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Evaluation of active carbon under sodic soil after gypsum and bio-compost application

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ABSTRACT

An experiment was conducted to evaluate the active carbon under sodic soil after the improvement through natural sources of gypsum and bio-compost. This experiment was carried out at the Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur), Bihar during the Kharif session of 2018 and 2019. The experimental site was laidout in split plot design with four treatments of gypsum and bio-compost application in main plots and ten rice genotypes sowed into subplots and replicated in thrice times. After the experiment results observed that the improved soil pH, ESP, and EC significantly. The active carbon was observed to the significantly higher in more application doses of bio-compost than gypsum and also observed that some rice genotypes helps in improving active carbon under-treated with bio-compost and gypsum plots i.e. CSR-36, CSR-27, CR-3884-244-8-5-6-1-1, and CSR-30.

Keywords: *Gypsum, Bio-compost, Salt-tolerant rice genotypes, Active carbon.*

1. Introduction

Globally, the total salt-affected land is 1000 Mha (Munns and Tester, 2008, Pereira et *al.,* 2020). However, India has the largest area under salt-affected soils i.e. 6.74 Mha. In India alone, 1.25 Mha areas are characterized by coastal salinity, 3.79 Mha as sodic, and 1.71 Mha area under saline soils. However, in Bihar, the total salt-affected soils are spread over 0.15 Mha area among which 0.11 Mha area is under alkaline (sodic) soils and 0.047 Mha area is under saline soils (NRSA and Associates 1996). Sodic soil is characterized by more soil pH, ESP, and low EC. A high pH of soil decreases the availability of essential nutrients & ESP increases sodium concentration in soil, it's increases the compactness of soil and reduces the organic carbon decreasing water holding capacity, infiltration rate, and also biological activity. Thus, it's need to study active carbon under sodic soils after applications of amendments.

2. Materials and Methods

Field experiments were carried out during the *kharif* seasons from 23rd June 2018 to 28th November 2018 and 23rd June 2019 to 28th November 2019. The experiment was conducted at the Indian Agricultural Research Institute, Sub Regional Station, Pusa (Samastipur) Bihar, which is situated at $85^0$40'19.7” E latitude $25^0$59'06.2" N longitudes with an elevation of 55.00 meters above mean sea level. The experimental site has a hot and humid climate with summers and too cold winters with an 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 treatments T_1-Control, T_2-Gypsum@100% G.R., T_3-Gypsum@50%G.R.+Biocompost@2.5 tha^{-1}, T_4-Biocompost@5.0 tha^{-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 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). The experiment site in each plot's size was 4.2 m ×2.7 m and spacing in each plot was 20 cm × 15 cm. Initial representative soil samples were analyzed and accordingly, gypsum requirement and organic carbon have been calculated for application in soil. Inorganic and organic amendments are applied only first year. After the incorporation of inorganic and organic amendments in the soil, each plot was little irrigated so that gypsum would dissolve and leaching of gypsum from the upper layer to the lower layer of soil would take place. Then, the field was left for 8-10 days for gypsum 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, and Pusa-44 were raised using a seed rate of 30 kg ha^{-1} and 25 days old seedling were transplanted manually. 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 day intervals. The composition of compost and gypsum are shown in Table-1 and Table-2, respectively.

Collection and preparation of representative soil samples from 0-15 cm depth were collected before rice sowing and after the rice harvesting stage *Kharif* (2018 and 2019), respectively. Collected soil samples were air-dried in shade and stored in polyethylene bags.

The soil reaction (pH) of soil was measured with the help of a pH meter, maintaining the soil, and water ratio of 1:2 as described by Jackson (1967).

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The electrical conductivity in the clear extract of soil-water ratio of 1:2 was determined with the help of a conductivity meter (Jackson 1967). The exchangeable sodium percentage (ESP) of the saturated extract was calculated from the given formula (USDA 1954), where the concentrations of soluble cations were expressed in percentage (%).

$$\text{Exchangeable sodium percentage (\%)} = \frac{100(-0.0126 + 0.01475\ \text{SAR})}{1 + (-0.0126 + 0.01475\ \text{SAR})}$$

Active carbon is an indicator of the small portion of soil organic matter that can serve as a readily available food and energy source for the soil microbial community, thus helping to maintain a healthy soil food web. Active carbon was measured by oxidization with $KMnO_4$ and absorbance measurement with active carbon (mg kg^{-1}) (Weil *et al.* 2003).

