

Effects of different plant populations of African night shade (*Solanum nigrum*) varieties on the vegetative growth parameters across two distinct agro-ecological zones (Bali and Jalingo) in Taraba state, Nigeria.

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ABSTRACT

A two-site factorial experiment was conducted during the 2024 rainy season in Bali and Jalingo, Taraba State, Nigeria, to evaluate the growth and leaf yield of three African nightshade (*Solanum nigrum*) varieties: Mbanga (V1), Mange (V2), and Pala Pala (V3). The study employed a 3×5 factorial arrangement in a Randomized Complete Block Design, investigating the effects of the three varieties and five plant spacing treatments (S1: 20×30 cm, S2: 25×30 cm, S3: 30×30 cm, S4: 35×30 cm, and S5: 40×40 cm). Data on vegetative growth and leaf yield were subjected to Analysis of Variance (ANOVA). Significant varietal differences ($p < 0.05$) were observed across all measured parameters. Pala Pala (V3) consistently exhibited the largest leaves across both locations, with maximum leaf length (10.176 cm) and width (7.558 cm) recorded at 6 Weeks After Transplanting (WAT) in Bali under S5 spacing. Mange (V2) demonstrated superior branching capacity (9.91 branches/plant at S5) and greater plant height (35.55 cm in combined analysis). Wider spacing (S5) significantly promoted larger leaf size (leaf length: 8.10 cm vs S1: 5.22 cm in combined analysis) and increased plant height (S5: 32.59 cm vs S1: 25.46 cm). Leaf yield analysis identified V3 and V2 as superior producers. Maximum yields per plant were recorded at 40×40 cm spacing (V3: 2,613.9 g/plot in Bali; V2: 2,599.8 g/plot). However, the highest yield per unit area was achieved at the closest spacing (20×30 cm), producing 2,775.8 g/plot in Bali. A significant variety × spacing interaction was observed ($p < 0.01$). Location effects were highly significant, with Bali outperforming Jalingo across all parameters due to more favorable rainfall (1,850 mm vs 1,058 mm) and temperature regimes. Optimal spacing varied with production objectives: 20×30 cm with V2 and V3 maximized leaf yield per unit area. These findings underscore the importance of site-specific recommendations for enhancing African nightshade productivity.

Keywords: African nightshade, plant population, *Solanum nigrum*, leaf yield, reproductive development, agro-ecological zones.

1. INTRODUCTION

African nightshade (*Solanum nigrum*) is a crucial indigenous leafy vegetable widely consumed across sub-Saharan Africa, including Nigeria (Chweya and Mnzava, 2020). It serves as a significant source of essential nutrients and provides economic sustenance, particularly for rural communities, despite its nutritional richness high in protein, vitamins (A, B, C), iron, calcium, and antioxidants and its role in combating malnutrition (Abukutsa-Onyango, 2020). *Solanum nigrum* remains largely underutilized in conventional agricultural systems (Romay *et al.*, 2016). Traditional cultivation methods, prevalent among smallholder farmers in regions like Taraba State, Nigeria, often limit its production potential due to suboptimal agronomic practices and insufficient research.

In Nigeria, African nightshade is often marginalized in agricultural policies, leading to limited investment in research and extension services. Farmers face various challenges, including poor seed quality, pest infestations, post-harvest losses, and a lack of formal market integration (Aworh, 2018). A critical knowledge gap exists concerning optimal plant spacing and population density, which directly impacts yield. Unlike major commercial crops, *Solanum nigrum* has received minimal agronomic investigation, resulting in a scarcity of evidence-based recommendations for farmers (Weinberger and Msuya, 2020). This study addresses this vital research gap by providing empirical data on ideal plant populations to maximize *Solanum nigrum* production across diverse agro-ecological zones of Taraba State, Nigeria. The insights gained are intended to inform farmers, policymakers, and development agencies, thereby promoting the cultivation of indigenous vegetables for sustainable nutrition and rural poverty alleviation.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was conducted at the Teaching and Research Farm of the Faculty of Agriculture, Taraba State University, Jalingo and at the Research school Farm, Federal Polytechnic, Bali. Jalingo is located between Latitude $8^{\circ}25'N$ and Longitude $11^{\circ}45'E$ of the equator. It is situated in the northern guinea savannah zone of the state with an annual rainfall of about 1058mm with maximum temperature varying between $30^{\circ}C$ and $39.4^{\circ}C$ and minimum temperatures range between $15^{\circ}C$ to $23^{\circ}C$ (Emeka and Abbas, 2011). Bali is situated in the Central part of the state with Latitude ($7^{\circ}53'11''N$ and $10^{\circ}58'18''E$) East of the Greenwich meridian with a mean annual rainfall of about 1850mm and temperature ranges between $22^{\circ}C$ – $35^{\circ}C$. Field experiments in these two locations (Jalingo and Bali) (Fig 1) under rain fed condition was conducted during the 2024 planting season. The locations are characterized by contrasting agro – climatic factors.

