USE OF BIOFERTILIZERS FOR IMPROVING PRODUCTIVITY OF COWPEA IN CEREAL-BASED CROPPING SYSTEMS IN NIGERIA.

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ABSTRACT
Nitrogen is one of the most frequently deficient nutrienst in tropical soils, and to optimize the supply of this nutrient in agricultural systems, legumes, such as cowpea that biologically fix nitrogen are integrated as part of the cropping systems. The objective of this study was to determine the response of cowpea to the use of biofertilizers for improving productivity in cereal-based cropping systems of some soils in Sudan savanna of Nigeria.A greenhouse study was carried out at the International Institute of Tropical Agriculture Kano.The experiment was laid out in a 15 x 2 x 4 factorial fitted to a completely randomized design (CRD) replicated three times. Theyconsisted of 15 locations, 2 proximity to homestead and 4 nitrogen sources. The locations were Bunkure, Rano, Bebeji, Tudun Wada, Kiru, Wudil, Gaya, Garko, Warawa, Albasu, Sumaila, Gezawa, Minjibir, Bichi, Bagwai, proximity to homestead (close to homestead < 50 m, and far from homestead > 250 m).Nitrogen sources were control, + N at the rate of 80 kg N/ha using Urea, Inoculation with strain USDA 3384 and strain USDA 3451. Result from this experiment shows that inoculation of cowpea withstrain USDA 3384 or strain USDA 3451 significantly ($p \leq 0.05$) increased the nodule dry weight of cowpea. The nodule dry weight and nodule number of cowpea inoculated with eitherstrain USDA 3384 or USDA 3451 were marginally higher than the N-supplied treatments in at least one of the location. Nodule dry weight inoculated with eitherstrain USDA 3384 or USDA was (0.73 and 0.65 g/plant) while the Nitrogentreated was (0.40 and 0.47g/plant)for bothclose and far proximity to homestead at Albasu, suggesting the effectiveness of the introduced strain. Soils sampled close to homestead had better physicochemical properties than those sampled away from homestead. There exist a significant relationship between location and proximity to homestead the close to homestead was greater in shoot and nodule dry weight in most of the locations.Inoculation is not a common practice in Nigeria, although field trials involving cowpea have been mixed. In this study, there was a response of cowpea to either strain USDA 3384 or USDA 3451 suggesting their suitability for use in Sudan Guinea Savanna of Nigeria.
Keywords: Biofertilization, Soil Nitrogen, Soil Productivity, Sudan Savanna

INTRODUCTION

Nitrogen is limited in agricultural soils due to continual removal of crop residues, low soil organic matter, leaching, bush burning, and volatilization (Albareda*et al.*, 2008). Leguminous crops such as cowpea can meet part of their nitrogen needs through biological nitrogen fixation (BNF) Bagayoko*et al*., 2000). Nitrogen inputs through BNF may sometimes be sub-optimal because of the absence or low number of effective indigenous rhizobia that are compatible with the host legume (O'Hara *et al*., 2002)). Under these circumstances, BNF can be improved through inoculation of soils with effective and compatible elite rhizobial strains (Abaidoo*et al*., 2007).

Cowpea response to inoculation has often been mixed, with some reports showing significant increases in yield (Giller, 2001) and others showing little or marginal differences between inoculated and uninoculated crops (GRDC, 2013). Responses to rhizobial inoculation by legumes are influenced by several ecological factors especially N and organic matter contents of soils as well as the size of indigenous rhizobial populations (Zilli*et al*.,2011). There exist within- and between-field variations in these and other soil factors and farms located within less than 50 m of homestead may often be of higher soil fertility than those that are further away (Zingore*et al*., 2007).

In Nigeria, cowpea is a major staple and a source of income for farm households. However, yields are often low, commonly being less than an average of 1000 kg/ha in most smallholder farms (Cissé and Hall, 2003). In addition to low soil fertility, sub-optimal BNF due to ineffective rhizobia may be contributory to the often observed low yields (FAO, 1984). Thus, the crop may benefit from inoculation with effective rhizobia. However, inoculation of cowpea is not a common practice in the country and little work has been done to determine cowpea response to inoculation. This study, therefore, wascarried out to (i) determine the response of cowpea to rhizobial inoculation in some soils of Sudan savanna of Nigeria, (ii) to establish whether proximity of fields to farm homesteads influence physico-chemical properties of soils, and (iii) to determine the effect of location and proximity of fields to farm homesteads on cowpea response to inoculation.

