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RESPONSE OF CABBAGE (*BRASSICA OLERACEA*L.) VARIETIES TO SPACING IN THE GUINEA AND SUDAN SAVANNA ZONES OF KEBBI STATE

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Abstract

This study investigated the response of Cabbage (Brassica oleracea L.) varieties to spacing in the Sudan and Northern Guinea savanna zones of Kebbi State, Nigeria, during the 2023/2024 dry season. The experiment was conducted at two locations: Jega, located in the Sudan savanna, and Ribah, situated in the Northern Guinea savanna. Jega is characterized by a semi-arid climate with annual rainfall ranging between 600 and 800 mm, mean temperatures of 28–38 °C during the growing season, and predominantly sandy loam soils of low organic matter content. Ribah, on the other hand, falls within the wetter Guinea savanna zone, with annual rainfall of 900–1,100 mm, moderate temperatures of 25–34 °C, and loamy soils with slightly higher fertility and moisture-retention capacity compared to Jega. These contrasting ecological conditions provided an opportunity to assess variety×spacing responses across different agro-ecological environments. The experiment employed a Randomized Complete Block Design (RCBD) with three replications, involving two cabbage varieties (Grafas and Copenhagen) and six spacing regimes (20 × 20 cm, 20 × 25 cm, 20 × 30 cm, 30 × 30 cm, 30 × 35 cm, and 30 × 40 cm). Growth parameters assessed included plant height, number of leaves, leaf area, leaf area index, days to 50% heading, crop growth rate, and relative growth rate. Yield and yield-related parameters measured were fresh plant weight, head diameter, head weight, number of folded leaves, total yield, and harvest index. The results revealed that variety Grafas consistently outperformed Copenhagen across most growth and yield parameters. Grafas produced taller plants, more leaves, heavier heads, larger head diameters, and higher harvest index, demonstrating superior adaptability to semi-arid conditions. Spacing also exerted a strong influence on performance. Wider spacing (30×40 cm) enhanced plant height, head size, and head compactness due to reduced intra-plant competition for light, nutrients, and water. Conversely, closer spacing (20 × 20 cm) produced higher yields per hectare as a result of high plant population density, although individual heads were smaller and less compact. Correlation analysis showed strong positive relationships between yield and traits such as plant height, number of leaves, fresh plant weight, head diameter, and folded leaves, indicating that these can be used as reliable predictors of cabbage productivity. The study concludes that Grafas is the superior variety for both Sudan and Northern Guinea savanna environments of Kebbi State.

Keywords: *Cabbage (Brassica oleracea L.), plant spacing, variety performance, savanna agro-ecology, yield components, Grafas, crop density, Nigeria.*

INTRODUCTION

Cabbage (*Brassica oleracea L.*) is a widely cultivated vegetable crop grown and belongs to the family *Brassicaceae*. (Sharma *et al*, 2017). The plant is cultivated worldwide in various climatic conditions. It is a leafy, green, red, or white biennial plant grown for its dense head (Adeyemi., 2022). Cabbage is believed to have originated in the Mediterranean region of Europe. Wild cabbage is found along the coastal region of Europe (Ahmed *et al.,* 2020). The crop has been in use as early as 600BC. Today it's grown worldwide due to its adaptability to various climate (Singh *et al.,* 2020). In Nigeria, cabbage production contributes significantly to vegetable farming, providing essential nutrients and income for farmers (Khan *et al.,* 2021)

In Nigeria cabbage is increasingly cultivated across several states particularly in the northern region like Plateau, Kaduna and Kano due to their favourable climatic conditions for cabbage farming (Hossain *et al.,* 2018). It is a crucial vegetable crop in tropical and subtropical regions due to its nutritional value and adaptability to various climatic conditions. Cabbage contains about 90 – 95% water, Carbohydrate 4 – 6%, Protein 1 – 2%, Fat less than 0.5%, it contains Vitamin C, K, B6, B9 and Minerals like Potassium, Calcium, Magnesium, Iron and Manganese (Adeyemi, 2022). Cabbage can be used fresh as salad or garnishes, and cooked as stew, soups, it has medicinal uses, can be used for decoration and waste for compost.

