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Assessment of Nitrogen Fixation of Soybean [*Glycine max* (L). MERR] in a Sodic Ferric Luvisol of the Nigerian Sudan Savanna

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Abstract
Agricultural practices under irrigation have negatively affected production of grain legumes due to salt stress; because ability to fix nitrogen is hampered by either salinity, sodicity or both. A field study was undertaken with Soybean (TGx 1904-6F) at the Irrigation Research Farm of Institute for Agricultural Research (IAR), Kadawa, Kano in the Sudan savanna to assess the effect of soil sodicity, nitrogen and phosphorus fertilizer application on biological nitrogen fixation (BNF). Sodic and non- sodic soils (control) each were cultivated. The treatments consist of two levels of nitrogen (0 and 20kgNha^{-1}) applied as urea, and four levels of phosphorus fertilizers (0, 6.6, 13.2, 26.4 kgPha^{-1}) applied as single super phosphate, while maize (*Zea mays*) variety SAMMAZ 14) was used as reference crop for estimating biological nitrogen fixation. The treatments were laid out in a randomized complete block design with levels of N and P in a factorial combined and replicated thrice. Nodule number and nodule weight of soybean was increased in sodic soils at 6WAP by 64.94% (nodule number)and at 8 WAP (88.12% and 50%) for nodule number and weight respectively; suggesting tolerance of native levels of *Bradyrhizobium sp.* were much higher. Nitrogen fixation was depressed by 13.10% and 64.67% and Ndfa increased at 6WAP by 15% and decreased by 3.22% at 8WAP due to sodicity. Increasing levels of N increased soybean nodulation by 52.94% and 51.32% and N_2 fixation by 13.87% and 2.77% at 6 and 8 WAP respectively. Application of 26.4kgPha^{-1} gave the highest nodulation and %Ndfa at both at 6 and 8WAP, while13.2 kgPha^{-1}gave the highest amount of N_2 fixed (103.10 and 102.99 kgNha^{-1}) respectively. This suggests that the soil P level was adequate for the indigenous strains of rhizobia to produce nodules.

Keywords: Sodic soil, nitrogen fixation, soybean and sudan savanna, ferric luvisols

Introduction

Sodicity resulting from irrigation is increasing and becoming a serious constraint to sustainable agriculture in northern Nigerian arid and semi-arid regions. This is expected to become a more serious constraint in the near future as the effects of global warming and climate change increases. This continuous increasing problem under irrigation farming has become a great concern to farmers in this region. These sodic soils are formed as a result accumulation of sodium salts from fertilizer application, poor quality irrigation water, insufficient rainfall and high soil temperatures, which occurs in this region due to high rate of evaporation. This in turn affects soil biogeochemical properties, soil fertility and productivity (Chinke and Udofot, 2017; Mathur *et al.*, 2007) thus, hindering sustainability of food production. Due to increasing human population and insufficient rainfall, irrigation farming in Kadawa, Kano, in the Sudan Savanna of Nigeria has become the order of the day to improve and sustain the living population conditions. Salt-affected soils are known to depress plant growth, biomass production, nodulation, total N, N_2 fixation, low grain and Stover yields in legumes like soybean (Chinke and Udofot, 2017; Mohammed *et al.,* 2014; Younesi and Moradi, 2013), in alfalfa (Esmail *et al*., 2011), and in faba bean and chick pea (Wood and Elsheikh, 1995; Rao *et al.*, 2002).

Irrigated farm lands of Kadawa, Kano in the Sudan Savanna of Nigeria are becoming degraded by salinity and sodicity. Grain legumes such as soybean that are economically important in this region have been suggested as appropriate crops for soil improvement, high productivity and reclamation of the soils, due to the benefits of these legumes in soil fertility improvement (Maina *et al*., 2012) in this region. In order to meet the high food demand and to achieve food security in Nigeria with the current challenges confronting sustainable food production under irrigation, there is need for continued research to identify the best legume crop that has higher nodulation capacity under salt stress and clearly identifying the factors that influence their nodulation and nitrogen fixing capacity which remains important. There is dearth of information available regarding the effect of sodicity on nitrogen fixation under field conditions on soybean in this region. The aim of this study therefore, was to assess the effect of sodicity on nodulation [nodule number and dry weight (nodulation)] and nitrogen fixation of soybean in soil.