2.0 MATERIALS AND METHODS

2.1 Study Area

Soil samples were collected from 15 locations within the Sudan savanna zone of Nigeria. At each location, soils were collected from sites close to homesteads (0-50m) and further away from homesteads (> 50 m).The Sudan Savanna agro-ecological zone extends between latitudes 9° 30[1] and 12° 31[1] N and longitutes 4°30[1] E to 14° 30[1] E, occupies about 22.8 million hectares (Manyong*etal*., 1995). Its rainfall pattern is unimodal and ranges in space from 600 to 1000 mm per annum.

The main soil types found in this part of the savanna are classified as Entisols, Inceptisols and Alfisols, which are well-drained and formed of parent materials rich in quartz and crystalline rocks of basement complex and sedimentary deposits (Enwezor*etal*., 1990). Textural classes range from loam to sand, a common feature of these soils is their low organic matter content, cation exchange capacity, and nutrient content, especially nitrogen and phosphorus.

Greenhouse Study

The study was conducted in a screen house at the International Institute of Tropical Agriculture Kano (Long 8° 30[1]00[11]E; Lat. 11° 30[1]00[11]N), the mean annual rainfall ranges from 1000 mm in the South to 800 mm in the North.. Kano state lies approximately between Latitudes 10° 33[1] N and 12° 23[1] N and Longitudes 7° 45[1] E and 9° 29[1] E, the wet season last from May to Mid - October with a peak in August while the dry season extends from Mid - October to Mid – May annual rainfall ranges from 800 mm to 900 mm with a mean annual temperature is about 26°C(Olofin, 2008). Soil samples were added to 3 L pots at the rate of 3 kg per pot and seeded at the rate of 4 seeds per pot. Cowpea variety ITK90-499 was used for the experiment. Each pot was thinned to 2 seedlings per pot one week after emergence.Plants were either supplied with nitrogen at 80 kg N/ha or inoculated with yeast extract mannitol (YEM) broth of *Bradyrhizobium* sp. strain USDA 3384 or strain USDA 33451 at the rate of 5 ml per plant stand. Nitrogen application and inoculation were carried out after thinning. Plants were watered regularly using sterile distilled water and harvested at 7weeks after emergence.

Experimental design and statistical analysis

The experiment was a 15 x 2 x 4 factorial in a completely randomized design (CRD) replicated three times. The factors were (i) location (15), (ii) proximity to homestead (near or away) and N sources (4). The N sources were (i) Control (ii) + N at the rate of 80 kg N/ha using Urea, (iii) Inoculation with strain USDA 3384 and (iv) Inoculation with strain USDA 3451.

2.2 Soil sampling and analysis

Soil samples were collected from 20 different points each at 0-20 cm depth using a sterilsed augerto avoid contamination and were bulked to form composites. The soil samples were taken to the laboratory and a subsample taken and air-dried for physico-chemical analyses.The remaining samples were prepared moist for greenhouse study. Soil aggregates were gently crushed and passed through a 2-mm sieve.Physical and chemical analyses were carried out by standard methods (IITA, 1989), withsoil particle size determined by the hydrometer method and pH using a pH-meter in water (soil solution ratio 1:2:5).Soil organic matter was determined using the Walkley and Black method, total nitrogen by the Kjeldahl method andavailable phosphorus by the Bray P1 method. The results of the soil analyses are as presented in Table 1.

2.3 Data Analysis

The datawere subjected to statistical analysis using MINITAB 16.0. Analysis of variance (ANOVA) of the general linear model was used to check for significant effects and significant means were separated using Duncan Multiple range test (DMRT).