The data recorded for different parameters were analyzed with the help of the analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for split-plot design. ANOVA was found significant and accordingly, results are presented at a 5% level of significance (P=0.05). Matplotlib module of Python programming language used for visualization of data.

3. Results

3.1 Physico-chemical properties of experimental soil

The soil of the experimental site belongs to order *Entisol,* silt loam in texture at the surface containing 10.45% sand, 72.06% silt, and 17.49% clay the physico-chemical properties of soil were wet aggregate stability of 8.45 %, Bulk density of 1.63 Mg m^{-3}, Water Holding Capacity 38.62 %, alkaline pH 9.69 in reaction, electrical conductivity 2.12 dS m^{-1}, organic carbon 2.6 g kg^{-1} and active carbon 114.42 g kg^{-1} (Table 3). The 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. Soils in salt-affected landscapes produce less biomass than non-saline soils resulting less in soil organic carbon (Wong *et al.* 2010).

3.2 Soil reaction (pH)

Soil reaction (pH) in all the genotypes was non-significant in the first year while in the second year genotypes Boro-3, Rajendra Neelam, and Pusa-44 were significantly higher than the all genotypes (Fig-1). The mean of soil reaction (pH) of all genotypes ranged from 9.10 to 9.23 in 2018 and 9.01 to 9.11 in 2019. All the soil amendments had significantly higher Soil reaction (pH) as compared to the gypsum @ 100% GR treated plot in both the years. Without treated in any amendments had a higher value than the combination of gypsum @ 50% GR and biocomposite @ 2.5 t ha^{-1} treated plot and biocomposite @ 5.0 t ha^{-1} treated plot. However, the biocomposite @ 5.0 t ha^{-1} treated plot had higher soil reaction (pH) than the combination of gypsum @ 50% GR and biocomposite @ 2.5 t ha^{-1} treated plot in both years. The interaction between genotype and soil amendment was non-significant in both years. Soil reaction (pH) ranged from 8.86 to 9.48 in the first year while in the second year, it ranged from 8.79 to 9.35. The pooled mean of the genotypes Boro-3, Rajendra Neelam, and Pusa-44 was significantly higher than the all genotypes. The mean of among the different genotypes, soil pH varied from 9.04 in CSR-36 and CSR-27 to 9.17 in check Pusa-44. Minimum values were observed among CSR-36, CSR-27 and CR-3884-244-8-5-6-1-1. All the soil amendments had significantly higher soil reaction (pH) as compared to the gypsum @ 100 % GR treated plot. Without treated in any amendments had a higher value than the combination of gypsum @ 50% GR and biocomposite @ 2.5 t ha^{-1} treated plot and biocomposite @ 5.0 t ha^{-1} treated plot. However, the biocompost @ 5.0 t ha^{-1} treated plot had higher soil reaction (pH) than the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} treated plot. The interaction between genotype and soil amendment was non-significant. Soil reaction (pH) was ranged from 8.84 to 9.42. Gypsum treatment and CSR-27 and CSR-36 genotypes had minimum value. The year effect was 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 sodic soils containing measurable amounts of $NaHCO_3$ and Na_2CO_3 which under normal conditions react with added gypsum ($CaSO_4.2H_2O$) to release frequent Ca ions by gypsum and their reaction with Na ions to replace them from soil and formation of sodium sulphate solution which gets leached out through drainage process. Moreover, the SO_4 ions of gypsum probably have contributed towards lowering the soil pH. The effect of the biocomposite applied, is the decomposition of organic matter which releases organic acid or acid-forming compounds that react with the soluble salts present in the soil and either convert them into insoluble salts or decrease their solubility which also lowers the soil pH. The combination of gypsum and biocompost treated plot was more lowering the soil pH than the biocompost treated plot. The results could be supported by studies of Singh *et al.* (2009); Dubey *et al.* (2012); Khan *et al.* (2014); Singh *et al.* (2016); Lakshmi *et al.* (2016); Saqib *et al.* (2017); Ram *et al.* (2017); Meena and Prakasha (2018); Sundhari *et al.* (2018); Khan *et al.* (2019) and Prabhavathi and Ramakrishna Parama (2019).