In Nigeria, particularly in the Guinea and Sudan savanna regions, cabbage cultivation is increasingly significant as it supports local economies and enhances food security (Bishoni *et al.,* 2019). The unique climatic conditions of Kebbi State, characterized by a short rainy season and extended dry periods, present both challenges and opportunities for optimizing crop production. Recent studies showed the importance of adapting agricultural practices to these specific environmental conditions to maximize yield and quality (Oyenuga and Fetuga, 2019). The spacing of cabbage plants is a critical agronomic practice that affects growth, yield, and overall plant health. Proper spacing ensures adequate light, water, and nutrient availability, which are essential for optimal cabbage development. Recent advancements in agricultural research have shown that spacing optimization is not a one-size-fits-all approach. For instance, studies by Moniruzzman *et al.* (2020), have demonstrated that varying spacing distances can impact cabbage head size, weight, and overall yield, depending on the specific variety and local soil conditions. This study aims at determining the best variety and spacing of cabbage in the Guinea and Sudan Savannah, and to determine the effect of spacing on the growth and yield of cabbage varieties.

Materials and Method

Two field trials were conducted simultaneously during the 2023/2024 dry season at Teaching and Research Farm, Abdullahi Fodio University of Science and Technology Aliero, (lat. 12°12.99' N; long. 4° 21.90'E; 197m above sea level) and Susu Farms Ribah (lat. 11°11.233' N; long. 5.633°E) in the Sudan and Northern Guinea Savanna of Kebbi State Nigeria. Treatments consist of two varieties of Cabbage (Grafas and Copenhagen) and 6 different spacing were used (20 x 20 cm, 20 x 25cm, 20 x 30cm, 30 x 30cm, 30 x 35cm and 30 x 40cm). The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. The sites were ploughed and harrowed to a good tilt and levelled to ensure free water movement and well drained. Two nursery beds of 2.5x2.5m each were made for raising seedlings. The land was marked into plots and replications. Border spaces of 0.5m between the plots and two ridges between replicates were also marked. Net plot of 6.25m² and a spacing of 1 m were left between blocks. Seeds were broadcasted on sunken beds by hand all over the bed and lightly raked for uniformity and contact with soil. The seedlings were transplanted at 3 weeks old at specified spacing. Data was collected base on the following growth (2 and 4 WAT) and yield parameters (at harvest).Plant height (cm), Number of leaves per plant, Leaf area, Leaf area index, Number of folded leaves, Crop growth rate (gm^{-1} wk^{-2}), Relative growth rate (gg^{-1} wk^{-1}), Days to 50% head initiation, Days to 50% heading, Fresh plant weight (kg), Head diameter, Weight of Head (kg), and Harvest Index (%)

Data collected was subjected to the Analysis of Variance (ANOVA) using SAS software and means that are significant were separated using Duncan's Multiple Test Range (DMRT) at 5 % level of probability.

RESULT AND DISCUSSION

Table 1 indicate that both variety and spacing significantly affected plant height and number of leaves per plant at both 2 and 4 weeks after transplanting (WAT). Cabbage grown at wider spacing (30 × 40 cm) recorded the tallest plants and highest number of leaves, particularly with Variety 6, which reached 12.70 cm in Ribah and 12.52 cm in Jega at 4 WAT. This agrees with Singh *et al.* (2018), who reported that wider spacing provides more light, nutrients, and water per plant, resulting in greater vegetative growth. Additionally, Oyenuga and Fetuga (2019) observed similar trends in cabbage, where closer spacing limited expansion and leaf production due to competition. Furthermore, the influence of variety suggests genotypic differences in vigour and adaptation, as also noted by Ahmad et al. (2020) in their study on brassica crops under varied spacing.