3.0 RESULTS

3.1 Soil characteristics of the study area

The physical and chemical properties of soils used for this experiment are presented in (Table 1). Soils obtained from the experimental site were slightly acidic to slightly alkaline for soils close to homestead 5.8-8.3 while for those away from homestead it ranges between moderately acidic to neutral 4.7-7.5

Total nitrogen was low for all locations (0.02 g kg^{-1} - 0.11g kg^{-1}), also organic carbon was low for all locations but a moderately high value was observed with Tudunwada and Kiruclose to homestead (9.3g kg^{-1} and 9.4g kg^{-1}).Available P ranges from low to moderately high but very high in Bebeji, Tudun Wada, Kiru, Wudil, Gaya, Warawa, Gezawa, Minjibir, Bichi, forsoils obtained close to homestead and Bebeji, Tudun Wada, Bunkure, Garko away from homestead.. Calcium and magnesium ranges between low and moderate in all locations except for Tudunwada which was high in calcium (10.64 cmol kg^{-1}), moderate in Magnesium with soils near homestead (1.04cmol kg^{-1}). Results of potassium ranges from low to moderately high in all location but high for Rano, and Kiru and very high in Tudunwadausingsoils close to homestead also in Garko and Bebeji further away from homestead.

RESULTS

Table 1.Physico-chemical characteristics of soils sampled across 15 locations in the Sudan Savanna

Location	pH ($H_2$0)	OC	N	P (mg kg^{-1})	sand	silt	clay	Ca	Mg	K
		(g kg^{-1})				%		cmol kg^{-1}		
Bunkure	5.8(6.7)	4.7 (7.7)	0.04 (0.07)	15.64(21.64)	74 (66)	13 (19)	12 (14)	3.66(6.30)	0.37 (0.48)	0.27(0.24)
Rano	6.5 (5.3)	7.1(6.2)	0.06 (0.06)	16.50(12.43)	58 (60)	25 (26)	16 (14)	5.20 (3.12)	0.51 (0.33)	0.70 (0.25)
Bebeji	7.4 (7.0)	6.4(8.4)	0.06 (0.09)	38.99(36.42)	58 (60)	27 (26)	14 (14)	6.64 (5.99)	0.57 (0.58)	0.44 (0.61)
Tudun Wada	8.2 (6.3)	9.3(8.4)	0.08 (0.07)	89.32(23.56)	58 (60)	27 (26)	14 (14)	10.64 (4.35)	1.04 (0.48)	1.75 (0.55)
Kiru	8.2 (5.3)	9.4(4.4)	0.11 (0.03)	44.43 (6.44)	62 (72)	25 (16)	12 (12)	7.59 (2.02)	0.81(0.26)	0.94 (0.21)
Wudil	8.3 (5.8)	4.6 (3.9)	0.04 (0.03)	39.85 (4.29)	82 (80)	7 (10)	10 (10)	2.91 (1.41)	0.51(0.23)	0.57 (0.23)
Gaya	7.5 (7.5)	3.5 (3.7)	0.03 (0.03)	28.49(11.15)	82 (84)	7 (6)	10 (10)	3.12 (3.87)	0.41 (0.34)	0.50 (0.26)
Garko	6.0 (6.4)	3.1 (4.8)	0.03 (0.04)	5.36 (20.99)	78 (76)	9 (12)	12 (12)	2.02 (3.66)	0.25 (0.50)	0.21 (0.77)
Warawa	7.0 (6.5)	5.3 (4.0)	0.05 (0.03)	41.99(14.57)	78 (74)	9 (14)	12 (12)	4.62 (3.56)	0.52 (0.47)	0.53 (0.22)
Albasu	6.6 (6.6)	4.2 (4.2)	0.04 (0.03)	9.22 (12.43)	70 (76)	15 (12)	14 (12)	4.14 (3.39)	0.50 (0.45)	0.39 (0.29)
Sumaila	6.6 (6.6)	2.9 (3.7)	0.03 (0.02)	11.79 (8.79)	74 (76)	13 (12)	12 (12)	2.91 (2.57)	0.26 (0.31)	0.21 (0.23)
Gezawa	7.0 (5.9)	5.3 (3.4)	0.05 (0.03)	29.56(10.93)	82 (80)	7 (10)	10 (10)	3.70 (1.14)	0.40 (0.21)	0.45 (0.23)
Minjibir	6.5 (5.5)	6.0 (4.2)	0.06 (0.03)	62.34(12.43)	82 (80)	7 (10)	10 (10)	2.57 (1.68)	0.33 (0.26)	0.44 (0.16)
Bichi	6.8 (5.8)	4.4 (4.3)	0.04 (0.04)	37.71 (5.79)	78 (86)	9 (6)	12 (8)	3.49 (1.17)	0.41 (0.14)	0.32 (0.15)
Bagwai	6.9 (6.5)	3.8(3.3)	0.03 (0.03)	16.71 (4.29)	84 (48)	5 (38)	10 (14)	2.91 (2.12)	0.41 (0.27)	0.37 (0.13)
Mean	**7.02 (6.3)**	**5.3 (5.0)**	**0.05(0.04)**	**32.53(13.74)**	**73.7(72.0)**	**13.9(17)**	**12 (12)**	**4.41(3.11)**	**0.49 (0.35)**	**0.50 (0.30)**