3.3 Electrical conductivity (EC)

The mean of electrical conductivity in all genotypes varied from 0.94 dS m^{-1} to 1.11 dS m^{-1} in the first year while in the second year, it varied from 0.83dS m^{-1} to 1.02 dS m^{-1}. All the genotypes had significantly higher electrical conductivity as compared to CSR-27 and CR-3884-244-8-5-6-1-1 in the first year while in the second year, all the genotypes had significantly higher than the CSR-27 found in Fig 2. During both the years the minimum and maximum values were obtained in CSR-27 and Rajendra Neelam, respectively. All the soil amendments had significantly higher electrical conductivity as compared to the gypsum @ 100 % GR treated plot in both years. Without treated in any amendments had a higher value than the combination of gypsum @ 50% GR and biocomposite @ 2.5 t ha^{-1} treated plot and biocomposite @ 5.0 t ha^{-1} treated plot. However, biocompost@ 5.0 t ha^{-1} treated plots had higher electrical conductivity than the combination of gypsum @ 50% GR and biocomposite @ 2.5 t ha^{-1} treated plots in both years. The interaction between genotype and soil amendment was significant in both years. Electrical conductivity (EC) varied from 0.49 to 1.53 dS m^{-1} in the first year while in the second year, it varied from 0.40 to 1.40 dS m^{-1}. Gypsum treatment and CSR-27 genotypes had minimum value. The response of gypsum, gypsum in combination with compost and biocompost treated soils among the different genotypes varied from 0.49 - 0.86 dS m^{-1}, 0.83 - 1.02 dS m^{-1} and 1.08 - 1.17 dS m^{-1} during 2018 and 0.40 - 0.76 dS m^{-1}, 0.84 - 0.96 dS m^{-1} and 0.93 - 1.07 dS m^{-1} during 2019. The pooled mean of all the genotypes was significantly higher than the CSR-27.

The mean of among the different genotypes, EC varied from 0.89 dS m^{-1} in CSR-27 to 1.06 dS m^{-1} in Rajendra Neelam. All the soil amendments had significantly higher electrical conductivity as compared to the gypsum @ 100 % G.R. treated plot. Without treated in any amendments had a higher value than the combination of gypsum @ 50% GR and biocomposite @ 2.5 t ha^{-1} treated plot and biocompost @ 5.0 t ha^{-1} treated plot. However, biocompost @ 5.0 t ha^{-1} treated plots had higher electrical conductivity than the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} treated plots. The interaction between genotype and soil amendment was significant. Electrical conductivity (EC) varied between 0.45 to 1.47 dS m^{-1}. Gypsum treatment and CSR-27 genotypes had minimum value. The response of gypsum, gypsum in combination with biocompost and biocompost treated soils among the different genotypes varied between 0.45 to 0.81 dS m^{-1}, 0.80 to 0.99 dS m^{-1} and 1.01 to 1.12 dS m^{-1}. The year effect was significant. Interaction between soil amendments with year was significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments, and year was non-significant. Reduction in EC higher in gypsum, gypsum in combination with biocompost than the compost treated plots could be due to removal of excess Na^{+} by the calcium from their exchange complex sites. The present findings are in concurrence with the findings of Hossain and Sarker (2015); Singh *et al.* (2016); Schultz *et al.* (2017); Saqib *et al.* (2017); Islam *et al.* (2017); Sundhari *et al.* (2018); Meena and Prakasha (2018); Khan *et al.* (2019) and Prabhavathi and Ramakrishna Parama (2019).

