Original Research Article

Effect of Stand Densities and NPK Fertilizer on Growth and Calyx Yield of Roselle (Hibiscus sabdariffa L.) in Sudan Savanna Zone of Nigeria part 1: Growth Characters

Abstract

Field experiment was conducted during 2019 rainy season at Teaching and Research Farm of the Centre for Dryland Agriculture (CDA), Bayero University, Kano, Nigeria (Latitude 11^{0}58'N and Longitude 8^{0}26') and Training and Research Farm of Kano University of Science and Technology, Wudil located at Gaya to evaluate the response of Roselle to NPK fertilizer and stand densities on calyx yield. The treatments consisted of five levels of NPK Fertilizer (0, 80, 100,120 and 140kg/ha) and four stand densities (2, 3, 4 and 5 plants/hill) which were laid out in a randomized completely block design (RCBD) with three replications. Data were collected on plant height, number of leaves per plant, leaf area per plant and number of branches per plant. These were subjected to analysis of variance (ANOVA) using GenStat 17th Edition and means were separated using Duncan Multiple Range Test (DMRT). The result showed that stand density of 5 plant/stand significantly produced the tallest plants. The result also showed that application of different NPK levels had significant ($P<0.05$) effect on plant height, number of leaves and leaf area of Roselle across the two experimental sites. The highest value of plant height, number of leaves, leaf area and number of branches were influenced by the application of 140kg/ha of NPK at both locations. The control plots recorded the lowest value for all the characters studied. Simple correlation showed that growth and yield characters were positively correlated at the two experimental sites. Based on these findings, 5 plant/stand and application of 140 kg/ha NPK fertilizers are recommended.

Keywords: Stand Densities Fertilizer, Calyx, Roselle, and Sudan Savanna

1.0 Introduction

Roselle is grown extensively in the Sudan Savanna for local consumption and for export to the Middle East and Europe. *Hibiscus sabdarifa* is adapted to a wide range of soil conditions and is often grown on relatively infertile soils, but economic yield are obtained on soils which are well-supplied with organic matter and essential nutrients (Imori *et al.*, 2012).Roselle is tolerant to relatively high temperature throughout the growing and fruiting periods (Morton, 1987).Roselle is very sensitive to frost. It thrives best in tropical and subtropical regions (Galandu, 2006). Where rainfall is inadequate, irrigation has given good results (Bala *et al.*, 2008).

Roselle is usually propagated by seed, but grows readily from cuttings which results in shorter plants preferred in India for inter-planting with tree crops though the yield of calyx obtained from this type of intercropping is relatively low (Gupta,1989 and Muoneke *et al*., 2001). Seedlings may also be raised in beds and transplanted when it is 7.5 to 10cm high, but seeds are more commonly planted directly in the field. In KwaZulu-Natal, the plant is usually sown using seed after a good summer rain. Deeper ploughing is recommended in preparing the seed bed as it is deep-rooted crop. The seeds are hand planted at the rate of 7 to 9 kg/h at 80 to 100cm between stands apart within the rows of 1.2 to 1.5cm apart giving a plant density of between 6,800 and 10,500 plants per hectare.

Constrains to Roselle production in West Africa and Nigeria in particular includes majorly the use of inappropriate agronomic practices and damage by pest and diseases. There is paucity of research information on the agronomy of the crop in the study area (Aliyu and Tanimu, 1998). In areas where the crop is being grown, farmers lack some basic research information on the crops planting/sowing time, best rate of seed/planting material per hectare and other important agronomic practices for better growth and yield.

Based on these constrains and the uses of Roselle as earlier highlighted to economic growth and human health coupled with paucity of research information on the agronomy of the crop, the present study provides relevant information on agronomic practices with respect to Stand Density and NPK Fertilizer Rates on the growth and yield of calyx.

2.0 Materials and Methods

2.1 Experimental Sites

Field experiments were conducted during 2019 wet seasons at the Teaching and Research Farm of Centre for Dryland Agriculture (CDA), Bayero University Kano (11^0 58'N,8^0 26'E and 460m above sea level) and Teaching and Research Farm of Kano University of Science and Technology, Wudil ($11^0$52N and longitude $9^0$20E). The two locations are in the Sudan savanna zone of Nigeria.

2.2 Land Preparation

The lands were ploughed, harrowed, ridged and marked out into plots as per treatments using tractor mounted disc plough and ridger at BUK and with animal plough at Gaya local government area.

