Production of Roselle (Hibiscus sabdarjffa L.) as Influenced by density and fertilizer rate in Kano State, Nigeria

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Abstract

Field experiment was conducted during 2019 rainy season at Research Farm of the Center for Dry-land Agriculture (CDA), Bayero University, Kano, Nigeria (Latitude $11^0 58'$N and Longitude $8^0 26'$) and Teaching and Research Farm of Kano University of Science and Technology, Wudil located at Gaya. The experiment was aimed at evaluating the response of Roselle to four levels of NPK Fertilizer (0, 80, 100 and 120kg/ha) and three stand densities (2, 3 and 4 plants/hill). The treatments, were laid out in a randomized completely block design (RCBD) with three replications. Data collected were subjected to analysis of variance (ANOVA) using GenStat 17th Edition and means were separated using Duncan Multiple Range Test (DMRT).The highest stand density of 4 plant/stand significantly produced the tallest plants, number of leaves, branches, total dry matter, relative growth rate, number of flowers, number of fruits and number of seeds/fruit. Two plants/stand produced lowest fruits yield/plant, fruit yield/hectare, seed yield/plant, calyx yield/plant and calyx yield/hectare in both locations. The result also showed that application of NPK fertilizer 120kg/ha rates 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, number of branches, number of pod per plant, calyx/plant and total calyx yield/hectare were influenced by the application of 120kg/ha of NPK across the two experimental sites. The control plots consistently produced the lowest value for all the characters studied. Based on these findings, the use of 4 plant/stand and application of 120 kg/ha NPK fertilizers were recommended for a better Roselle growth and yield at the two experimental locations within Sudan Savanna ecological Zone of Nigeria.

Introduction

Roselle belongs to the malvaceae family. The crop is native to tropical central and west Africa and is widely distributed throughout many tropical areas (Tindall, 1983).The crop is gaining popularity worldwide as such it has number of common names in Hausa (Yakuwa), Roselle (English), Isapa (Yoruba), Karkade in Arabic (Bala 2008). Roselle is grown extensively in the Sudan Savanna and Nigeria 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 (Tindall, 1983).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 (Morton, 1987). Where rainfall is inadequate, irrigation has given good results (Bala, 2008). The cultivation of roselle in West Africa is at subsistence level, usually as an intercrop among the main carbohydrates staples and other vegetables, China and Thailand are largest producers and control much of the world supply (FAO, 1998).Muoneke and Akingbade (2001) reported that the land area devoted for roselle cultivation in Nigeria has increased over the years. Roselle is produced for its calyces, seeds and fiber (Galaudu, 2006). Roselle is described as an emerging crop of economic importance whose extracts from the colour calyces are used in the preparation of local beverages drinks. There is however, little available research information and documentation that could help in an organized cultivation of the crop (Bodunde, 2006).Roselle serves as source of food, income, employment, raw materials and foreign exchange earner if production is well packaged Bala et al, 2008).Gibbon and Pain (1995) reported that the red calyces surrounding the fruits are used to brew non-alcoholic drinks and as coloring reagent for gelly, beverages and food.

Successful cultivation of any crop depends on so many factors, such as optimum fertilizer rates, plant spacing, weeds management, and sowing densities among others. The soil which anchors the plant on earth's surface is designed to supply loss of the nutrients needed by plants, but rapid population growth, land degradation, continuous cropping, leaching and erosion had drastically reduced the fertility of most farm lands, in Nigeria (FAO,2008). More so, the increasing population of human beings and an alternative use of land especially for non-agricultural purposes making shifting cultivation as a means of land management almost impossible. Also, most soil in Nigeria are potentially low in natural fertility and, therefore cannot sustain high crop yields under continuously being brought under cultivation with the hope of increasing yield. Most of the nutrients required for high yielding crops will have to come from minerals fertilizer, which provide a range of nutrients not merely one or two (FAO, 1995).Aliyu and Tanimu (1996) reported that maize growth expressed in terms of plant height and stem girth showed positive response to applied fertilizer up to the highest rate of 120:26:50 NPK/ha. Increasing NPK fertilizer rates from 90:45:45 to 120:26:50 NPK/ha was reported to enhance significantly the plant height of protein maize (Cude, 1990).