3.4 Exchangeable Sodium Percentage (ESP)

Most of the genotypes had significantly higher exchangeable sodium percentages as compared to the Rajendra Neelam, CR-3884-244-8-5-6-1-1, CSR-36, Suwasini, and Pusa-44 during 2018 and CR-3884-244-8-5-6-1-1, CSR-36, Rajendra Neelam and Suwasini during 2019 found in Fig 3. The mean exchangeable sodium percentage varied between 26.12% to 30.72% during 2018 and 29.87% to 33.71% during 2019. The exchangeable sodium percentage in the different amendments was significantly higher than the gypsum @ 100% GR treated plot. Without being treated in any amendments had a higher value than the other two amendments treated plot. However, biocompost @ 5.0 t ha^{-1}-treated plots had higher exchangeable sodium percentages than the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} treated plots in both years. The interaction between genotype and soil amendment was non-significant in both years. Exchangeable sodium percentage varied between 19.02% to 38.82% in 2018 and 22.91% to 40.04% in 2019. The pooled mean of all the genotypes had significantly higher exchangeable sodium percentages as compared to the CR-3884-244-8-5-6-1-1, Rajendra Neelam, and CSR-36. The mean exchangeable sodium percentage varied between 28.16 % to 32.21 %. All the soil amendments had significantly higher exchangeable sodium percentages as compared to the gypsum @ 100 % GR treated plot. Without being treated in any amendments had higher value than the other two amendments treated plot. However, biocompost @ 5.0 t ha^{-1} treated plots had higher exchangeable sodium percentages than the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} treated plots. The interaction between genotype and soil amendment was significant. Exchangeable sodium percentage varied between 20.96 % to 39.31 %. Gypsum treatment and CR-3884-244-8-5-6-1-1 genotypes had minimum value. The response of exchangeable sodium percentage in gypsum, gypsum in combination with biocompost and biocompost treated soils among the different genotypes varied between 20.96 % to 25.01 %, 24.53 % to 28.00 % and 29.73 % to 36.55 %. The year effect was 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. The decline ESP was highest in gypsum, gypsum in combination with biocompost then the biocompost treated plots due to the replacement of sodium (Na^{+}) by calcium (Ca$^{2+)}$ ions from exchange complex and its replacement from the soil via leaching. The results are in agreement with those of Singh *et al.* (2016); Lakshmi *et al.* (2016); Sundhari *et al.* (2018) and Meena and Prakasha (2018).

3.5 Active Carbon (AC)

All the genotypes had significantly higher active carbon contents of soil as compared to the check, Pusa-44 in the first year while in the second year, it was higher in CSR-36, CSR-27, CR-3884-244-8-5-6-1-1 and CSR-30 (Fig 4). The active carbon of the genotypes varied between 117.88 g kg^{-1} to 123.48 g kg^{-1} during 2018 and 118.80 g kg^{-1} to 122.39 g kg^{-1} during 2019. Pusa-44 is widely acclaimed as sodicity-susceptible variety which is considered as check. Almost similar contents of active carbon in soil were observed in the salt-tolerant genotypes: CSR-27, CR-C884-244-8-5-6-1-1, CSR-36, CSR-30 (Salt tolerant Basmati), and Boro-3. Among the different treatments, biocompost applied @5.0 t ha^{-1} had the highest active carbon content. The treatment having a combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} was found superior to gypsum @ 100% GR. All the amendments were significantly effective in increasing the active carbon content of the soil. The interaction between genotype and soil amendment was significant during 2018 while it was non-significant during 2019. Active carbon varied between 104.42 g kg^{-1} to 136.23 g kg^{-1} in the first year while in the second year, it varied between 110.21 g kg^{-1} to 131.69 g kg^{-1}. Without application of any amendment, all the varieties were found superior to Pusa-44. These genotypes also responded significantly higher to biocompost @ 5 t ha^{-1} as compared to Pusa-44. The response of gypsum, compost, and their combination varied from 115.54 - 118.57 g kg^{-1}, 126.38 - 136.23 g kg^{-1}, and 122.82 - 127.38 g kg^{-1}, respectively during 2018. The pooled mean of all the genotypes had significantly higher active carbon contents of soil as compared to the check, Pusa-44. The mean of among the different genotypes, active carbon varied between 118.32 g kg^{-1} in Pusa-44 to 122.93 g kg^{-1} in CSR-27. Similar values were observed among CSR-27, CSR-30, CSR-36, and CR-3884-244-8-5-6-1-1. All the soil amendments had significantly higher active carbon contents as compared to the control. The biocompost @ 5.0 t ha^{-1} had higher active carbon (130.61 g kg^{-1}) than the other two amendments. However, the combination of gypsum @ 50% GR and biocompost @ 2.5 t ha^{-1} had higher active carbon contents than the gypsum @ 100% GR application. The interaction between genotype and soil amendment was significant. Active carbon varied between 107.54 g kg^{-1} to 133.96 g kg^{-1}. Biocompost treatment and CSR-27 genotypes had the highest value. The response of gypsum, biocompost, and their combination varied from 116.37 to 118.75 g kg^{-1}, 125.66 to 133.96 g kg$^{-1,}$ and 121.92 to 126.14 g kg^{-1}. The year effect was non-significant. Interaction between soil amendments with year was significant and genotypes with year were non-significant. Interaction between genotypes, soil amendments, and year was non-significant.