Table.2 shows that leaf area and leaf area index (LAI) were significantly higher in wider spacing, especially at 20 × 20 cm and 20 × 25 cm, and in the Grafas variety. At 4 WAT, the highest LAI (508.90) was recorded in Jega at 20 × 20 cm spacing. Increased LAI under closer spacing could be due to overlapping leaves and more ground coverage, but this does not necessarily imply better plant health. According to Baloch et al. (2017), a higher LAI at close spacing may lead to self-shading and reduce photosynthetic efficiency. However, Moniruzzaman et al. (2020) suggest that moderate spacing balances LAI and leaf expansion, which optimizes growth. The varietal difference in leaf area confirms Singh et al. (2018) findings that leaf morphology is highly genotype-dependent.

Table 3 reveal significant varietal and spacing influences on days to 50% heading, crop growth rate (CGR), and relative growth rate (RGR). Grafas showed faster heading than Copenhagen, particularly under wider spacing (30 × 35 cm and 30 × 40 cm), which also promoted higher CGR and RGR. These findings are consistent with Abdullahi et al. (2019), who reported that wider spacing improves carbohydrate accumulation and translocation, enhancing growth rates. Moreover, Meena *et al.* (2017) suggested that CGR and RGR are higher under optimal spacing due to better resource utilization. The earlier heading in Grafas is indicative of its physiological maturity and efficiency, similar to observations by Khan et al. (2021) in early-maturing cabbage varieties.

Table 4, the widest spacing (30 × 40 cm) resulted in significantly higher fresh plant weight, head diameter, and head weight, particularly in the Grafas variety. These findings are in line with those of Law-Ogbomo and Egharevba (2018) who reported increased biomass and head size with wider spacing due to reduced competition. The superiority of Grafas over Copenhagen aligns with Ahmed et al. (2019) who concluded that hybrid cabbage varieties typically outperform open-pollinated ones in weight and size. Onyango et al. (2020) also emphasized the role of adequate spacing in achieving maximum marketable head weight.

Table 5 illustrates that wider spacing (30 × 40 cm) significantly increased the number of folded leaves, head yield, and harvest index, especially in the Grafas variety. A higher number of folded leaves indicates vigorous leaf growth, which contributes to larger heads. According to Sharma et al. (2017), folded leaves are crucial for head formation and serve as a reliable indicator of future yield. The higher yield at wider spacing can be attributed to optimal resource use, as suggested by Bishnoi*et al.* (2019). Additionally, Ajayi and Olaniran (2020) found that harvest index increases with plant health and efficient biomass partitioning under ideal plant density.

(Tables 6 and 7) show strong and significant positive relationships between yield and traits like plant height, leaf number, LAI, folded leaves, fresh plant weight, and head diameter at both sites. These findings agree with Hussain *et al.* (2018), who emphasized that yield is a function of vegetative growth and morphological parameters. Chowdhury et al. (2020) also reported that yield improvement is directly related to traits like head diameter and folded leaves. Moreover, Oyenuga and Fetuga (2019). concluded that understanding trait correlations is essential for selecting high-performing cabbage genotypes.

Table 1 Effect of spacing on plant height and number of leaves per plant of Cabbage varieties during 2022/2023 dry season at Jega and Ribah