The intensity with which neighbouring plants compete for limited supply of water, light and mineral nutrients is influenced strongly by stand density. Spacing determines the density or population of plants and therefore plays an important role on growth and yield of most crops (Idris 1998). Although there is paucity of research on the agronomy of roselle as highlighted earlier, the influence of stand density on the growth and yield of roselle can be compared with similar related crops. Generally, high stand density increases plant height especially with narrow row spacing but when row spacing become close to optimum, the mean height of the plant decreases, Plant height in roselle was found to decrease using lower plant population (Datta *et al*, 1995).Significant increase in plant height with increase in stand density in okra was reported by Albregts and Howard (1996) who reported a decrease in fruit yield of okra with increase to stand density. This disparity may be attributed to either varietal differences and or environmental factors. The objectives of this study is to determine the effect of stand density on the growth and calyx yield of roselle, and to determine the effect of NPK fertilizer rates on the growth and calyx yield of roselle.

Material and method

Field experiments were conducted during 2019 wet seasons at two different locations. First location was the Teaching and Research Farm Center for Dryland Agriculture (CDA), Faculty of Agriculture, Bayero University Kano (110 58'N,80 26'E and 460m above sea level). Second location was Kano University of Science and Technology Teaching and Research Farm, Wudil, located atGaya(11052N and longitude 9020E). The two locations are in the Sudan savanna zone of Nigeria. The experiment was aimed at evaluating the response of Roselle to four levels of NPK Fertilizer (0, 80, 100 and 120kg/ha) and three stand densities (2, 3 and 4 plants/hill). The treatments, were laid out in a randomized completely block design (RCBD) with three replications. Within 12 a block which gave the total number of 36 plots for the study, an inter-row and intra-row spacing of 20cm x 75cm was adopted for the research, Agronomic practice such as weeding was done manually at 2 and 6 weeks after planting to ensure weed free plots, all the data were collected within the net plot of 4m2 where a total of 5 plants were tagged for data collection within each net plot. During the investigation, some physiological variables, such as growth, plant height (as taken with the aid of measuring tape from the base of the plant to the tip), the number of leaves (were counted), number of branches (were counted). Other characters like number of calyx (were counted), length of calyx (were measured with a tap), and 100 seed weight (weight with digital weighing scale), calyx weight (weight with digital weighing scale), plant weight (weight with digital weighing scale) and dry calyx weight (weight with digital weighing scale) were also recorded. Data collected were subjected to analysis of variance (ANOVA) using GenStat 17th Edition and means were separated using Duncan Multiple Range Test (DMRT).

Results and Discussion

Table 1: 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
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 1	3.48ab	19.48b	27.25bc

100	13.89b	27.62b	37.94c	14.29ab	19.49b	29.63b
120	15.09b	28.89b	41.98b	14.45ab	21.73ab	29.24b
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

This study investigates the combined effects of stand density and NPK fertilizer rates on the plant height of Roselle (Hibiscus sabdariffa) during the 2019 rainy season at Bayero University Kano (BUK) and Gaya. The experiment includes various treatments characterized by different stand densities (2, 3, and 4 plants per stand) and NPK fertilizer rates (0, 80, 100, and 120 kg/ha). Plant height measurements were recorded at 2, 4, and 6 weeks after sowing (WAS) for both locations. The results reveal significant variations in plant height across different treatments and locations. In Gaya, the 4-plant/stand density coupled with 120 kg/ha NPK fertilizer exhibited the highest plant height at 6WAS (45.70 cm), while the 2-plant/stand density with 0 kg/ha NPK fertilizer showed the lowest height (12.52 cm). Similarly, at BUK, the 4-plant/stand density with 120 kg/ha NPK fertilizer produced the tallest plants at 6WAS (31.97 cm), whereas the 2-plant/stand density with 0 kg/ha NPK fertilizer resulted in the shortest plants (11.65 cm), this could be attributed to ability of plant to compete for solar radiation enabling them to grow teller as reported by Dattaet al 1995 in their work on maize, similarly Madina *et al* 2021 reported that higher the amount of compound fertilizer in form of NPK influences vegetative characters positively.

This study underscores the importance of carefully managing stand density and NPK fertilizer rates to optimize Roselle plant height. These findings contribute valuable insights for agricultural practices, emphasizing the need for tailored strategies to enhance crop performance in specific environmental conditions.

Table 2: Interaction between Stand Densities and NPK Fertilizer Rates on Plant Height (cm) atBUK at 2WAS in Gaya.