Materials and Methods

Site Description

This experiment was conducted at the Irrigation Research Station of the Institute for Agricultural Research (IAR) located at Kadawa-Kano (11°56′N, 08°42′E) for the non-salt field and (11°56′N, 08°41′E) for the salt affected field and 500 meters above sea level in the Sudan ecological zone of Nigeria. The mean daily maximum and minimum temperature were 31°C and 21°C respectively. Temperatures fall to as low as 15°C between November to January and could rise to 40°C or more between March to May (Maina *et al*., 2012). The experimental site was previously cropped with Artemisia in the rainy season before the establishment of the study during the dry season of same year and P fertilizer at the rate of 25, 50 and 75kgP_2O_5 was applied. Fig. 1 shows the map showing the study area.

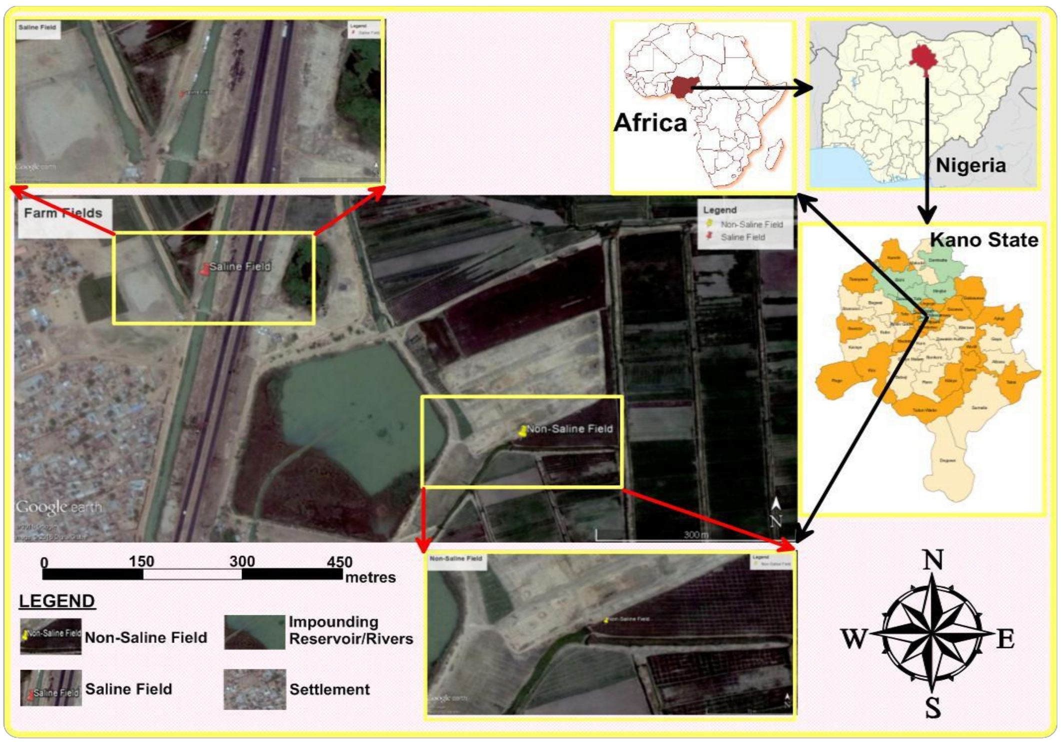

Fig. 1: Showing the map of the study site

Materials and Methods

Soil Sampling, Land Preparation and Agronomic Practices

Soil sampling was done at two depths (0-15cm and 15-30 cm) for both the sodic and non-sodic soils. Samples were collected diagonally from eight sampling points from each depth, air-dried mixed thoroughly to get the composite soil sample. The soil samples were then ground and passed through 2mm sieve and sub-sampled for routine soil analysis. Following standard recommended methods, Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Dr, 2002). Soil pH was determined in 1:2.5 soil: water ratio and salt (0.01M $CaCl_2$) suspension with a glass electrode pH meter. Organic carbon was determined using the wet oxidation method of Walkley- Black, total nitrogen by the Kjeldahl method and available P using Bray-1 method were determined as described by Okalebo *et al*. (2002). Exchangeable bases were determined as follows; Ca and Mg using Atomic Absorption Spectrophotometer (AAS); K and Na by Flame Emission Photometry after extraction by 1N NH_4OAc (Hesse, 1971). Exchangeable acidity (Al^{3+} + H^+) was determined by titration method after extraction with 1N KCl (Anderson and Ingram, 1993). The total exchangeable bases obtained and the exchangeable acidity was summed up to give Effective Cation Exchange Capacity (ECEC). Electrical conductivity (EC) was measured using conductivity meter (Rayment and Higgison, 1992). For the field trial, the field was ploughed, harrowed and ridged at 75cm apart and planted with soybean at inter and intra spacing of 75cm×4cm and 75cm×20cm respectively. Two seeds per hole were sown by dribbling and at two weeks after germination were thinned down to one plant per stand. All plots were manually weeded using the hoe, at three and six weeks after planting (WAP). Fertilizer application was done a week after sowing.

Treatments and Experimental Design