2.3 Treatments and Experimental Design

The treatments consisted of five NPK Fertilizer rates (0, 80, 100, 120, and 140 $kgha^{-1}$) and four stand densities (2, 3, 4 and 5, plants/hill). These were factorially combined and laid out in a Randomized Completely Block Design (RCBD) with three replications. The plot sizes consisted of 4 ridges each of 3m (12 m^2) lengths and 0.75m spacing. The net plot size consisted of two inner ridges given an area of $4.5m^2$. The gross plot size was 3m x 3m ($9m^2$) Including all the discards of 1m and 0.5m between each plots and replications respectively. This is to facilitate easy and safe movement within the trial. Soil samples were taken at 3 points at both locations. The samples were bulked and analyzed for physico-chemical properties.

The seeds were sown as per the sowing date and were spaced at 75cm x 50cm using seed rates in accordance with the stand population for each treatment. Local variety (mai kofi) of roselle was used and was sourced at Yankaba Local market located at Hadejia Road in Nasarawa Local Government, Kano State. Hoe weeding was carried out at intervals of 3 weeks to keep the plots weeds free. A total of three hoe weeding were carried out beginning from third week after sowing (WAS). At each location, NPK (15:15:15) fertilizer) was applied at 0kg/ha, 80kg/ha, 100kg/ha 120kg and 140kg/ha. The fertilizer applications were done as split doses at 4 and 6 weeks after sowing (WAS).

2.4 Data Collection and Statistical Analysis

Data was collected on plant height (taken with the aid of measuring tape from the base of the plant to the tip), number of leaves per plant, leaf area per plant and number of branches per plant. The data collected was subjected to analysis of variance (ANOVA) using Genstat 17th Edition (Genstat, 2011). The treatment means that were significantly different were compared using Duncan (Duncan, 1995) multiple range test (DMRT). Relationship and association between some important growth and yield characters were calculated using simple correlation analysis to describe the form of the relationship.

3.0 Results

3.1 Results

The physico-chemical properties of the soil of the experimental sites before the establishment of the trials are presented on Table 1. The soil texture at BUK and Gaya was sandy-loam. The soil reaction of BUK and Gaya was slightly neutral. The total Nitrogen in BUK (0.32g/kg) at 15cm was also higher than that of Gaya but are found to be low and below critical level. However, the organic carbon content in Gaya was lower than that of BUK. The cation exchange capacity (CEC) of Gaya was higher than that of BUK. But there was some variation in the concentration of some exchangeable bases of the soils from the two locations. Results show that at 15cm, the concentration of Mg at BUK is (1.18) cmol/kg but (1.34) cmol/kg at Gaya.

3.1.1 Plant height

The effects of stand densities and inorganic fertilizers on plant height of Roselle at the two experimental sites are presented on Table 2. The highest plant height was recorded from the stand densities of 5plant/hill and 4plant/hill at Gaya and BUK respectively. The shortest plant was from the 3 plant/hill. No significant effects were observed from the 2 plant per hill across the two trial locations.

Effects of NPK fertilizer was significant ($p>0.05$) at 4 and 6 WAS only at the two experimental locations. The tallest plant was recorded from the application of 100kg/ha of NPK at 6 WAS in both location a. While the shortest plant was obtained from the control plot. The other treatments 40, 60, and 80 kg/ha produced plants that were consistently taller than the ones obtained from the control plots.

Significant interaction of stand density and NPK fertilizer rates on plant height of Roselle were observed at 4 WAS in Gaya and 6 WAS in BUK as presented in Table 3. At 6 WAS the tallest plant was obtained from combined 5 plant/hill and 100 kg/ha of stand density and NPK fertilizer at Gaya. The shortest Roselle crop was also recorded on control plot were neither of the fertilizer was applied.

3.1.2 Number of Leaves per Plant

Table 4 shows the effect of stand densities and NPK fertilizer on the number of leaves of Roselle at various sampling periods in BUK and Gaya. Neither stand densities nor NPK fertilizer significantly ($p<0.05$) affected the number of leaves of Roselle at 2, 4 and 6 WAS at the two trial locations. However, the highest mean value of number of leaves were obtained from 120kg NPK/ha compared to the other levels and the control plots. Likewise, the interaction of factors on number of leaves per plant was not significant, at the two locations.