	Plant height (cm)				Number of leaves per plant			
	2WAT		4WAT		2WAT		4WAT	
VARIETY (V)	**Ribah**	**Jega**	**Ribah**	**Jega**	**Ribah**	**Jega**	**Ribah**	**Jega**
1	7.46	10.76^{a}	7.65^{a}	11.09^{a}	4.33	9.38^{a}	4.58	9.58^{a}
2	7.31	9.75^{b}	6.88^{b}	10.06^{b}	4.44	8.61^{b}	4.41	8.63^{b}
SE±	**0.041**	**0.111**	**0.111**	**0.175**	**0.121**	**0.190**	**0.109**	**0.014**
SPACING (S)								
1	6.60^{d}	8.42^{e}	6.15^{c}	8.87^{d}	3.66^{b}	7.00^{c}	4.16^{c}	7.08^{e}
2	6.68^{c}	9.73^{cd}	6.49^{c}	10.05^{c}	3.83^{b}	8.50^{b}	4.08^{c}	8.00^{d}
3	7.35^{b}	9.08^{d}	7.20^{b}	9.73^{c}	4.33^{ab}	9.00^{b}	4.08^{c}	8.75^{cd}
4	7.83^{ab}	10.18^{c}	7.73^{ab}	10.29^{c}	4.50^{ab}	9.33^{b}	4.58^{c}	9.16^{bc}
5	7.73^{ab}	11.42^{b}	7.45^{ab}	11.53^{b}	4.83^{a}	9.50^{b}	4.75^{b}	9.75^{b}
6	7.93^{a}	12.70^{a}	8.10^{a}	12.52^{a}	5.16^{a}	10.66^{a}	5.25^{a}	10.92^{a}
SE±	**0.215**	**0.334**	**0.134**	**0.310**	**0.215**	**0.134**	**0.334**	**0.310**
VxS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed with different letters (a,b,c) within column are statistically difference at (0.05%) level of probability. SE± = standard error, VxS= interaction

between Varieties and spacing, cm=centimetre.

Table 2 Effect of spacing on leaf area and leaf area index of Cabbage varieties during 2022/2023 dry season at Jega and Ribah

	Leaf area (cm^2)				Leaf area index			
	2WAT		4WAT		2WAT4WAT		4WAT4WAT	
VARIETY (V)	**Ribah**	**Jega**	**Ribah**	**Jega**	**Ribah**	**Jega**	**Ribah**	**Jega**
Grafas	21.94	65.56	22.65	67.52	10.92	346.40[a]	10.85	367.30[a]
Copenhagen	21.93	63.34	20.68	60.42	10.59	320.30[b]	9.94	322.40[b]
SE±	**1.360**	**0.384**	**0.281**	**0.226**	**0.231**	**0.041**	**0.704**	**0.180**
SPACING (cm)								
20 x 20	24.89	85.14a	23.69a	83.65a	12.89a	504.56a	11.67	508.90a
20 x 25	23.78ab	74.50a	22.91ab	71.99b	11.72ab	434.10b	11.14	432.89b
20 x 30	21.81b	66.68ab	22.49ab	64.89b	10.04b	333.75c	10.29	329.51c
30 x 30	21.53b	57.91bc	22.35ab	53.72c	10.59bc	302.80c	10.25	294.10d
30 x 35	21.53b	55.80cd	20.02b	53.03c	9.51cd	222.40d	9.64	226.20e
30 x 40	18.11b	46.70d	16.99c	46.72c	8.83d	202.52d	8.70	219.06e
SE±	**0.450**	**0.540**	**0.355**	**0.361**	**0.400**	**0.192**	**0.109**	**0.173**
VxS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed with different letters (a,b,c) within column are statistically difference at (0.05%) level of probability. SE± = standard error, VxS= interaction

Between Varieties and spacing, cm=centimetre.

Table 3 Effect of spacing on days to 50% heading, Crop growth rate and relative growth rate of Cabbage varieties during 2022/2023 dry season at Jega and Ribah

	Days to 50% heading		Crop growth rate ($g\ m^{-2}wk^{-1}$)		Relative growth rate ($g\ g^{-1}wk^{-1}$)	
VARIETY (V)	**Ribah**	**Jega**	**Ribah**	**Jega**	**Ribah**	**Jega**
Grafas	34.83	38.00	2.15[b]	11.54	0.02	26.63
Copenhagen	36.38	22.05	3.22[a]	8.93	0.03	18.21
SE±	**0.169**	**0.138**	**0.031**	**0.141**	**0.011**	**0.621**
SPACING (cm)						
20 x 20	37.50[a]	22.91	2.02[c]	6.89	0.03[a]	18.76
20 x 25	36.16[b]	22.25	2.11[c]	7.82	0.02[b]	18.09
20 x 30	35.33[bc]	21.83	3.01[b]	9.24	0.03[a]	17.68
30 x 30	35.16[bc]	21.50	3.15[ab]	9.49	0.03[a]	17.59
30 x 35	34.83[c]	21.41	3.20[a]	10.41	0.02[b]	17.42
30 x 40	34.66[c]	21.25	3.22[a]	10.91	0.02[b]	17.34
SE±	**1.131**	**1.052**	**0.221**	**0.782**	**0.001**	**0.701**
VxS	NS	NS	NS	NS	NS	NS