The treatments consist of two levels of nitrogen (0 and 20 $kgNha^{-1}$) applied as urea and four levels of phosphorus fertilizer (0, 6.6, 13.2, 26.4 $kgPha^{-1}$) applied as single super phosphate and one (1) soybean (*Glycine max* L. Merr) variety TGX 1904-6F. The treatments were laid out in a randomized complete block design with levels of N and P in a factorial combination and replicated thrice. Alleys were allowed 0.5m within plots and 1m between replications on both the salt and non-salt affected fields. The plot size was 4m by 4.5m ($18m^2$). The two inner ridges were used as net plot, while the two outer ones as sampling plot.

Plant sampling and Harvesting

At 6 WAS and 8 WAS, five plants samples were taken from the sampling plots for nodulation and nitrogen fixation assessments. Five plants each from each sampling plots were uprooted carefully from the root, washed under running water and taken to the laboratory for nodulation assessment. The nodules were detached from the roots of each five plants sampled and counted and then dried in the oven at 40°C to a constant weight to determine the nodule dry weight. For the nitrogen fixation assessment, the N-difference method as described by Murray *et al.* (2008) was used and maize variety SAMMAZ 14 was planted on the sampling plots and used as the reference crop. At physiological maturity (12 WAS), the grains were harvested and threshed from the pods. The threshed grains were further sun dried to a moisture content of about 12% using a Dickey-John grain moisture tester. All the pods from the net plot of each treatment were harvested and threshed and grain yield recorded in kilogram per hectare.

Determination of N_2 Fixed

Total N difference

The amount of N_2 fixed by Soybean was estimated using the Total Nitrogen Difference (TND) method. This was done by comparing total N of the legume with that of a non-legume (maize- Sammaz 14) used as the reference crop (Murray *et al*., 2008). The amount of N fixed was calculated by subtracting total N of the reference crop (maize- Sammaz 14) from that of the legume (Soybean), and the difference was assumed as N derived by BNF (N_2 fixed). Thus;

$$N_2\text{Fixed} = \text{Total N in Legume} - \text{Total N in reference crop} \ldots (1)$$

$$\text{Total N in plants} = \frac{\text{Dry matter weight } (\frac{kg}{ha}) \text{ x \% N in plants}}{100g} \ldots\ldots (2)$$

$$\%\ \text{Ndfa} = \frac{\text{Total N in legume} - \text{Total N in reference crop}}{\text{Total N in legume}} \text{ x } 100 \ldots\ldots (3)$$

Where % Ndfa is the percentage of N_2 derived from the atmosphere.

Statistical Analysis

Data collected was subjected to analysis of variance (ANOVA) using SAS statistical package (SAS, 2009) and differences in treatments means were determined using the Duncan Multiple Range Test at 5% level of significance (Duncan, 1955).