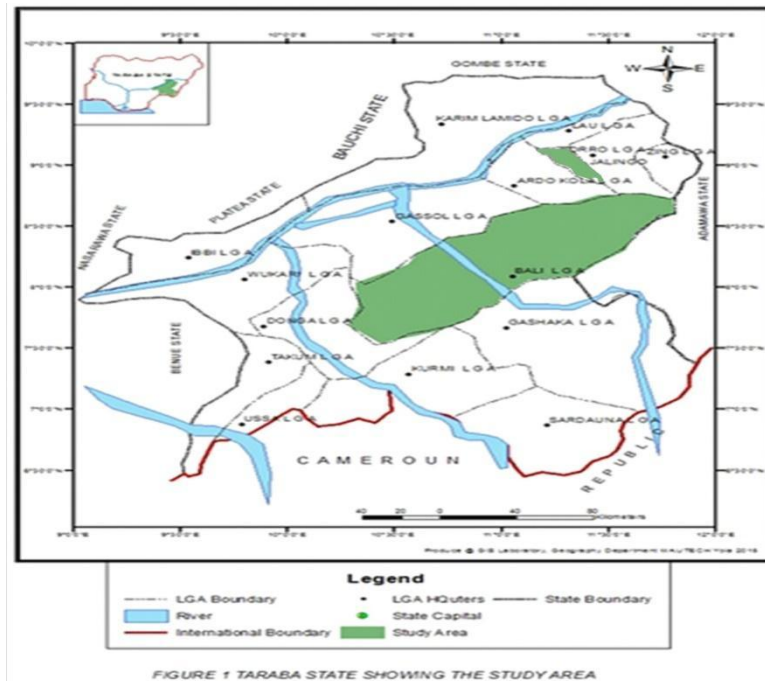


Figure 1. Map of Taraba State Showing study locations, Jalingo and Bali.

The study was conducted during the 2024 rainy season in two distinct agro-ecological zones of Taraba State, Nigeria: Jalingo and Bali. The experiment was designed as a 3×5 factorial arrangement, implemented in a Randomized Complete Block Design (RCBD) with three replications at each location. The factors under investigation included three African nightshade varieties (Mbanga - V1, Mange - V2, and Pala Pala - V3) and five plant spacing treatments.

2.2 Plant Materials and Agronomic Practices

The three African nightshade varieties utilized in the experiment were sourced locally. Land preparation followed conventional agricultural practices. Seedlings were initially raised in a nursery and subsequently transplanted to the field at 4 and 6 weeks after transplanting (WAT). The five spacing treatments applied were: S1 (20×30 cm), S2 (25×30 cm), S3 (30×30 cm), S4 (35×30 cm), and S5 (40×40 cm). Weeds were controlled manually as required throughout the growing period. Inorganic fertilizer (Urea) was applied at two weeks after transplanting, using the side placement method.

2.3 Data Collection

Data were collected from four randomly tagged plants within each plot for various growth and yield parameters. These parameters included:

Number of leaves per plant: Counted at both 4 and 6 WAT.

Plant height (cm): Measured from ground level to the canopy top at 4 and 6 WAT.

Leaf length (cm) and Leaf width (cm): Measured from randomly selected mature leaves on tagged plants at 4 and 6 WAT.