Means followed with different letters (a,b,c) within column are statistically difference at (0.05%) level of probability. SE± = standard error, VxS= interaction

between Varieties and spacing, cm=centimetre.

Table 4 Effect of spacing on fresh plant weight, head diameter and head weight of Cabbage varieties during 2022/2023 dry season at Jega and Ribah

	Fresh plant weight (kg)		Head Diameter (cm)		Head Weight (kg)	
VARIETY (V)	**Ribah**	**Jega**	**Ribah**	**Jega**	**Ribah**	**Jega**
Grafas	2.56	2.00	8.69	8.55^{a}	1.82^{a}	1.88^{a}
Copenhagen	2.24	1.12	7.55	7.40^{b}	1.59^{b}	1.54^{b}
SE±	**0.120**	**0.111**	**0.441**	**0.412**	**0.010**	**0.110**
SPACING (cm)						
20 x 20	1.75^{e}	0.81	6.17^{d}	6.20^{d}	1.17	1.10^{f}
20 x 25	2.02^{d}	1.07	7.08^{c}	6.83^{cd}	1.40	1.39^{e}
20 x 30	2.36^{c}	1.26	8.33^{b}	7.37^{b}	1.62	1.64^{d}
30 x 30	2.45^{c}	1.29	8.58^{b}	7.91^{b}	1.75	1.68^{c}
30 x 35	2.76^{b}	1.35	9.25^{a}	8.75^{a}	2.00	1.95^{b}
30 x 40	3.05^{a}	1.55	9.33^{a}	9.33^{a}	2.33	2.29^{a}
SE±	**0.131**	**0.112**	**0.461**	**0.339**	**0.00**	**0.010**
VxS	NS	NS	NS	NS	NS	NS

Means followed with different letters (a,b,c) within column are statistically difference at (0.05%) level of probability. SE± = standard error, VxS= interaction

between Varieties and spacing, cm=centimetre.

Table 5 Effect of spacing on number of folded leaf, head yield and harvest index of Cabbage varieties during 2022/2023 dry season at Jega and Ribah

	Number of folder leaf		Yield (tha^{-1})		Harvest index (%)	
VARIETY (V)	**Ribah**	**Jega**	**Ribah**	**Jega**	**Ribah**	**Jega**
Grafas	56.50^{a}	58.48^{a}	30.33^{a}	31.33^{a}	71.45^{a}	70.43
Copenhagen	52.50^{b}	50.30^{b}	26.49^{b}	25.66^{b}	69.67^{b}	69.57
SE±	**1.310**	**1.288**	**1.230**	**1.321**	**2.011**	**2.102**
SPACING (cm)						
20 x 20	32.00^{f}	33.08^{f}	29.25^{a}	27.50^{a}	66.46^{b}	66.74^{e}
20 x 25	44.50^{e}	43.63^{e}	28.00^{a}	27.80^{a}	72.33^{ab}	70.74^{d}
20 x 30	53.83^{d}	51.50^{d}	26.99^{b}	27.33^{a}	65.75^{b}	63.75^{e}
30 x 30	59.00^{c}	56.66^{c}	19.44^{c}	18.22^{b}	71.00^{ab}	68.91^{cd}
30 x 35	65.00^{b}	62.66^{b}	19.04^{c}	18.57^{b}	71.66^{ab}	72.75^{ab}
30 x 40	72.66^{a}	68.66^{a}	19.41^{c}	19.08^{b}	76.16^{a}	78.08^{a}
SE±	**1.502**	**1.390**	**1.091**	**1.091**	**1.088**	**2.015**
VxS	NS	NS	NS	NS	NS	NS

Means followed with different letters (a,b,c) within column are statistically difference at (0.05%) level of probability. SE± = standard error, VxS= interaction

between Varieties and spacing, cm=centimetre.

