

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

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Sodic soils have immense productivity potential, if managed through proper technology interventions. Bio-compost is prepared by composting pressmud 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 laid out in split-plot design with four treatments i.e. T₁(Control plots), T₂ (Gypsum@100% G.R. amended plots), T₃(Gypsum @ 50% G.R.+ Bio-compost @ 2.5 tha⁻¹ amended plots), and T₄(Biocompost @ 5.0 tha⁻¹ amended plots) 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 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.

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1. INTRODUCTION

Salinity in soil is a major abiotic stress limiting plant growth and development. In crops known as glycophyte or salt susceptible [1,2], 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) [3]. 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 [4,5]. 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 *Azotobacter* 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.

2. MATERIALS AND METHODS

A field experiments were carried out during 23rd June 2018 to 28th November 2018 and 23rd 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° 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). A field experiment laid out in split-plots 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), and T_4 (Biocompost @ 5.0 t ha⁻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 in thrice. The main plots and sub plots are permanent plots for both the years (2018 and 2019).

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 (P ₂ O ₅) (%)	1.72%
9	Available Potassium (K ₂ O) (%)	1.49%
10	Calcium (%)	3.2%
11	Magnesium (%)	1.1%
12	Available Sulphur (%)	1.3%

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

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. 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) were raised using a seed rate of 30 kg ha⁻¹ and 25 days old seedling were transplanted manually.

2.1 Gypsum Composition

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

2.2 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 hours in darkness and then turgid weight (TW) was determined. The leaves were dried in an oven at 68°C for 24 hours and the dry weight (DW) was taken. Afterwards RWC was calculated as by

using the methodology which was given by Whetherley et al. [6].

2.3 Statistical Analysis

The analyzed experimentally recorded data with the help of the ANOVA technique for a split-plots design according to Gomez and Gomez [7]. A result of ANOVA was found significantly and it's presented at a 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Initial Physico-chemical Properties of Soil

The experimental site belongs to the *Entisol* order and is characterized by, silt loam texture at the surface containing sand content is 10.45%, silt content is 72.06%, and clay content is 17.49% (Table 2). The initial soil's Physico-chemical properties were alkaline in nature of pH 9.69, with electrical conductivity (EC) of 2.12 dS m⁻¹ and organic carbon (OC) received 2.6 g kg⁻¹. The available N, P, K, and S in soil were 136.8 kg ha⁻¹, 7.83 kg ha⁻¹, 93.2 kg ha⁻¹, and 3.53 kg ha⁻¹, respectively. High pH and low EC of the experimental site might be an excessive accumulation of exchangeable Na⁺ in the soil particles. This indicates that the soil of the experimental site was sodic [8]. The soil had very less amount of organic carbon content indicating the medium 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 [9].

Table 2. Physico-chemical properties of experimental soil (0-15 cm depth before starting the experiment)

Properties	Value
Physical properties of soil	
Bulk density	1.63 g cm ⁻³
Water Holding Capacity	38.62 %
Wet Aggregate Stability	8.45 %
Textural Class	Silt loam
Sand	10.45 %
Silt	72.06 %
Clay	17.49 %
Chemical properties of soil	
Soil reaction (pH 1:2 Soil : Water)	9.69
EC	2.12 dS m ⁻¹
Organic Carbon (OC)	2.6 g kg ⁻¹ soil
Available N	136.8 kg ha ⁻¹
Available P (P ₂ O ₅)	7.83 kg ha ⁻¹
Available K (K ₂ O)	93.2 kg ha ⁻¹
Available S	3.53 kg ha ⁻¹

3.2 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. Ca²⁺

helps in removal of excess sodium ion and biocompost increase water holding capacity.

3.3 Plant Water Status at Grain Filling Stage

Leaf relative water content at grain filling stage in most of the rice genotypes were significantly higher RWC than the Pusa-44 and Rajendra Bhagwati in the first year while in the second year all the genotypes were found significantly higher than the Pusa-44. 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 (Table 4).

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.

Salt concentration in the root zone is very high, which causes osmotic stress, restricts absorption

of water by the plants and increase 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. [10]; Kumar et al. [11] and Taffouo et al. [12].