3.1.3 Leaf Area (cm^2) per Plant

Table 5 shows the effect of stand densities and NPK fertilizer on the leaf area of Roselle at the various sampling periods in the two locations. Roselle crop responded significantly to the stand densities at both sampling period in both locations. The highest value for leaf area were obtained from the stand density of 5 plant per hill at Gaya and it was followed by 3 plant/hill while the least mean leaf area was obtained from the 2 plant/hill. Also, at 8 WAS in BUK the highest mean leaf area was obtained from the stand density of 5 plant/hill which was more than that obtained from stand density of 3 and 2 plant/hill that were statistically at par. Likewise application of NPK significantly influenced leaf area at both sampling period in both locations. Roselle crop that received 100kg NPK/ha had the highest LA, followed by that of 80 and 60 kg NPK/ha then 40 kg NPK/ha while the control had the least value. An interaction of stand density and NPK fertilizer was observed at 4WAS in Gaya (Table 6).

3.1.4 Number of Branches per Plant

Number of branches per plant as influenced by stand densities and NPK fertilizer rates at 2, 4 and 6 WAS at the experimental locations (Gaya and BUK) are presented on Table 7. Stand densities did not significantly ($p<0.05$) affect the number of branches at the two experimental locations. Likewise, application of NPK fertilizer did not significantly affect the number of branches of Roselle at the two trial locations.

Table 1: Physico-chemical properties of the soil at BUK and GAYA

Soil properties	0-15cm		15-30cm	
	BUK	GAYA	BUK	GAYA
Physical composition (%)				
Clay	14	11	9	8
Silt	25	29	17	13
Sand	56	53	65	44
Textural class	Sandy-loam	Sandy-loam	Sandy-loam	Sandy-loam
Chemical composition				
PH in H_2O	7.43	7.52	7.20	5.87
Organic carbon (g kg^{-1})	0.30	0.21	0.22	0.43
Total Nitrogen) (g kg^{-1})	0.52	0.27	0.11	0.21
Available phosphorus (mg kg^{-1}	19.75	15.68	11.88	10.62
Exchangeable Bases (cmol/kg)				
Ca^{2+}	4.24	1.20	2.27	2.10
Mg^{2+}	2.14	2.44	1.18	1.34
K^{+}	0.30	2.70	1.23	1.58

Na^+	1.58	1.13	0.14	0.13
CEC	9.32	9.63	4.82	4.35

Analyzed at Soil Science Laboratory CDA, Faculty of Agriculture, BUK

Table 2: Effect of Stand Density and NPK Fertilizer Rates on Plant Height (cm) of Roselle during 2019 Rainy Season at BUK and Gaya.

Treatment	GAYA			BUK		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
Stand densities (SD)						
2 plant/stand	12.52c	20.37c	25.08d	11.65c	15.73c	28.69
3 plant/stand	13.87b	23.90b	28.16c	11.24c	14.82c	25.09
4 plant/stand	15.01b	32.28a	45.70b	18.33a	24.82b	31.97
5 plant/stand	17.48a	32.38a	55.40a	15.26b	28.11a	33.23
Prob.-level	0.024	0.002	0.003	0.041	0.010	0.140
SE ±	0.434	0.838	0.983	0.670	0.992	1.775
NPK (kg/ha)						
0	13.61c	22.70c	31.46d	13.37b	19.47b	25.76c
80	13.43c	24.72c	34.89c	13.48ab	19.48b	27.25bc
100	13.89bc	27.62b	37.94c	14.29ab	19.49b	29.63b
120	15.09b	28.89b	41.98b	14.45ab	21.73ab	29.24b
140	17.59a	33.33a	46.65a	15.03a	23.35a	36.85a
Prob.-level	0.004	0.001	0.016	0.004	0.022	0.009
SE ±	0.483	0.937	1.099	0.509	0.749	1.030
Interaction						
SD*NPK	0.021	0.324	0.641	0.390	0.233	0.412

Means followed by different letter (s) differ significantly at 5% level using DMRT

Table 3: Interaction between Stand Densities and NPK Fertilizer Rates on Plant Height (cm) at BUK.

Treatment	NPK (kg/ha)				
	0	80	100	120	140
Stand density					
2 plant/stand	15.34c	18.50c	23.30b	24.20b	34.13a
3 plant/stand	15.22d	20.74c	22.87b	28.15c	40.64c
4 plant/stand	18.10b	23.61b	28.90b	32.41b	46.32b
5 plant/stand	32.08c	35.59b	56.64a	56.86a	62.30a
SE ±			3.968		

Means along the same column and row with different letter (s) are significantly difference at 5% level of significant.

