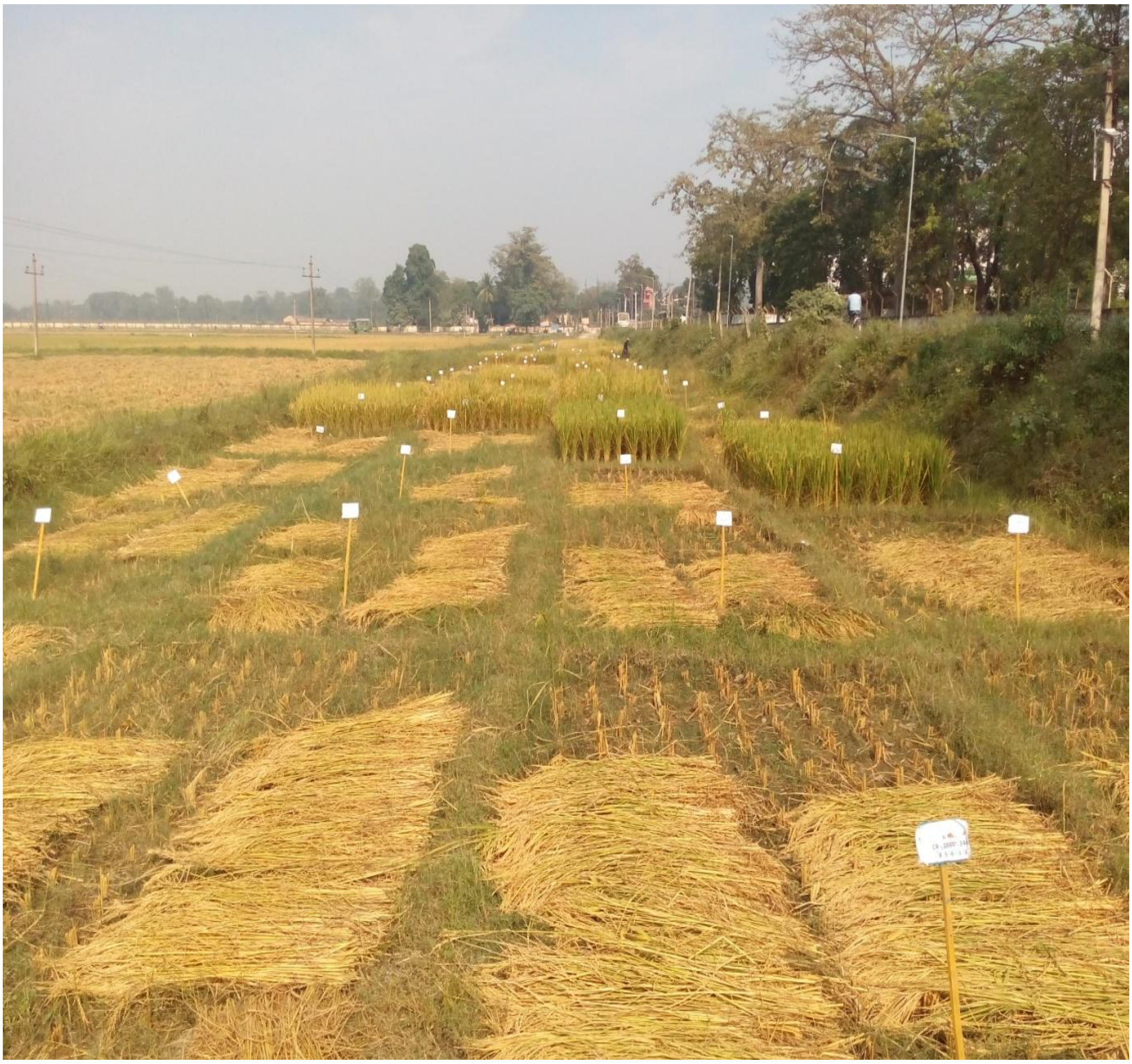


Figure 4: Harvest stage of rice genotypes.