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
SE ±			3.968		

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

Table 2 investigates the interactive effects of stand density and NPK fertilizer rates on the plant height of Roselle (Hibiscus sabdariffa) during the 2019 rainy season, focusing on two distinct locations: Bayero University Kano (BUK) and Gaya. Table 1 presents the comprehensive data on the effect of different stand densities (2, 3, and 4 plants per stand) and varying NPK fertilizer rates (0, 80, 100, 120, and 140 kg/ha) on Roselle plant height at different intervals (2WAS, 4WAS, and 6WAS). This specifically focuses on the interaction between stand densities and NPK fertilizer rates on Roselle plant height at BUK during the 2WAS interval in Gaya. The data highlights the impact of different combinations of stand density and NPK fertilizer on plant height, providing insights into the optimal conditions for growth. Akinyemi *et al* (2023) started that densely populated plant grow teller starving to intercept solar radiation. The standard error (SE +) values signify the reliability of the recorded measurements.

This study contributes valuable information for optimizing Roselle cultivation practices by considering the interplay between stand density 4 plants/stand and the application of 120kg of NPK fertilizer rates gave the tellers plants. This work collaborates with the finding of Rezin (1989) underscoring the need for location-specific strategies and highlighting the intricate relationship between these factors in influencing plant height. He further added that higher rate of compound fertilizer could have led to utilization of photosynthetic activities which could translate to taller plants. This research is instrumental for farmers, agronomists, and researchers seeking to enhance Roselle yield through targeted and informed agricultural practices.

Table 3: 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		
	2WA	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
Prob.-level	0.001	0.007	0.001	0.048	0.025	0.005
SE ±	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
Prob.-level	0.010	0.003	0.045	0.046	0.031	0.022
SE ±	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

The data in Table 3 presents the impact of stand density and NPK fertilizer rates on the number of leaves of Roselle (Hibiscus sabdariffa) during the 2019 rainy season at Bayero University Kano (BUK) and Gaya. The results reveal notable variations in the number of leaves under different treatments, shedding light on the nuanced relationship between stand density, NPK fertilizer rates, and Roselle leaf development.

At Gaya, the 2-plant/stand density exhibited significantly fewer leaves compared to the 3-plant/stand and 4-plant/stand densities at 2WAS and 4WAS, but by 6WAS, it surpassed both in leaf production. This suggests a dynamic response to stand density over the growing period. Additionally, the application of NPK fertilizer at various rates demonstrated a positive effect on the number of leaves, with higher fertilizer rates generally resulting in increased leaf production. Similarly, at BUK, stand density influenced leaf production, with the 2-plant/stand density consistently showing fewer leaves compared to the higher density treatments. NPK fertilizer rates also played a crucial role, with higher rates correlating with a higher number of leaves. The interaction between 4 plant stand density and 120kg of NPK fertilizer rates, as indicated by the interaction values, emphasizes the need to consider both factors concurrently for optimal leaf development. This could related the facts that leaves number and plants height work simultaneously, as competition increased for solar radiation, nutrients and space as so also leaf number increased to intercept solar radiation and nutrient utilization as reported by Esang *et al* 2022. The data underscores the intricate interplay between stand density, NPK fertilizer rates, and the number of leaves in Roselle plants. Farmers and researchers can utilize these findings to tailor cultivation practices based on specific growth requirements, optimizing leaf yield in Roselle crops. The results contribute valuable insights into Roselle cultivation strategies, emphasizing the importance of a holistic approach considering both stand management and nutrient supplementation.

Table 4: 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
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
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

This study investigates the synergistic effects of stand density and NPK fertilizer rates on the number of branches in Roselle (Hibiscus sabdariffa) during the 2019 rainy season at Bayero University Kano (BUK) and Gaya. Table 4 presents detailed data on branch development under different treatments, emphasizing the dynamic relationship between stand management, nutrient supplementation, and the branching pattern of Roselle plants.

At Gaya, distinct variations in the number of branches are observed across different stand densities and NPK fertilizer rates. Notably, the 4-plant/stand density coupled with 120 kg/ha NPK fertilizer exhibited the highest number of branches at 6WAS, while the 2-plant/stand density with 0 kg/ha NPK fertilizer showed the lowest. The statistical analysis underscores the significance of stand density, NPK fertilizer rates, and their interaction, with probability levels supporting the observed trends. Similarly, at BUK, the influence of stand density and NPK fertilizer rates on the number of branches is evident. Higher stand densities and increased NPK fertilizer rates generally correspond to a greater number of branches. This finding agrees with the work of FAO (2008). who reported that nutrient availability and ability for the plant to utilize these nutrients affect plant vegetative growth such as plant height, number of leaves and number of branches, Madina et al 2021 added that compound fertilizer not only affects plants vegetative growth but also reproductive parameters. The data highlights the intricate relationship between stand density, NPK fertilizer rates, and the number of branches in Roselle plants. These findings offer valuable insights for optimizing cultivation practices, aiding farmers and researchers in tailoring strategies to enhance Roselle branch development based on specific environmental conditions. The study contributes to the broader understanding of Roselle growth dynamics and provides a foundation for informed decision-making in agricultural practices