Table 6 Matrix of Correlation Coefficient between Growth and Yield Attributes of Cabbage during 2022/2023 dry Season at Jega

	Yield	**Plant height 4WAT**	**Number of leave**	**Leaf area index**	**Crop growth rate**	**Fresh plant weight**	**Head diameter**	**Number of folded leaf**
Yield	1.000							
Plant height 4WAT	0.69*	1.000						
Number of leaves	0.59*	0.58*	1.000					
Leaf area index 4WAT	0.72*	0.62*	0.95*	1.000				
Crop growth rate	0.19*	0.31*	0.48	0.47	1.000			
Fresh plant weight	0.66*	0.69*	0.72*	0.75*	0.43*	1.000		
Head diameter	0.77*	0.71*	0.76*	0.86*	0.41*	0.92*	1.000	
Number of folded leaf	0.72*	0.65*	0.72*	0.80*	0.47*	0.91*	0.94*	1.000

Table 7 Matrix of Correlation Coefficient between Growth and Yield Attributes of Cabbage during 2022/2023 dry Season at Ribah

	Yield	**Plant Height**	**Number of leave**	**Leaf area index**	**Crop growth rate**	**Fresh plant weight**	**Head diameter**	**Number of folded leaf**
Yield	1.000							
Plant height 4WAT	0.67*	1.000						
Number of leaves	0.65*	0.63*	1.000					
Leaf area index 4WAT	0.57*	0.34*	0.53*	1.000				
Crop growth rate	0.86*	0.79*	0.69*	0.47	1.000			
Fresh plant weight	0.82*	0.81*	0.73*	0.44	0.94*	1.000		
Head diameter	0.66*	0.76*	0.62*	0.25	0.73*	0.76*	1.000	
Number of folded leaf	0.85*	0.78*	0.76*	0.56*	0.92*	0.92*	0.72*	1.000

CONCLUSION/ RECOMMENDATIONS

From the results of this study, it can be concluded that both variety and spacing play critical roles in determining the growth and yield performance of cabbage in the semi-arid conditions of Kebbi State. The variety Grafas demonstrated superior performance in nearly all growth and yield parameters compared to Copenhagen, suggesting that it is better adapted and more suitable for production in the study area.

The findings also revealed that spacing strongly influenced both vegetative growth and yield outcomes. Wider spacing (30 × 40 cm) enhanced vegetative growth, fresh plant weight, head size, and compactness, which are desirable for premium markets. Conversely, closer spacing (20 × 20 cm) produced higher yield per hectare, making it more suitable for smallholder farmers focused on maximizing land productivity. The study therefore concludes that the **Grafas variety, combined with appropriate spacing tailored to market objectives,** offers the best strategy for improving cabbage production in semi-arid environments of Nigeria. Based on the findings of the study, the following recommendations were made:

1. **Adopt 45 x 45 cm Spacing**: Farmers should use a spacing of 45 x 45 cm for cabbage planting to optimize growth, reduce competition for resources, and improve overall yield.
2. **Select Locally Adapted Varieties**: It is recommended to use cabbage varieties that are well-suited to the climatic conditions of the Guinea and Sudan Savanna Zones, with a focus on pest resistance and shorter growing cycles.
3. **Implement Integrated Pest Management (IPM)**: Farmers should incorporate IPM practices alongside optimized spacing to manage pest populations and prevent crop damage, ensuring better yield and quality.
4. **Enhance Soil Fertility Management**: Soil tests should be conducted to guide fertilizer application, and organic matter or manure should be incorporated to improve soil structure and nutrient availability, enhancing cabbage growth.

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