Table 4: Effect of Stand Density and NPK Fertilizer Rates on Number of Leaves of Roselle during 2019 Rainy Season at BUK and Gaya.

Treatments	GAYA			BUK		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
Stand Densities						
2 plant/stand	5.27c	8.25c	52.42a	3.29d	6.11c	9.39c
3 plant/stand	13.35a	19.24b	34.92b	4.41c	6.66c	9.36c
4 plant/stand	11.32b	30.93a	22.08c	5.14b	7.50b	13.80b
5 plant/stand	14.67a	32.30a	10.46d	7.99a	18.34a	30.76a
Prob.-level	0.001	0.007	0.001	0.048	0.025	0.005
SE $\pm$	0.516	0.642	1.032	0.224	0.228	1.156
NPK (kg/ha)						
0	9.38c	25.61c	29.73d	4.73b	12.42bc	15.38b
80	10.20bc	27.36c	33.07cd	5.24b	11.32c	17.92b
100	10.33bc	27.29c	37.13c	5.00b	13.51b	18.53b
120	11.60b	31.04b	44.60b	5.24b	15.64b	19.99b
140	14.25a	38.56a	52.02a	6.06a	26.25a	34.08a
Prob.-level	0.010	0.003	0.045	0.046	0.031	0.022
SE $\pm$	0.577	1.154	1.674	0.272	1.292	2.100
Interaction						
SD*NPK	0.225	0.144	0.554	0.203	0.233	0.341

Means followed by different letter (s) differ significantly at 5% level using DMRT

NB: NS Not significant, WAS= Weeks after sowing

Table 5: Effect of Stand Density and NPK Fertilizer Rates on Leaf Area (cm^2) of Roselle during 2019 Rainy Season at BUK and Gaya.

Treatment	Leaf Area/Plant (cm^2)					
	GAYA			BUK		
	4WAS	6WAS	8WAS	4WAS	6WAS	8WAS
Stand densities						
2 plant/stand	35.79c	63.35b	50.84c	28.74ab	54.00a	61.99a
3 plant/stand	52.50bc	69.05b	87.14a	33.80a	45.08ab	62.36a
4 plant/stand	73.92a	0.135	101.65a	61.44bc	25.40ab	38.67b
5 plant/stand	87.10a	51.95b	71.44b	20.90b	37.32b	65.65
Prob.-level	0.035	0.007	0.009	0.040	0.028	0.021
SE ±	8.546	8.254	5.245	3.802	4.683	7.923
NPK (kg/ha)						
0	56.85c	59.26c	68.49	29.47	41.81	61.10
80	58.11c	84.44 a	62.74	32.81	45.64	63.24
100	66.15b	60.80bc	64.22	25.64	46.96	62.41
120	50.29d	85.24 a	67.69	25.65	44.38	66.20
140	80.23a	67.75 b	74.93	22.58	40.05	57.78
Prob.-level	0.004	0.001	0.032	0.044	0.035	0.042
SE ±	9.555	9.229	5.866	4.251	5.36	8.858
Interaction						
SD*NPK	0.066	0.302	0.411	0.277	0.612	0.180

Means followed by different letter (s) differ significantly at 5% level using DMRT
NB: NS Not significant, WAS= Weeks after sowing

Table 6: Interaction between Stand Densities and NPK Fertilizer Rates on Leaf Area (cm^2) at Gaya at 2 WAS

Treatment	NPK (kg/ha)				
	0	80	100	120	180
Stand density					
2 plant/stand	39.11f	41.12ef	42.93ef	59.4bcd	51.1bcd
3 plant/stand	48.1def	59.6bcd	60.2bcd	63.80bcd	74.0bc
4 plant/stand	51.3cdef	72.6bc	79.3ab	67.3bcd	82.41bc
5 plant/stand	53.11cdef	74.25bc	79.7bc	69.44bcd	102.9a
SE ±			2.197		

Means along the same column and row with different letter (s) are significantly difference at 5% level of significant (<0.05)

Table 7: Effect of Stand Density and NPK Fertilizer Rates on Number of Branches of Roselle during 2019 Rainy Season at BUK and Gaya.