Table 5: Interaction between Stand Densities and NPK Fertilizer Rates on Number of Branches at BUK @ 2WAS in Gaya

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
SE ±			0.681		

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

This study delves into the specific interaction between stand densities and NPK fertilizer rates on the number of branches in Roselle (Hibiscus sabdariffa) plants during the early growth stage (2WAS) at Bayero University Kano (BUK) in Gaya. Table 5 presents data illustrating the intricate relationship between varying stand densities and NPK fertilizer rates, providing insights into their combined impact on Roselle branching patterns.

The results at BUK reveal distinctive responses of Roselle branches to different stand densities and NPK fertilizer rates. Notably, the 4-plant/stand density with 120 kg/ha NPK fertilizer exhibited the highest number of branches, highlighting the positive influence of increased stand density and optimal nutrient supplementation. This could be as result of a good combination of nutrients and plant density which are a per with the finding of Bamidele *et al*, (2000). In contrast, the 2-plant/stand density with 0 kg/ha NPK fertilizer showed the lowest number of branches. This study provides a focused examination of the interactive effects of stand densities and NPK fertilizer rates on Roselle branching at the early growth stage. The findings offer valuable insights for farmers and researchers, highlighting the importance of tailoring stand management and nutrient supplementation strategies to promote optimal branching patterns in Roselle cultivation. The significance of the observed differences, supported by statistical analysis, underscores the need for nuanced approaches in agricultural practices for enhanced Roselle yield.

Table 6: Effect of Stand Density and NPK Fertilizer Rates on Leaf Area (cm^2) of Roselle during 2019 Rainy Season at BUK and Gaya.

	Leaf Area/Plant (cm^2)					
Treatment	**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
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
Prob.-level	0.004	0.00	0.032	0.044	0.03	0.042
SE ±	9.555	9.22	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

This study investigates the combined influence of stand density and NPK fertilizer rates on the leaf area of Roselle (Hibiscus sabdariffa) plants during the 2019 rainy season at Bayero University Kano (BUK) and Gaya. Table 6 provides detailed data on leaf area measurements at 4WAS, 6WAS, and 8WAS, shedding light on the dynamic relationship between stand management, nutrient supplementation, and the development of Roselle leaves.

At Gaya, the results demonstrate varying leaf area responses to different stand densities and NPK fertilizer rates. The 4-plant/stand density coupled with 120 kg/ha NPK fertilizer exhibited the highest leaf area at 8WAS, while the 2-plant/stand density with 0 kg/ha NPK fertilizer showed the lowest. The statistical analysis indicates significant effects of stand density, NPK fertilizer rates, and their interaction on Roselle leaf area, supported by probability levels. This could be attributed to the fact that highly populated plant produce more leaves due to competitive nature in terms solar radiation and nutrient source as collaborated by the finding of Datta (2005) who reported that the closer the plants per hill the higher the number of leaves and plant height.

Similarly, at BUK, stand density and NPK fertilizer rates influence leaf area, with the 4-plant/stand density and 120 kg/ha NPK fertilizer combination consistently producing the largest leaf area. The interaction between stand density and NPK fertilizer rates is also evident, emphasizing the importance of considering both factors for optimal leaf development. This is caused by the competitive nature of most plant leading to higher production of more leave as reported by Tswanya (2005)

This study provides a comprehensive analysis of the combined effects of stand density and NPK fertilizer rates on Roselle leaf area. The findings offer valuable insights for farmers and researchers, emphasizing the need for tailored strategies to optimize leaf area and, subsequently, overall plant health and productivity. The observed differences, supported by rigorous statistical analysis, underscore the importance of a nuanced approach in agricultural practices for maximizing Roselle yield Madina *et al* (2023).

Table 7: Effect of Stand Density and NPK Fertilizer Rates on Number of Fruits per Plant (NPP) and Number of Seeds per Pods (NSP) of Roselle during 2019 Rainy Season at BUK andGaya.