Means without bracket are close to homestead while those in bracket are away from homestead

OC= Organic Carbon, N= Total Nitrogen, P= Available Phosphorus, Ca= Calcium, Mg= Magnessium, K= potassiu

Table2: Interaction between Location, Proximity to Homestead, And NSource for Nodule Dry Weight of Cowpea (g/Plant)

Nodule dry weight recorded the highest in plant inoculated with USDA 3451 in soils sampled away from homestead at Albasu. The plant inoculated with USDA 3384 or treated with N on soil sampled near homestead at Tudunwada had the lowest nodule weight.

LOCATION	FAR AWAY				HOMESTEAD			
	CONTROL	USDA3384	+N (Urea)	USDA3451	CONTROL	USDA3384	+N (Urea)	USDA3451
RANO	0.04[cd]	0.08[cd]	0.07[cd]	0.12[bcd]	0.09[cd]	0.25[abcd]	0.10[bcd]	0.17[bcd]
BICHI	0.14[bd]	0.44[abcd]	0.20[abcd]	0.27[abcd]	0.12[bcd]	0.19[bcd]	0.10[bcd]	0.20[abcd]
TUDU WADA	0.37[abcd]	0.15[bcd]	0.24[abcd]	0.20[abcd]	0.03[cd]	0.01[d]	0.003[d]	0.10[bcd]
BUNKURE	0.09[bcd]	0.24[abcd]	0.03[cd]	0.05[cd]	0.10[bcd]	0.06[cd]	0.03[cd]	0.11[bcd]
MINJIBIR	0.17[abcd]	0.04[cd]	0.03[cd]	0.04[cd]	0.17[bcd]	0.20[abcd]	0.20[abcd]	0.30[abcd]
ALBASU	0.27[abcd]	0.23[abcd]	0.40[abcd]	0.73[a]	0.46[abcd]	0.65[ab]	0.47[abcd]	0.23[abcd]

Means with the same letters are not statistically different (P>0.05)

Table 3: Interaction between Locations, Soil and N Source for Number Nodule of Cowpea (g/plant)

Number of Nodule had the highest in plant inoculated with USDA 3451 in soils sampled close to homestead at Gaya. The plant treated with N close to Homestead recorded the lowest at Bunkure, which was statistically similar to soils inoculated with USDA 3384 close to Homestead and USDA 3384 Further away from Homestead at Minjibir.

LOCATION	FAR AWAY				HOMESTEAD			
	CONTROL	USDA3384	+N (Urea)	USDA3451	CONTROL	USDA3384	+N (Urea)	USDA3451
KIRU	26.67[abc]	24.67[abc]	9.67[bc]	41.33[abc]	22.67[abc]	13.67[abc]	15.33[abc]	16.00[abc]
TUDU WADA	12.33[abc]	24.67[abc]	2.33[c]	13.67[abc]	59.67[abc]	27.00[abc]	63.67[abc]	28.00[abc]
BUNKURE	72.00[ab]	23.00[abc]	11.67[abc]	18.00[abc]	7.00[bc]	3.33[c]	1.33[c]	20.33[abc]
MINJIBIR	26.33[abc]	4.00[c]	7.67[bc]	10.33[bc]	18.33[abc]	26.00[abc]	35.67[abc]	61.33[abc]
GAYA	54.33[abc]	30.67[abc]	9.67[bc]	24.67[abc]	38.67[abc]	35.00[abc]	18.67[abc]	83.67[a]
ALBASU	68.67[abc]	28.67[abc]	46.00[abc]	73.33[ab]	37.00[abc]	77.47[ab]	44.00[abc]	33.67[abc]

Means with the same letters are not statistically different (P>0.05)