Number of branches per plant: Counted at 6 WAT.

Leaf yield per plot (g): Fresh leaf weight was measured using a digital electronic scale after harvesting leaves from the four sampled plants.

2.4 Statistical Analysis

All collected data were subjected to Analysis of Variance (ANOVA). Significant treatment means were further separated using the Least Significant Difference (LSD) at a 5% level of probability to identify specific differences among varieties, spacing treatments, and their interactions.

3. RESULTS & DISCUSSION

The study demonstrated significant variations in the growth, reproductive development, and leaf yield of African nightshade, influenced by varietal differences, plant spacing, and geographical location.

3.1 Vegetative Growth

Significant varietal differences ($p < 0.01$) were observed in the number of branches per plant across both experimental locations. Pala Pala (V3) consistently exhibited the largest leaves. Specifically, maximum leaf length (10.176 cm) and leaf width (7.558 cm) were recorded at 6 WAT in Bali under the S5 (40×40 cm) spacing treatment. Mange (V2) demonstrated a superior branching capacity, averaging 9.91 branches per plant at S5 spacing. In a combined analysis, Mange (V2) also achieved greater plant height, reaching 35.55 cm. Wider spacing (S5) significantly promoted larger leaf size, with an average leaf length of 8.10 cm compared to 5.22 cm at S1 (20×30 cm) in the combined analysis. Similarly, plant height was greater at S5 (32.59 cm) compared to S1 (25.46 cm).

3.2 Leaf Yield

Leaf yield analysis identified Pala Pala (V3) and Mange (V2) as superior producers. The highest individual plot yields were recorded at the 40×40 cm spacing, with V3 yielding 2,613.9 g/plot in Bali and V2 yielding 2,599.8 g/plot. However, when considering yield per unit area, the closest spacing (20×30 cm) proved most effective, producing 2,775.8 g/plot in Bali.

3.3 Interactions and Location Effects

A significant variety × spacing interaction was observed ($p < 0.01$), indicating that the optimal spacing varied depending on the African nightshade variety. Furthermore, location exerted a highly significant influence on all measured parameters, with Bali consistently outperforming Jalingo. This superior performance in Bali was attributed to more favorable environmental conditions, notably higher rainfall (1,850 mm vs 1,058 mm) and more conducive temperature regimes.

The observed variations in vegetative growth parameters, including leaf length, leaf width, and number of leaves per plant, underscore the substantial genetic diversity among the African nightshade varieties studied. Pala Pala (V3)'s consistent display of larger leaf expansion suggests a genetic predisposition towards higher photosynthetic efficiency and greater biomass accumulation. The enhanced branching capacity of Mange (V2) indicates its potential for increased overall productivity through the development of more fruiting points.

These findings are consistent with existing literature that highlights genetic variations in the vegetative growth characteristics of African nightshade varieties.

Wider plant spacing consistently promoted robust vegetative development, manifested by larger leaf size and increased plant height. This can be attributed to reduced intra-specific competition for vital resources such as light, water, and soil nutrients. Conversely, narrower spacing likely restricted leaf expansion due to intensified competition among plants. This observation corroborates previous studies, such as that by Mwai *et al.* (2009b), which indicate that wider spacing positively influences leaf expansion. The increase in branching at wider spacings can also lead to a greater number of flowers and subsequent fruit sets, thereby contributing to overall yield.

In terms of leaf yield, both V2 and V3 emerged as superior producers. While maximum yields per plant were achieved at wider spacings (40×40 cm), the highest yield per unit area was attained at the closest spacing (20×30 cm). This indicates a critical trade-off: wider spacing enhances the performance of individual plants, whereas closer spacing maximizes total biomass per plot due to a higher plant density, despite a potentially lower yield per individual plant. The pronounced superior performance of African nightshade in Bali compared to Jalingo underscores the significant influence of environmental factors, particularly rainfall and temperature, on the crop's overall productivity and yield potential.

3.3.1 Planting materials

The three (3) common varieties of African nightshade (*Solanum nigrum*) in the experimental areas: **Mbamga, Mange and Pala palawere** sourced from Farmers seed banks in Jalingo and Bali.