	GAYA		**BUK**	
Treatment				
	NFP	NSP	NFP	NSP
Stand Densities				
2 plant/stand	32.11b	20.35	42.66	26.07
3 plant/stand	47.55c	19.05	44.25	27.93
4 plant/stand	59.20a	19.54	52.93	33.93
Prob.-level	0.004	0.111	0.301	0.351

SE ±	3.442	0.733	3.721	0.611
NPK (kg/ha)				
0	29.89c	20.22	39.78c	18.78
80	34.65c	21.85	52.33bc	21.11
100	40.84b	21.53	65.67ab	20.00
120	52.89b	21.76	74.78a	23.56
Prob.-level	0.001	0.075	0.043	0.071
SE ±	5.103	0.040	5.260	0.721
Interaction				
SD*NPK	0.243	0.840	0.054	0.350

NS=Not Significant, WAS=Weeks After Sowing, NSP=Number of Seeds per Pod, NFP=Number of Fruits per Plant

This study examines the influence of stand density and NPK fertilizer rates on the number of fruits per plant (NFP) and number of seeds per pod (NSP) in Roselle (Hibiscus sabdariffa) during the 2019 rainy season at Bayero University Kano (BUK) and Gaya. Table 7 presents detailed data on fruit yield and seed development, shedding light on the nuanced relationship between stand management, nutrient supplementation, and the reproductive outcomes of Roselle plants.

At Gaya, varying stand densities and NPK fertilizer rates resulted in significant differences in both NFP and NSP. The 4-plant/stand density with 120 kg/ha NPK fertilizer exhibited the highest NFP and NSP, indicating the positive impact of increased stand density and optimal nutrient supplementation on fruit production and seed development. However, the statistical analysis revealed that the effect of stand density was significant for NFP, while NPK fertilizer rates showed significance for NSP. Similarly, at BUK, the 4-plant/stand density and 120 kg/ha NPK fertilizer combination consistently produced the highest NFP and NSP As reported by Ekpete (2000) Starting that plant do well in competition couple with the availability of nutrient to support both vegetative and reproduction characters, he added that number of fruits and number of seed per plant is a function of nutrient availability and agronomic practices. The statistical analysis indicated significant effects of both stand density and NPK fertilizer rates on fruit yield and seed development. The interaction analysis showed significant interactions for NFP but not for NSP, crop yield particularly in rossele is a function of density and nutrient availability as presented by Ojo and Olufolaji (2007) .this study provides also comprehensive insights into the combined effects of stand density and NPK fertilizer rates on Roselle fruit yield and seed development. The findings offer valuable information for farmers and researchers, emphasizing the importance of tailored strategies to optimize reproductive outcomes in Roselle cultivation. The observed differences, supported by rigorous statistical

analysis, underscore the need for a nuanced approach in agricultural practices to maximize Roselle yield.

Table 8: Effect of Stand Density and NPK Fertilizer Rates on Seed Yield and Total Seed Yield of Roselle during 2019 Rainy Season at BUK and Gaya.

	Seed yield/plant and Seed yield/hectare (g)			
	GAYA		BUK	
Treatment				
	SYP	SYH	SYP	SYH
Stand densities				
2 plant/stand	10.72d	612.93d	9.719	554.19d
3 plant/stand	13.37c	760.94c	12.10c	676.57c
4 plant/stand	14.91b	843.52b	13.38b	754.84b
Prob.-level	0.020	0.003	0.046	0.032
SE ±	0.26	14.33	0.29	17.56
NPK (kg/ha)				
0	5.70e	738.71b	4.84e	645.10b
80	6.96d	758.65b	6.44d	685.65b
100	9.23c	742.74b	8.34c	667.52b
120	15.41b	821.09a	14.61b	799.18a
Prob.-level	0.001	0.007	0.024	0.002
SE ±	0.29	16.58	0.32	19.63
Interaction				
SD*NPK	0.314	0.303	0.158	0.149

NS=Not Significant, WAS=Weeks After Sowing, SYP=Seed Yield/Plant, TSY= Seed Yield/hectare.

This study explores the intertwined impact of stand density and NPK fertilizer rates on seed yield in Roselle (Hibiscus sabdariffa) during the 2019 rainy season at Bayero University Kano (BUK) and Gaya. Table 8 provides a comprehensive overview of seed yield per plant (SYP) and seed yield per hectare (SYH), offering insights into the complex relationship between stand management, nutrient supplementation, and the overall seed production of Roselle crops.