Results and Discussion

Results

Physical and Chemical properties of the Soil

The physical and chemical properties of the sites of study are shown in Table 1. The soils were sandy loam in texture. The soil reaction was slightly acidic in the non-sodic soil at both depths (0-15 and 15- 30 cm) having pH values of 6.59 and 6.61respectively, while the sodic soil was strongly alkaline (pH 9.05 and pH 9.30). The organic carbon for the two depths in non- sodic (7.76 and $4.98gkg^{1}$) and sodic (2.66 and $1.59gkg^{-1}$) soils were considered low. The available P for non-sodic (82.71 and $77.0mgkg^{-1}$) and sodic (28.7 and $41.12mgkg^{-1}$) soils were very high. The total N was 0.7 and $0.14gkg^{-1}$(non-sodic soil) and 0.14 and $0.14gkg^{-1}$ (sodic soil) was low according (FMANR, 1990). Exchangeable Ca (3.7 and $4.0cmolkg^{-1}$non-sodic soil and 4.4 and $5.2cmolkg^{-1}$sodic soil) was medium, while exchangeable Mg (2.5 and $1.7cmolkg^{-1}$) and (2.3 and $3.4cmolkg^{-1}$) were high respectively. Exchangeable K was 0.13 and $0.08cmolkg^{-1}$ (non-sodic) and 0.14 and $0.11cmolkg^{-1}$(sodic soil) were low, while exchangeable Na was medium (0.14 and 0.26cmol kg^{-1}) in the non-sodic soil and high (0.71 and $2.19cmolkg^{-1}$) in the sodic soil. Effective cation exchange capacity (ECEC) (7.77 and $6.64cmolkg^{-1}$) was medium for non-sodic soil and medium to high (8.15 and $11.5cmolkg^{-1}$) in sodic soil (FMANR, 1990). The electrical conductivity (EC) values were generally low (0.81 and $1.15dSm^{-1}$) and (0.75 and $0.9dSm^{-1}$) for the non-sodic and sodic soils respectively. Exchangeable sodium percentage (ESP) (1.8 and 3.91%) for non-sodic soil was within safe limits (<15%) and (8.71 and 19.04%) for sodic soil showed sodium build-up at the sub-surface (15- 30cm) depth. The sodium adsorption ratio (SAR) values were (0.08 and 0.15) and (0.38 and 1.05) for both soils respectively, indicating low salinity and high sodium as depth increases and crop may be in danger of development of exchange sodium and salinity. This may destroy the soil structure due to dispersion of clay particles.

Nodulation of soybean in the Non-sodic and Sodic soils

Results of nodule count and weight obtained for soybean (Table 2) showed that there was no significant (P>0.05) difference between sodic and non-sodic soil at 6WAS, however, at 8WAS, nodule number was highly significant (P>0.01). The sodic soil gave higher nodule number at both 6 and 8 WAS compared to the non-sodic soil, though the highest value (25.25) was obtained in the sodic soil at 8WAS. At 6WAS, the non-sodic soil gave the lowest nodule number (1.62). Result obtained also showed that nodule weight of soybean at 6WAS differed significantly (P<0.05) in the non-sodic and sodic soils (0.01 and 0.00) respectively, while there were no significant differences on nodule weight at 8WAS for both soils, though sodic field had the highest nodule weight at week 8 (0.04). There was also no significant ($P>0.05$) difference in both nodule number and weight as influenced by N rates, though N at 20kgN ha^{-1} gave the highest values. There was significant interaction ($P<0.05$) between N application and soil type at 6WAS on nodule number (Table 2). It was observed from the interaction at 6WAS on non-sodic soil, N application gave high nodule number. Also, there was no significant ($P>0.05$) difference between the P rates for both nodule number and weight though P at 26.4kgPha^{-1} gave slightly higher values compared to the other rates.

Influence of Non-sodic and Sodic soils on N_2 fixed and Proportion of N derived from the atmosphere (%Ndfa) at 6 and 8WAS of Soybean

Results obtained in Table 3 shows that there was no significant ($P>0.05$) difference in N_2fixed between sodic and non-sodic soils at 6WAS, though generally, non-sodic soil gave the highest amount of N_2 fixed. At 8WAS, there was significant ($P<0.001$) difference between sodic and non-sodic soils, the non-sodic field gave the highest amount of N_2 fixed (136.18kgNha^{-1}). Also, there was highly significant ($P<0.01$) difference at 6WAS on %Ndfa between sodic and sodic soils. The sodic soil had 83.69% Ndfa compared to the non-sodic soil (70.82%) nitrogen derived from the atmosphere. There was no significant ($P>0.05$) difference at 8WAS, though the non-sodic soil gave higher nitrogen derived from the atmosphere (70.47%). There was no significant ($P>0.05$) difference for the effects of N and P application as well as interactions amongst the experimental factors.