It might be due to genotypes generating more total biomass in a rich source of organic carbon and the addition of biocompost is the well-decomposed source of organic carbon.

4. Discussion

The present study showed that the initial physical properties of soil were low wet aggregate stability, water-holding capacity, and high bulk density. Chemical properties of soil were high pH, ESP and low electrical conductivity, organic carbon content and active carbon, and excessive accumulation of exchangeable Na^+ in the soil particles. This indicates that the soil of the experimental site was *sodic* (USDA 1954). It might be due to high pH, low EC and excessive accumulation of exchangeable Na^+ in the soil particles increasing mortality of rice genotypes.

Conclusion

Gypsum application @ 100% G.R. had the highest improvement followed by a combination of gypsum @ 50% G.R. and biocompost @ 2.5 t ha^{-1}. CSR-30, CSR-36, CR-3884-244-8-5-6-1-1, and CSR-27 significantly decreased soil pH and EC as compared to Pusa-44. All the soil amendments significantly decreased soil pH and EC as compared to control. Gypsum application @ 100% G.R. highest effect followed by a combination of gypsum and biocompost. Rajendra Neelam, CSR-36 and CR-3884-244-8-5-6-1-1 genotypes had significantly decreased exchangeable sodium percentage as compared to CSR-27. All the soil amendments significantly decreased exchangeable sodium percentage as compared to control. Gypsum application @ 100% G.R. highest effect followed by a combination of gypsum @ 50% G.R. and biocompost @ 2.5 t ha^{-1}. Most of the salt-tolerant genotypes had a significant improvement in soil active carbon as compared to check Pusa-44. All the soil amendments significantly improved soil active carbon as compared to control. However, biocompost had the highest value followed by the combination of gypsum @ 50% G.R. and biocompost @ 2.5 t ha^{-1} applications.

Disclosure

This research is part of a Ph.D thesis titled "Influence of inorganic and organic amendments on salt-tolerant rice genotypes in sodic soils of Bihar.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Authors' Contributions

This work was carried out in collaboration between both authors. The first author designed the experiment and analyzed the data. Both of the authors interpreted the data, read the final manuscript, and agreed with all contents.