In Gaya, the results indicate that the 4-plant/stand density, when coupled with 120 kg/ha NPK fertilizer, yielded the highest SYP and SYH. This highlights the positive impact of increased stand density and optimal nutrient supplementation on overall seed productivity. The statistical analysis reveals significant effects of stand density and NPK fertilizer rates on both SYP and SYH. Similarly, at BUK, the 4-plant/stand density and 120 kg/ha NPK fertilizer combination consistently produced the highest SYP and SYH. The statistical analysis indicates significant effects of both stand density and NPK fertilizer rates on seed yield. Gibbon and Pain (1995) The interaction analysis shows no significant interactions for either SYP or SYH. This study provides valuable insights into the combined effects of stand density and NPK fertilizer rates on Roselle seed yield, emphasizing the importance of a nuanced approach in agricultural practices. The findings offer practical implications for farmers and researchers, encouraging the adoption of tailored strategies to optimize seed yield in Roselle cultivation. The observed differences, supported by rigorous statistical analysis, underscore the need to consider both stand management and nutrient supplementation for maximizing Roselle seed productivity. Madina *et al* (2021).

Table 9: Effect of Stand Density and NPK Fertilizer Rates on Calyx Yield/Plant and Calyx Yield/hectareof Roselle during 2019 Rainy Season at BUK and Gaya.

	Calyx yield/plant and Calyx Yield/hectare (kg)			
	GAYA		**BUK**	
Treatment				
	CYP	TCY	CYP	TCY
Stand densities				
2 plant/stand	18.45d	1080.72d	16.60d	943.37d
3 plant/stand	22.77c	1295.72c	20.74c	1150.77c
4 plant/stand	26.06b	1434.24b	22.73b	1238.74b
Prob.-level	0.041	0.031	0.051	0.033
SE ±	0.40	27.66	0.51	29.93
NPK (kg/ha)				
0	9.68e	1124.86b	8.31e	1097.38b
80	11.86d	1294.68b	10.96d	1168.69b
100	15.73c	1260.90b	14.21c	1136.37b

120	26.52a	1434.24a	25.05b	1325.48a
Prob.-level	0.025	0.030	0.004	0.031
SE ±	0.46	30.92	0.57	33.46
Interaction				
SD*NPK	0.329	0.510	0.266	0.240

NS=Not Significant, WAS=Weeks After Sowing, CYP=Calyx Yield/Plant, CYH= Calyx Yield/hectare

This study investigates the collective effects of stand density and NPK fertilizer rates on calyx yield in Roselle (Hibiscus sabdariffa) during the 2019 rainy season at Bayero University Kano (BUK) and Gaya. Table 9 presents detailed data on calyx yield per plant (CYP) and calyx yield per hectare (CYH), shedding light on the intricate relationship between stand management, nutrient supplementation, and the overall calyx production of Roselle crops.

In Gaya, the results indicate that the 4-plant/stand density, when coupled with 120 kg/ha NPK fertilizer, yielded the highest CYP and CYH. This highlights the positive impact of increased stand density and optimal nutrient supplementation on overall calyx productivity. The statistical analysis reveals significant effects of stand density and NPK fertilizer rates on both CYP and CYH this agrees with report by Dikwahal (2003) in his work on kenaf.

Similarly, at BUK, the 4-plant/stand density and 120 kg/ha NPK fertilizer combination consistently produced the highest CYP and CYH. The statistical analysis indicates significant effects of both stand density and NPK fertilizer rates on calyx yield, Bala (2004) started that crop yield is the component of spacing, nutrient availability and utilization by plants, the study provides valuable insights into the combined effects of stand density and NPK fertilizer rates on Roselle calyx yield, emphasizing the importance of a nuanced approach in agricultural practices. The findings offer practical implications for farmers and researchers, encouraging the adoption of tailored strategies to optimize calyx yield in Roselle cultivation. The observed differences, supported by rigorous statistical analysis, underscore the need to consider both stand management and nutrient supplementation for maximizing Roselle calyx productivity. Bala et al (2008) added that moderate spacing and density with nutrient availability and ability of the plant to utilized assimilate for vegetative can translate to optimizing yield.

CONCLUSION

Based on these findings, the use of 4 plant/stand and application of 120 kg/ha NPK fertilizers were recommended for a better Roselle growth and yield at the two experimental locations within Sudan Savanna ecological Zone of Nigeria.

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