Discussion

Soil Characteristics

Physical and chemical properties of the sites before commencement of study as shown in Table 1, indicated that the texture of the soils was sandy loam at both soil depths (0-15 and 15-30cm). The clay content of the soils was low and with dominant sand fraction as expected of the Sudan savanna soils. This may be due to sorting of soil materials by soil organisms, clay movement or surface runoff or a combination of these (Eche, 2011). This agrees with the findings of Jibrin *et al*. (2008) and Adamu *et al*. (2014) who also reported low silt and clay contents of the soils at Kadawa. Clay content increased with depth from the surface (14.6 and 14.1) to (19.3 and 18.0) the subsoil for the non-sodic and sodic soils respectively. This could be due to clay illuviation to lower depths, causing restricted infiltration deeper in the root zone. Root development will be restricted as a result and could prevent the crop from withstanding moderate drought conditions resulting in poor crop growth leading to low yield. Soil reaction of the non-sodic soil was slightly acidic, but tended towards neutral, which is a common feature of savanna soils (Jones and Wild, 1975). pH values were within the normal range of 5.5 - 7.0 considered optimum for the release of plant nutrients (Odunze *et al*., 2006 and Sharu *et al*., 2013). Based on the soil pH observed of the study site, the soil can be considered suitable for soybean and cowpea growth and development. The sodic soil was strongly alkaline which poses as a problem for nutrient solubility.

The organic carbon and nitrogen content for both locations were low and can be attributed to the inherent low carbon content of savanna soils (Ogunwole *et al*., 2010) due to intensive cultivation over the years resulting in low organic matter. This agrees with the findings of Jibrin *et al*., 2008, who worked on the fertility status of Kadawa soils and observed that the carbon and N contents were low. The available P contents for both experimental soils were particularly high. The high P concentration obtained could have resulted from previous land use, and particularly the application of 25, 50 and 75kgP_2O_5 to the previous crop (Artemisia) in 2015 rainy season before the establishment of the trial during the dry season of the same year and this could have left high levels of residual P in the soil as P is a slow release nutrient element and not mobile in soil. Also, contributions from harmattan dust could have contributed to the high available P content observed. This agrees with the findings of Malgwi (2001) and Adamu *et al*. (2014), who observed considerable amounts of P released through harmattan dust deposits on the surface soil. However, the higher values in the subsoil may be lithogenic in nature (Malgwi, 2001).

The results obtained for exchangeable bases (Table 1) showed that Ca^{2+}, Mg^{2+}, K^+ and Na^+ were within plant tolerable range and posed no threat to crop production at both locations, except for Na^+ in the sodic field that was high (0.71 and 2.19cmolkg^{-1}) for the surface and subsurface depths respectively, indicating sodium build up. This result agrees with that of Malgwi (2001) and Jibrin *et al*. (2008). All the basic cations were observed to increase with depth at both locations except for K^+ (found to be low at both depths) which could be due to leaching effect. Similar observation was made by Odunze and Kureh (2009) who reported increase in exchangeable bases with depth and attributed it to leaching effect as the nutrient cations move along with soil solution. The ECEC of the study sites were medium for the non-sodic soil (7.77 and 6.64cmolkg^{-1}) and medium to high (8.15 and 11.50cmolkg^{-1}) for sodic soil at the 0-15cm and 15-30cm depths respectively (FMANR, 1990) suggesting a dominance of low activity clays and the ability of the soil to bind nutrients and pollutants. The EC values obtained (Table 4.1) from the saturated soil extract were within safe limits, <4dSm^{-1}, prescribed for alkaline and salt-affected soils (Landon, 1991). The result further shows that the soil of the study site tended towards sodicity. The exchangeable sodium percentage of the non-sodic field was low (1.80 and 3.91%), while (8.71 and 19.04%) for sodic soil, confirming that the key problem of the study site was sodicity which reflected in the high exchangeable Na^+ content obtained. The SAR values increased with increase in soil depth in both trial fields.