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				
	Gypsum and Bio-compost amendment				Mean value	Gypsum and Bio-compost amendment				Mean value
	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	TxG	GxT		T	G	TxG	GxT	
CD value (P = 5 %)	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	

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				
	Gypsum and Bio-compost amendment				Mean value	Gypsum and Bio-compost amendment				Mean value
	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	TxG	GxT		T	G	TxG	GxT	
CD value (P = 5 %)	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	



Fig. 1. Relative water content measurement



Fig. 2. Pre-flowering stage of rice genotypes



Fig. 3. Grain filling stage or rice genotypes

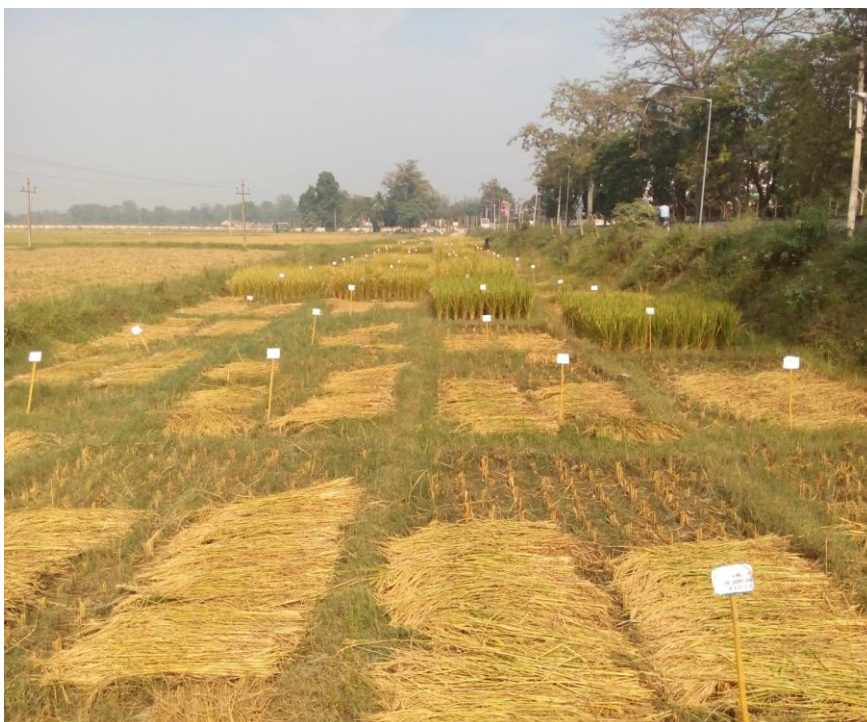


Fig. 4. Harvest stage of rice genotypes

4. CONCLUSION

Rice genotypes CSR-27, CSR-36, and CR-3884-244-8-5-6-1-1 in relative water content at the pre-flowering stage and grain filling stage was significantly higher than all rice genotypes. The treatment was a combination of gypsum @ 50% G.R. and bio-compost @ 2.5 t ha⁻¹ application has superior to the gypsum application @ 100% G.R.