Treatment	GAYA			BUK		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
Stand densities (SD)						
2 plant/stand	1.34c	2.56c	2.86d	2.02d	4.41c	6.63c
3 plant/stand	2.69b	5.15b	7.12c	3.03c	7.33b	9.37c
4 plant/stand	3.68a	7.58a	9.53b	5.77b	8.05b	8.05b
5 plant/stand	4.05a	8.02a	13.04a	7.76a	12.10a	15.09a
Prob.-level	0.029	0.001	0.131	0.039	0.014	0.220
SE +	0.159	0.326	0.305	0.222	0.618	0.250
NPK (kg/ha)						
0	1.94c	3.37c	3.86d	3.62c	5.95b	7.23c
80	2.50b	4.97b	6.00c	4.30bc	6.75b	8.32c
100	3.09a	5.56b	8.37b	4.37b	6.61b	8.62c
120	3.57a	5.92b	10.32b	4.76b	8.03b	11.06b
140	3.60a	9.31a	12.15a	6.13a	12.52a	15.50a
Prob.-level	0.013	0.002	0.024	0.031	0.024	0.011
SE +	0.173	0.364	0.341	0.248	0.691	0.581
Interaction						
SD*NPK	0.008	0.612	0.133	0.477	0.342	0.774

Means followed by different letter (s) differ significantly at 5% level using DMRT
NB: NS Not significant, WAS= Weeks after sowing

Table 8: Interaction between Stand Densities and NPK Fertilizer Rates on Number of Branches at BUK

Treatment	NPK (kg/ha)				
	0	80	100	120	140
Stand Density					
2 plant/stand	5.93e	7.10d	6.29e	24.20a	1.52g
3 plant/stand	8.96e	9.00e	6.28e	28.15a	2.88f
4 plant/stand	15.92b	11.29c	8.21e	32.41a	2.88f
5 plant/stand	18.880	16.25b	10.92c	56.86a	5.92e
SE +			0.681		

Interaction means in the year followed by letter(s) are significantly difference at 5% level of significant (<0.05) using DMRT.

Discussion

Effect of Stand Density on Growth of Roselle

The result from the experiment revealed that stand density significantly influenced most of the growth parameters of Roselle in both locations of the trials. Higher stand density tended to produce taller plants because of competition for sunlight and space. Similar observations were earlier reported by Arowosoge (2008).

Lower stand density at one plant/stand gave highest number of leaves and branches. Similar observation was earlier reported by Manga *et al*. (2009). This could be attributed to lower competition for water, nutrient and light, which allows the plant to express their full leaf production potentials.

Effect of NPK Fertilizer on Growth Characters of Roselle

Plant height was significantly influenced by the application of NPK at 4 and 6 WAS at BUK and Gaya respectively. This agreed with findings of Bala *et al*. (2008) who reported increase in plant height of Roselle from application of NPK at the rate of 60:30:30 on deep red Roselle cultivar. Meanwhile the tallest` performing plant height was recorded from application of 140 kg NPK at 12 WAS in BUK.

Application of the different NPK rates significantly affected the number of leaves and leaf area per plant at both locations. The least mean value leaf area was recorded from non-fertilized plots. The significant response of leaf area at different measurement periods shows the NPK applied influenced the photosynthetic path ways which in turn affect the source and sink of the plant in the two experimental locations. Similar findings by Alegbejo (1998) showed that increase in leaf, stem, total fresh and grain yield of grain amaranth increased with application of NPK fertilizer.

Number of branches of Roselle was not significantly affected from NPK fertilizer rates at the two trial locations. Lowest number of branches per plant was generally obtained from control plots. But progressive increase in the number of branches per plant of Roselle was observed with application of the different NPK levels. This disagree with findings of Bala *et al.* (2008), who reported significant increase from the application of NPK.

Chaudhary (2000) also observed that the N part of NPK promote vegetative performance of vegetables while Bamidele *et al*, (2000) reported that differences in growth indices of crops is normally attributed to their genetic make-up. Bala (2004) similarly recommended the use of compound fertilizer (NPK 20:10:10) at the rate of 205kg/ha for better growth performance.

Interaction of Stand Densities and NPK Fertilizer Rates on Growth of Roselle

Some interaction between the two factors were found to be significant on growth and of yield of Roselle. The two factors significantly affect plant height, number of branches/plants, number of flowers/plant and number of fruits/plants. No interaction effect on some characters such as stem diameter and number of seed per pod might be because of the morphological characteristics of the Roselle plant. Alofe *et al* (1995) and (El-Gamal *et al.*,1983) reported that increase dosage of N either singly or in combination with K or other nutrients stimulated vegetative growths of maize and Roselle plants. From most of the parameters recorded, no significant interaction was observed at both locations.

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