Influence of Non-sodic and Sodic soils on Nodulation of Soybean

Nodule number for soybean increased in the sodic soil compared to the non-sodic soil at 6 and 8WAS. Nodule number of soybean increased by 185% and 742% at 6 and 8WAS respectively, over non-sodic field. The reason for such increase in the sodic soil is not clear, but could have been due to early attachment and infection thread formation of the soybean Bradyrhizobium on the root hairs (which is an important step in nodule formation) before the severe salt stress. The salt condition was not introduced later in the season. It was there from the on-set. The nodulating bacteria could have been salt tolerant This finding agrees with Lakshmi *et al*. (1974) who worked with Lucerne (*Medicago sativa L*.) and observed that the root-hair infection and nodule formation preceded the effect of salt stress and resulted in the increase in nodule number of Lucerne. The lower nodule number in the non-sodic soil could be due to antagonistic effect of microorganisms on the indigenous rhizobium strains. This agrees with the finding of Saha and Haque (2005) who reported low nodule number in soils as a result of antagonistic effect of other soil microorganisms on the rhizobium strains.

Influence of Non-sodic and Sodic soils on BNF of Soybean

N_2 fixed in the non-sodic field increased at 6 and 8WAS by 13.10% and 64.67% over sodic soil and also by 3.32% of Ndfa at 8WAS, while %Ndfa in the sodic soil increased at 6WAS by 15.38% over non-sodic soil. This could be attributed to the effect of sodium salt. This agrees with the finding of Shetta *et al*. (2011) who observed significant reduction in N_2 fixation in legumes due to salt stress. Application of 20kgNha^{-1} gave higher N_2 fixed and Ndfa indicating that mineral N could have positively imparted on the activities of nitrogenase enzyme complex responsible for nitrogen fixation in legumes. The average amount of N_2 fixed was within the range of 90 - 118kgNha^{-1}. These values fall within the range of 55 - 188kgNha^{-1} reported by Giller (2001). However, this is contrary to the findings of Yusuf *et al*. (2006) who reported ranges of 4-50kgNha^{-1} in the Northern Guinea Savanna. The large range of these estimates could be due to differences in N-fixing capability of the genotypes, the fertility of the soil (Sanginga *et al*., 1997), the indigenous Bradyrhizobia sp and crop management (Okogun *et al*., 2005). The high amount offixed N_2 shows a higher potential to alleviate soil N deficiency. The average amount of percent Ndfa obtained was between 68-74%. This range falls within 26-87% reported by Sanginga *et al*. (1997). This result shows that the main contribution of grain legumes to soil fertility improvement in cropping systems lies in their ability to fix atmospheric N as observed by Yusuf *et al*. (2008) also. Thus, genotypes that derive high amounts of their N_2 from atmospheric fixation will be highly desired mainly in N deficient soils, and suitable for soil improvement.

Conclusion

Results show that Nodule number and nodule weight of soybean increased in sodic soils at 6WAP by 64.94% (nodule number) and at 8 WAP (88.12% and 50%) for nodule number and weight respectively, suggesting tolerance of native levels of *Bradyrhizobium sp.* were much higher. Nitrogen fixation was depressed by 13.10% and 64.67% and Ndfa increased at 6WAP by 15% and decreased by 3.22% at 8WAP due to sodicity. Increasing levels of N increased soybean nodulation by 52.94% and 51.32% and N_2 fixation by 13.87% and 2.77% at 6 and 8 WAP respectively. Application of 26.4kgPha^{-1} gave the highest nodulation and %Ndfa at both 6 and 8WAP, while 13.2kgPha^{-1} gave the highest amount of N_2 fixed (103.10 and 102.99kgNha^{-1}) respectively. This suggests that the soil P level was adequate for the indigenous strains of rhizobia to produce nodules.