The interaction between Location and Proximity to homestead for Nodule Number of cowpea (g/plant)

The interaction between site and proximity to homestead significantlyaffected the number of plant nodules. Plant grown on soil sampled near the homestead at Albasu had the highest number of nodules, which where only marginally higher than those grown on soils near the homestead in Rano and those grown on soils away from the homestead in Albasu, Gaya, Warawa, Tudunwada, and Babeji (Fig.1).The lowest number of nodules were obtained in plant grown on soils near the homestead Bichi and those grown on soils away from homestead in Bunkure. Nodule number of plants grown on soils near homesteads was greater than those on soils away from homesteads. Only at Rano, Bagwai and Bunkure, while nodule number of those on soils away from homestead were greater than those near homesteads at Kiru, Bebeji, Tudunwada, Bichi and Minjibir.

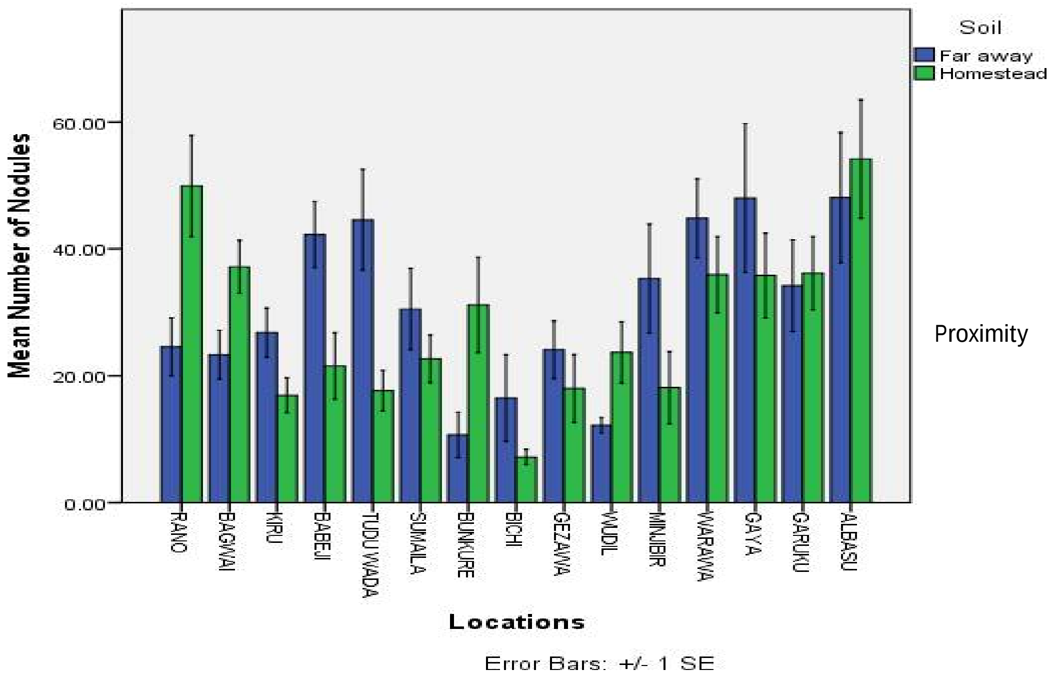

Fig.1: Interaction between location and proximity to homestead for Number of Nodules per plant.

The interaction between Location and proximity to homestead of shoot dry weight of cowpea (g/plant)

The interaction between proximity to homestead significantly affected the shoot dry weight of plants g/plant (Fig.2). Plant grown on soils further away from homestead had the highest shoot dry weight in Tudun wada followed by Babegi, which was marginally higher than albasu further away from homestead and also plant grown on soils close to homesteads at Rano, Bagwai, Kiru, Gezawa, Warawa (Fig 2). The lowest plant grown on soil sampled far away from homesteads was at Bunkure and Gezawa while plant grown on soils close to homestead Minjibir and Tudun wada recorded the lowest dry weight of shoot.Generally, the highest shoot dry weight was recorded at Tudun wada and Babegi for far away from homestead while Rano, Bagwai, Kiru, Bunkure , Gezawa, wudil and Warawa had the highest dry shoot weight for soil close to homestead