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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

Table-2: Gypsum Composition

S.No.	Properties	Value
1	Ca (%)	29.2%
2	S (%)	18.6%

Table-3: Physico-chemical properties of experimental soil (0-15 cm depth before start of the experiment

	Properties	Value
S.No.	Physical properties	
1	Sand (%)	10.45%
2	Silt (%)	72.06%
3	Clay (%)	17.49%
4	Textural Class	Silt loam
5	Bulk density(Mg m-3)	1.63
6	Water Holding Capacity (%)	38.62%
7	Wet Aggregate Stability (%)	8.45%
8	pH (1:2 Soil : Water) (0 -15 cm depth)	9.69
9	EC (dS m-1)	2.12
10	Organic Carbon (g kg-1)	2.6
20	Active Carbon (mg g-1)	114.42

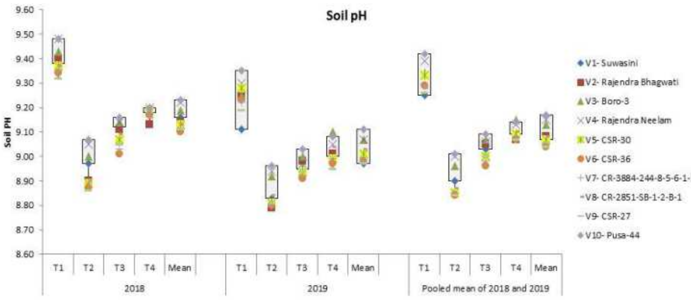

Fig 1: Soil reaction (pH) of different treatments of amendments application under different rice genotypes. (Error bars with line showing maximum to minimum values).

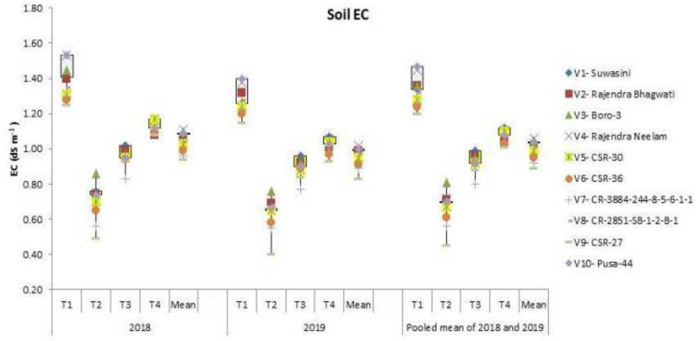

Fig 2: Soil EC of different treatments of amendments application under different rice varieties (Error bars with line showing maximum to minimum values).

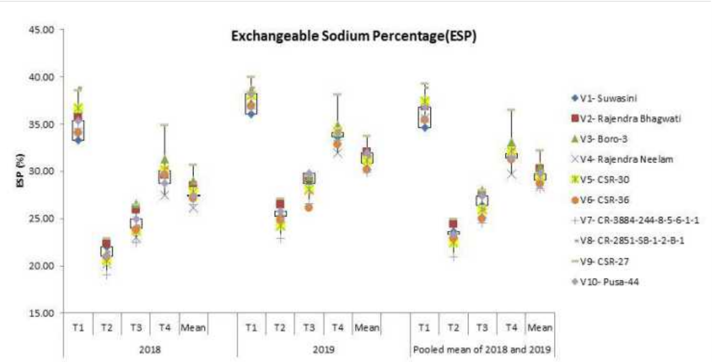

Fig 3: Exchangeable Sodium Ratio of different treatments of amendments application under different rice varieties (Error bars with line showing maximum to minimum values).

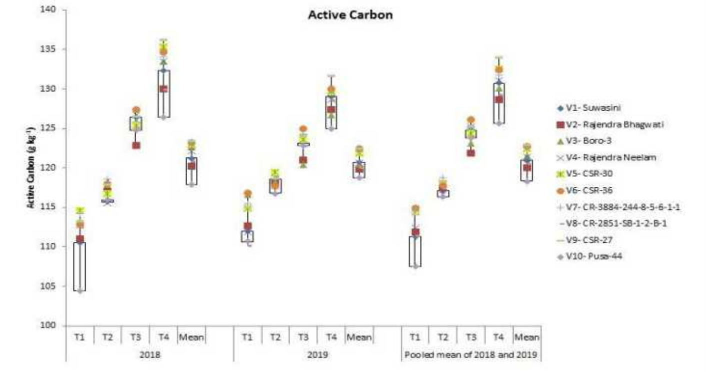

Fig 4: Active Carbon of different treatments of amendments application under different rice varieties (Error bars with line showing maximum to minimum values).

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