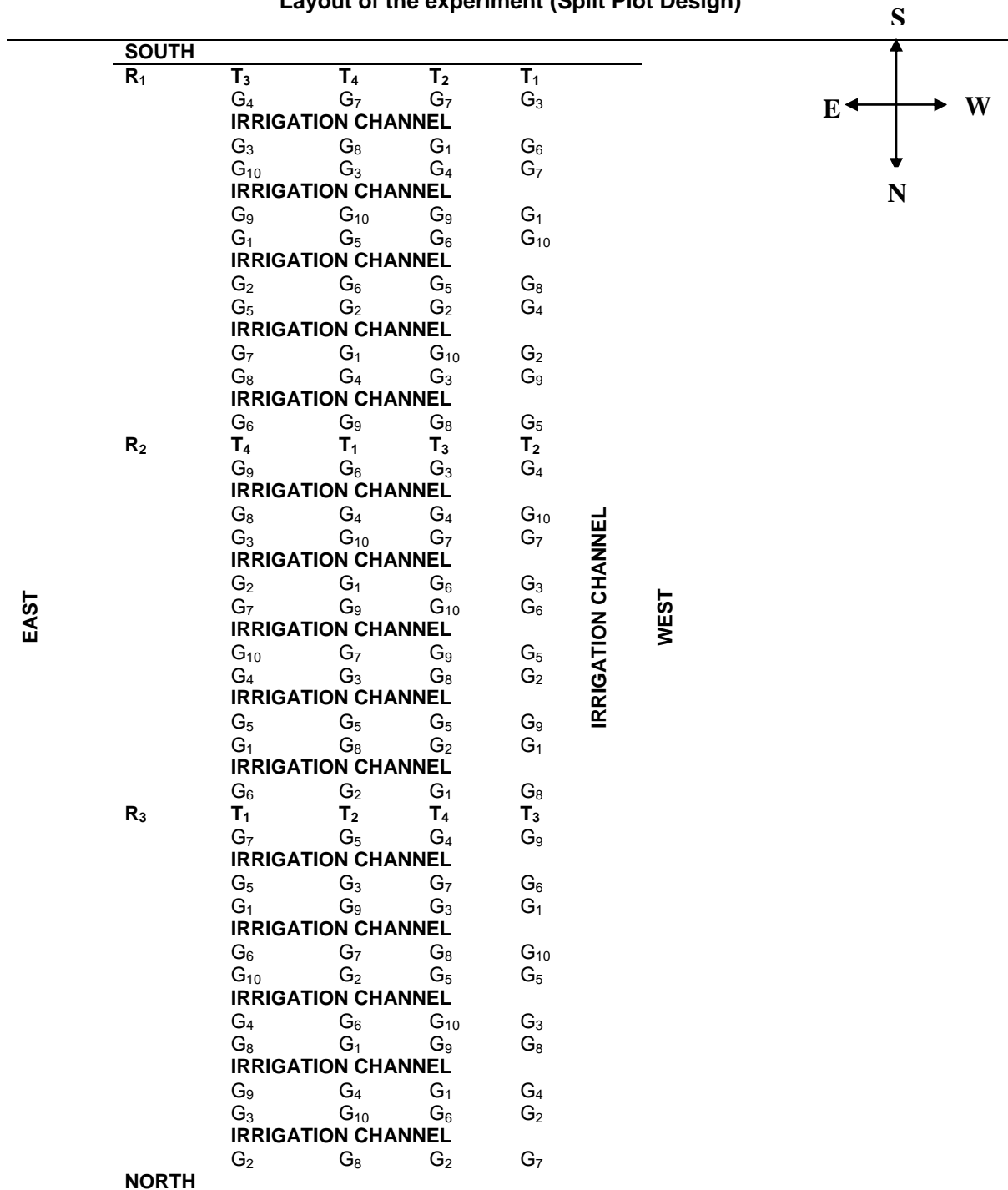
COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hasegawa PM, Bressan RA, Zhu JK, Bohnert HJ. Plant Cellular and Molecular Responses to High Salinity. Annual Review of Plant Physiology and Molecular Biology. 2000;51:463-499. Available:<http://dx.doi.org/10.1146/annurev.arplant.51.1.463>
2. Qadir M, Oster JD, Schubert S, Noble AD, Sahrawat KL. Phytoremediation of Sodic and Saline-Sodic Soils. Advances in Agronomy. 2007;96:197- 247. Available: [http://dx.doi.org/10.1016/S0065-2113\(07\)96006-X](http://dx.doi.org/10.1016/S0065-2113(07)96006-X)
3. Tanji KK. Salinity in the Soil Environment, In: A. Lauchli and U. Luttge, Eds., Salinity Environment-Plant- Molecules. Kluwer Academic, Dordrecht. 2002;21-51.
4. Mansour MMF, Salama KHA. Cellular Basis of Salinity Tolerance in Plants, Environmental and Experimental of Botany. 2000;52:113-122. Available:<http://dx.doi.org/10.1016/j.envexpbot.2004.01.009>
5. Chinnusamy V, Jagendorf A, Zhu JK. Understanding and Improving Salt Tolerance in Plants. Crop Science. 2005;45:437-448. Available:<http://dx.doi.org/10.2135/cropsci2005.0437>
6. Whetherley PE. Studies in the water relation of cotton plants. I. The field measurement of water deficit in leaves. New Phytologist. 1950;49:81-87.
7. Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research, 2nd Edition. An International Rice Research Institute Book. A Wiley-Inter-science. Publication, John Wiley and Sons, New York;1984.
8. USDA. Diagnosis and Improvement of Saline and Alkali soils. United States Salinity Laboratory staff. Agriculture Handbook No. 60, USDA, US. Govt Printing Office, Washington DC. 1954;26.
9. Wong VN, Greene RSB, Dalal RC, Murphy BW. Soil carbon dynamics in saline and sodic soils: a review. Soil use and management 2010;26(1):2-11.
10. Singh A, Sharma PC, Kumar A, Meena MD, Sharma DK. Salinity induced changes in chlorophyll pigments and ionic relations in bael (*Aegle marmelos* Correa) cultivars. Journal of Soil Salinity and Water Quality. 2015;7(1):40-44.
11. Kumar A, Lata C, Kumar P, Devi R, Singh K, Krishnamurthy SL, Kulshreshtha N, Yadav RK, Sharma SK. Salinity and drought induced changes in gas exchange attributes and chlorophyll fluorescence characteristics of rice (*Oryza sativa*) varieties. Indian Journal of Agricultural Sciences. 2016;86(6): 718-726.
12. Taffouo VD, Nouck AE, Nyemene KP, Tonfack B, Meguekam TL, Youmbi E. Effects of salt stress on plant growth, nutrient partitioning, chlorophyll content, leaf relative water content, accumulation of osmolytes and antioxidant compounds in pepper (*Capsicum annuum* L.) cultivars. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2017;45(2):481-490.

Layout of the experiment (Split Plot Design)



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