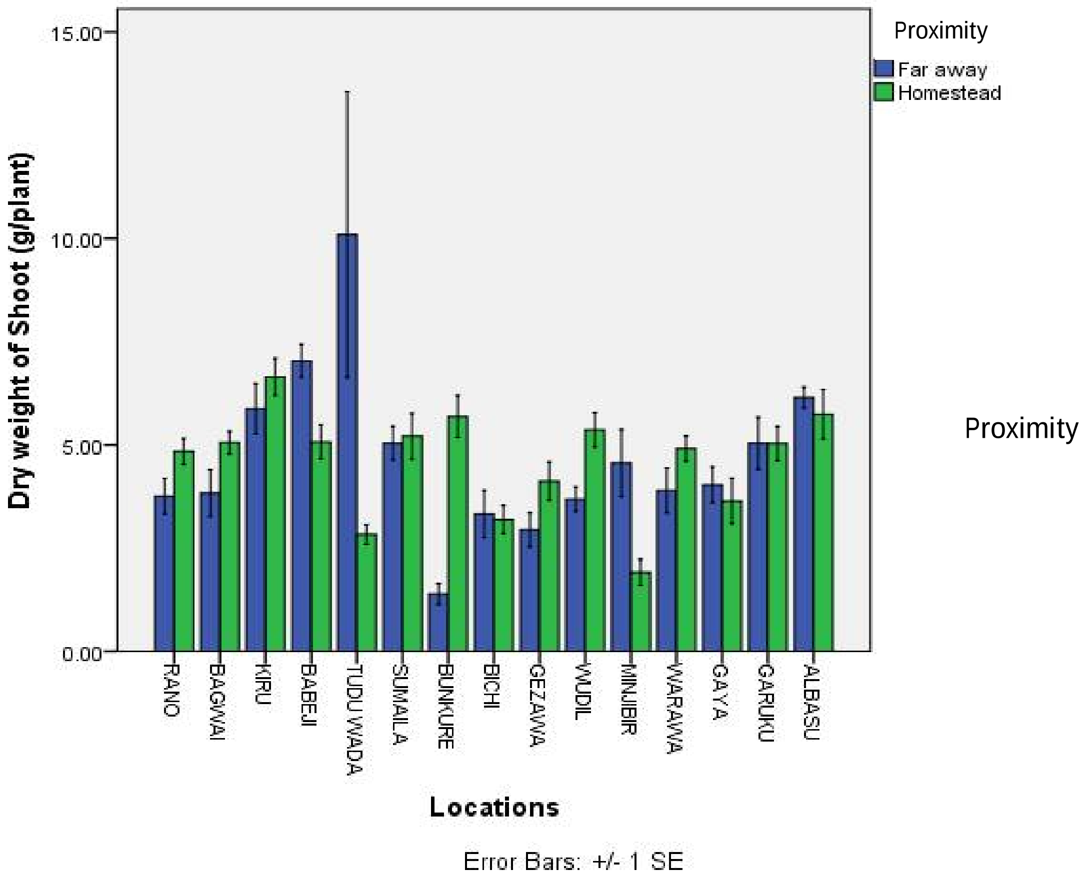

Fig2: Interaction between Location and proximityto homesteads for shoot dry weight of cowpea (g/plant)

The interaction between Location and proximity to homestead on nodule dry weight of cowpea (g/plant)

The interaction effect between plant grown on soils sampled significantly affected the the dry weight of nodule in g/plant. Plant grown on soil sampled further away from homesteads recorded the highest dry weight of nodules at Albasu, Gaya, Babeji, sumaila, and tudun wada while plant grown from soils sampled close to homestead had the highest dry weight of nodules at Rano, Bagwai, kiru, Bunkure, Wudil and warawa. The lowest dry weight of nodules was recorded at Bunkure, and Rano for plant grown on soil further away from homestead also Bichi and Minjibirrecorded the lowest for plant grown on soil close to homestead. Dry weight of nodules were greater under plants grown on soils further away from homestead only at Albasu, Gaya, and Bichi. While plant grown on soils close to homesteads was higher than those further away from soils under Homestead in Rano, Bagwai, Kiru, Bunkure, Warawa, Garuku.