3.3.2 Land preparation

The Field for this research was properly cleared, ploughed and harrowed to get the soils pulverized at both locations.

3.4 Agronomic Practices

3.4.1 Raising of seedlings in a Nursery

The nurseries were established in Jalingo and Bali respectively. The seedlings were raised in fine – tilled seedbeds with appropriate amounts of manure. The land was prepared by digging to a depth of 30cm and well decomposed manure worked in. The size of each nursery bed was 3m × 3m (9m²). Seeds were broadcast on each nursery bed through mixing with sand in order to have even distribution during sowing (Mwai *et al.*, 2007). Dry grass mulch was used on the nursery bed and irrigated for two weeks. Dry grass was removed when seedlings were about 3cm tall.

3.4.2 Transplanting

Seedlings were ready for transplanting at 4 weeks after emergence. Transplanting operations was done in the evening in order to minimize transplanting shock (Schippers, 2002; AVRDC, 2004; Mwai, 2007). Seedlings were hardened by reducing the frequency of irrigation prior to the week of transplanting but thorough watering was done before transplanting to reduce root damage. The seedlings were uprooted gently from the nursery beds and then immediately transplanted into the plots. Only strong and disease free seedlings were transplanted. The

seedlings were transplanted into the five levels of spacing: 20cm × 30cm, 25cm × 30cm, 30cm × 30cm, 35cm × 30cm, 40cm × 40cm to each bed of 2m × 2m (4m²). For the first, second, third, fourth and fifth spacing gave plant population of 66 plants, 48 plants, 36 plants, 30 plants and 25 plants per plot respectively. Gap filling was done as soon as possible to ensure a uniform crop (Schippers, 2002).

3.4.3 Weed control

Weeding of plots was carried out manually using hoe at 3 and 7 weeks after transplanting.

3.4.4 Fertilizer application

Application of nitrogen is vital for increased leaf production of nightshades. Nitrogen deficiency leads to reduced photosynthesis resulting in lower biomass accumulation (Zhao *et al.*, 2005). Under limited nitrogen supply, nightshade plants have been shown to respond by drastic reduction in leaf area (Masinde *et al.*, 2009). Inorganic fertilizer (Urea) was applied equally at two (2) weeks after transplanting using bottle cover through side placement fertilizer method.

3.5 Data Collection

Data collected were growth parameters and plant yield. For growth parameters, four (4) tagged plants were used to collect the following Data (Table 2).

Table 1: Growth parameters assessed in the field trial during 2024 rainy season.

Characters	Measurement
Number of leaves	This was done by counting the number of leaves per plant at 4 and 6 weeks after transplanting and the mean recorded.
Plant height (cm)	The height of four tagged plants in each plot was measured from ground level to the top of the canopy, or the highest part of the plant using measuring tape in cm. at 4 and 6 weeks after transplanting.
Leaf length (cm)	The tip to the apical part of each leaf on four tagged picked plants was measured using meter rule (cm) at 4 and 6 weeks after transplanting.
Leaf width (cm)	The widest portion of randomly selected leaves on tagged plants was measured using meter rule (cm) at 4 and 6 weeks after transplanting.
Number of branches per plant	Four tagged plants branches were counted and mean was recorded at 6 weeks after transplanting (6WAT)
Leaf yield per plot (g)	After harvesting of four sampled plant's leaves, leaves were weighed on a digital electronic weighing counter in grammes.

Table 2: The three African nightshade varieties (V1, V2, and V3) exhibited statistically significant differences ($P < 0.01$) in leaf length at both four and six weeks after transplanting

in Bali, Jalingo, and combined locations. At 4 weeks After Transplanting (WAT) V3 consistently outperformed V1 and V2, recording the highest mean leaf length (7.259 cm), followed by V1 (4.279cm), and V2 (3.731cm). However, the same pattern was recorded at Jalingo and combined with V3 (4.72cm), V1 (2.54cm), V2 (2.184cm) in Jalingo and V3 (5.99cm), V1 (3.41cm), and V2 (2.96cm) in combined locations were recorded respectively.