Table1: Physical and chemical properties of the soil of the experimental sites

Parameters	Non-sodic soil		Sodic soil	
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**
Sand(g/kg)	660	654	753	740
Silt(g/kg)	194	153	106	80
Clay(g/kg)	146	193	141	180
Textural Class	Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH(H_2O)	6.59	6.61	9.05	9.30
pH($CaCl_2$)	6.38	6.46	7.28	7.72
Org. C(g/kg)	7.76	4.98	2.66	1.59
Total N(g/kg)	0.70	0.14	0.14	0.14
Avail. P(mg/kg)	82.71	77.00	28.70	41.12
Total P(mg/kg)	704.50	1000	545.40	500
Exchangeable Bases (col/kg)				
Ca^{2+}	3.70	4.00	4.40	5.20
Mg^{2+}	2.50	1.70	2.30	3.40
K^{+}	0.13	0.08	0.14	0.11
Na^{+}	0.14	0.26	0.71	2.19
EA($H^{+}+Al^{3+}$)	1.30	0.60	0.60	0.60
ECEC	7.77	6.64	8.15	11.50
EC(dSm^{-1})	0.81	1.15	0.75	0.90
ESP(%)	1.80	3.91	8.71	19.04
SAR	0.08	0.15	0.38	1.05

Org. C=Organic Carbon, Avail. P= Available Phosphorus, ECEC=Effective Cation Exchange Capacity, ESP=Exchangeable Sodium Percentage, SAR= Sodium Adsorption Ratio. EA=Exchangeable acidity, EC=Electrical conductivity

Table 2: Effect of non-sodic and sodic soils on nodulation of cowpea and soybean

Treatments	Soybean			
Soil	**NN6**	**NN8**	**NW6**	**NW8**
Non-sodic	1.62	3.00^{b}	0.01^{a}	0.02
Sodic	4.62	25.25^{a}	0.00^{b}	0.04
SE(±)	1.185	5.686	0.003	0.015
Nitrogen (kg N/ha)				
0	2.00	9.25	0.00	0.03
20	4.25	19.00	0.01	0.03
SE(±)	1.185	5.686	0.003	0.015
Phosphorus (kg P/ha)				
0	6.08	16.50	0.01	0.04
6.6	1.66	8.25	0.01	0.02
13.2	2.08	15.42	0.00	0.02
26.4	2.66	16.33	0.00	0.04
SE(±)	1.677	8.042	0.003	0.021
Interactions				
N*Soil	*	NS	NS	NS
P*Soil	NS	NS	NS	NS
N*P	NS	NS	NS	NS
N*P*Soil	NS	NS	NS	NS

[abc] Means having the same letter within the same column and treatments are not significantly(P>0.05) different. NN6 =Nodule number at week 6, NN8=Nodule number at week 8, NW6=Nodule dry weight at week 6, NW8=Nodule dry weight at week 8 and SE=Standard error

Table 3: Effect of non-sodic and sodic soils on Nitrogen Fixation of soybean

Treatments	N_2fixed6	N_2fixed8	Ndfa6	Ndfa8
	kg N ha^{-1}		%	
Soil				
Non-affected	120.35	136.18[a]	70.82[b]	70.47
Salt-affected	104.59	48.11[b]	83.69[a]	68.20
SE(±)	12.618	13.144	3.015	4.872
Nitrogen (kg N/ha)				
0	106.53	90.85	77.61	70.04
20	118.42	93.44	76.90	68.63
SE(±)	12.618	13.144	3.015	4.872
Phosphorus (kg P/ha)				
0	129.62	79.95	81.49	69.96
6.6	118.62	91.62	79.79	69.60
13.2	103.10	102.99	70.42	67.58
26.4	98.55	94.02	77.31	70.20
SE(±)	17.845	18.588	4.264	6.890
Interactions				
N*Soil	NS	NS	NS	NS
P*Soil	NS	NS	NS	NS
N*P	NS	NS	NS	NS
N*P*Soil	NS	NS	NS	NS

[abc]Means within the same column having the same letter are not significantly(P>0.05) different. N_2fixed6=Nitrogen fixed at week6, N_2fixed8=Nitrogen fixed at week 8, Ndfa6=Nitrogen derived from the atmosphere at week 6, Ndfa8=Nitrogen derived from the atmosphere at week 8 and SE=Standard error

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