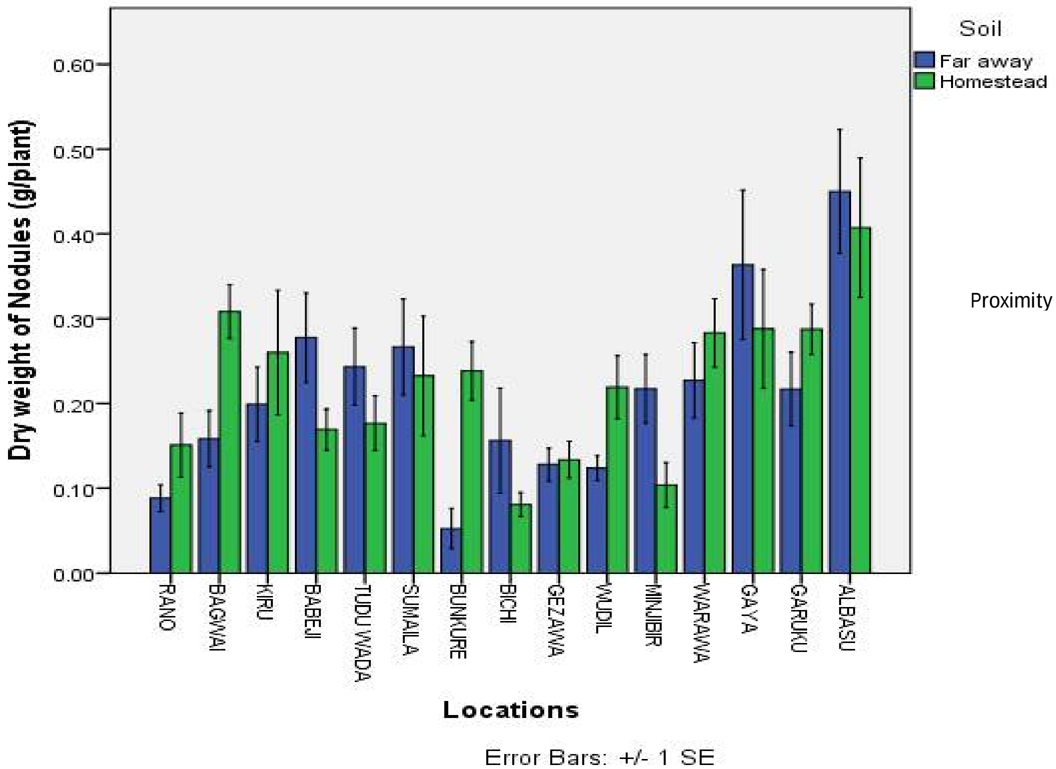

Fig3: Interaction between location and proximity soil for dry weight of Nodules (g/plant)

The interaction between Location and proximity to Homestead forChlorophyll content (ppm)

The interaction between site and proximity to Homestead significantly affects the Chlorophyll content in (ppm). Plans grown on soils close to homestead had the highest chlorophyll content at Kiru, Babegi, Tudunwada, Garuku and Albasu which was statistically similar to Rano, Bunkure, and warawa close to homestead (Fig. 4). The lowest chlorophyll content was at Bunkure further away from homestead while for plant grown on soils close to homestead, Minjibir and tudunwada recorded the lowest chlorophyll content.

Generally, kiru and Babeji had the highest chlorophyll content under plant grown on soils far away from homestead while Rano and Bunkure recorded the highest for plant grown on soils close to homesteads.

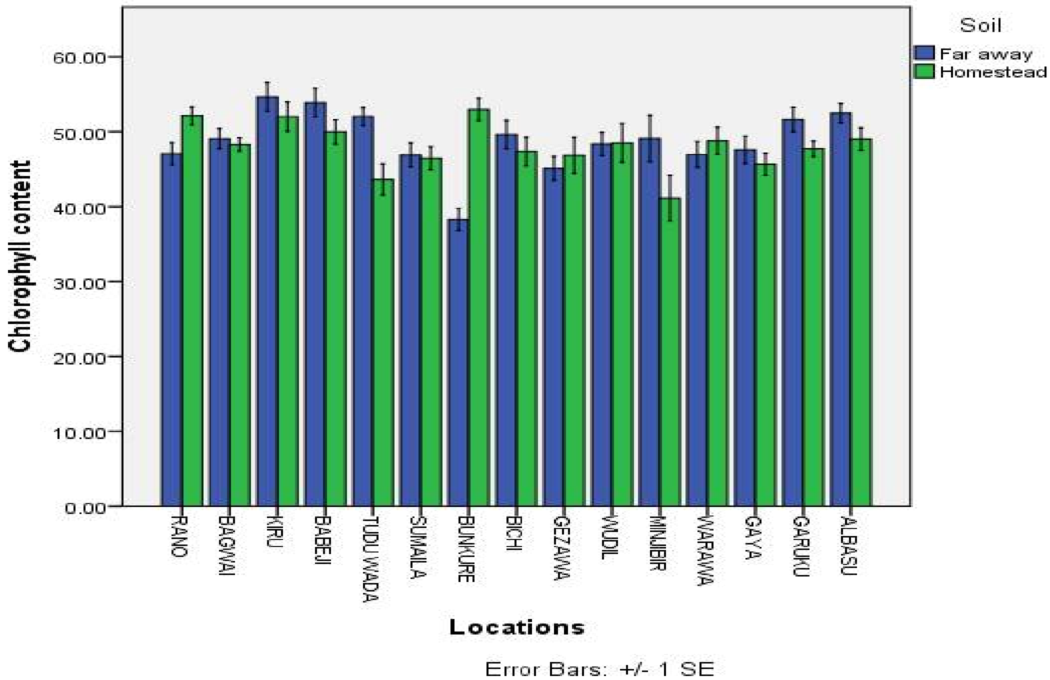

Fig4: Interaction between site and proximity for Chlorophyll content (ppm)

4.0DISCUSSION

Location and proximity had a significant effect on yield and yield parameters of cowpea, suggesting the effect of environment and management practices which may lead to variation in soil properties as a result of differential accumulation of organic matter, nutrients and soil water. These will in turn affect the population of microorganisms to different degrees. For instance, organic matter plays an important role in mineral nutrition of rhizobia in the soil by acting as a source of C, N, Ca and S required for their growth and survival (Singh, 2000). Additionally, a buildup of organic matter and the addition of manure are likely to create conditions that encourage survival and persistence of rhizobia in soil (Sanginga*et al*., 2002). However, the organic matterand nitrogen contents of the soils used for the current study were generally low (Enwezor et al., 1989), which may account for the ineffectiveness of native rhizobia in some of the locations and total nitrogen could be attributed to the effects of soil erosion, leaching and bush burning predominant in the sampling area. Similarly, the low exchangeable cations may be due to the low clay activity and low organic content of the soil. Percent sand was higher compare to clay and silt also the soil pH ranges from slightly acid to neutral in all locations. Several researchers showedthat the texture of soil remain a major constraint to cropproduction in large scale in tropical Africa. In this way,Nyabyenda (2005) reported that the production of grainlegumes had been low due to declining soil fertility as aresult of soils impoverishment in organic matter contentand corresponding texture.

In this study, proximity of fields to homesteads yields were significantly higher which is in accordance to the research carriedout in South Africa by Waddington and Karigwindi (2001); Zingore *et al.*(2007) whose study shows that the fertile plots is often closest to homesteads, as a result of continous accumulation of organic ammendment including all kinds of manure and household waste applied directly surrounding the villages.

In this studies, yield parameters were significantly higher in soils further away from homstead. Interaction between location and site significantly affect the yield and yield parameters,Cowpea yield can be relatively high when grown in soils with low fertility. Moreover, high rates of nitrogen and excessive moisture are detrimental and can result in excessive vegetative growth, delayed maturity and pod shattering (Ali *et al.*, 2004).

Soils sampled from different location in this study have allowed us to understand the effects of inoculation on the yield parameters of cowpea. Interaction between location, soil and N source significantly affect Nodulation and N fixation and are a function of legume fix and are affected by the rhizobia strain, Management practices, cropping system and environmental factors. Failure of inoculation to elicit response in cowpea could be attributed to the presence of effective indigenous rhizobia or highly competitive but ineffective indigenous strains that lock out the inoculant strains from occupying the nodules (Theuri*et al*., 2006).

CONCLUSION

Yield and yield parameters are more affected by the influence of location than the influence of N source suggesting the effectiveness of indigenous cowpea rhizobia in most of the soil studied.

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