Plant spacing (S1 to S5) exhibited a profound impact on leaf length, with wider spacing (S5) consistently yielding the largest leaves. At four weeks, S5 recorded the highest leaf length (5.65cm in Bali, 3.492cm in Jalingo, 4.57cm combined). This trend persisted at six weeks, with S5 displaying the most expansive leaf dimensions ($p < 0.01$). Wider spacing reduces intra-specific competition for light, water, and nutrients, facilitating greater vegetative growth. Conversely, narrow spacing (S1) restricted leaf expansion due to increased resource competition, leading to lower overall leaf length.

This trend continued at six weeks, where V3 maintained superior values. At Bali, V3 produced longest leaf length (10.176cm), followed by V1 (5.841cm), and V2 (5.131cm), at Jalingo, V3 produced longest leaf length (6.027cm), then V1 (3.69cm), and V3 (3.095cm), for combined V3 had 8.10cm, while V1 and V2 produced 4.77cm and 4.11cm respectively.

S4 and S5 produced longest leaf length (7.791cm and 7.504cm) at Bali location, followed by S3 (6.977cm), while S1 and S2 were not significantly different from each other (6.409cm and 6.566cm). Bali location showed that S4 and S5 were not significantly different from each other at ($P < 0.05$), likewise S2 and S3 were not significantly different with only S3 differs at ($P < 0.05$) to S1, S2 and S4 and S5. For combined location, S3, S4 and S5 were significantly different ($P < 0.05$), while S1 and S2 were not significantly different from each other. Variety by spacing was also significant at ($P < 0.05$).

Table 2: Effect of leaf length on three (3) African nightshade varieties at Bali, Jalingo and combined Locations in 2024 cropping season.

	4 WEEKS AFTER PLANTING			6 WEEKS AFTER PLANTING		
VARIETY/LOCATION	BAL	JAL	COM	BAL	JAL	COM
V1	4.279 b	2.54 b	3.41 b	5.841 b	3.69 b	4.77 b
V2	3.731 c	2.184 c	2.96 c	5.131 c	3.095 c	4.11 c
V3	7.259 a	4.72 a	5.99 a	10.176a	6.027 a	8.10 a
SIG	**	**	*	**	**	**
S.E(±)	0.24	0.03	0.12	0.33	0.03	0.17
L.S.D	1.65	0.0862	0.280	0.43	0.08	0.46
SPACING						
S1	4.537 c	2.842 c	3.69 d	6.409 c	4.038 c	5.22 d
S2	4.723 c	2.92 c	3.82 d	6.566 c	4.25 b	5.41 d
S3	5.097 b	3.07 b	4.08 c	6.977 b	4.25 b	5.61 c
S4	5.443 a	3.417 a	4.43 b	7.504 a	4.388 a	5.95 b
S5	5.65 a	3.492 a	4.57 a	7.791 a	4.427 a	6.11 a
SIG	**	*	*	**	**	**
V × S	*	**	*	**	**	**
S.E(±)	0.11	0.04	0.06	0.18	0.06	0.09
L.S.D	0.13	0.086	0.117	0.6564	0.0803	0.1931

ns: non – significant, * significant at 5%, ** significant 1%, SE: Standard Error, V1: Mbamga, V2: Mange, V3: Pala Pala. S: Spacing
V× S: Variety by Spacing, V1: 20cm × 30cm, V2: 25cm × 30cm, V3: 30cm × 30cm, V4: 35cm × 30cm, V5: 40cm × 40cm

Table 3 showed the effect of variety and spacing on leaf width at 4 weeks after transplanting and 6 weeks after transplanting. At 4 weeks the varieties were significantly different at ($P < 0.05$), V3 had largest leaf width (5.269cm, 3.234cm and 4.25cm) at Bali, Jalingo and in combined followed by V1 (3.176cm, 2.08cm, 2.63cm) and V2 produced leaf width with (2.429cm, 1.61cm and 2.02cm) respectively.

At Bali location, S5 was significantly different from other spacing levels ($P < 0.05$), while S3 and S4 did not differ from each other, likewise S1 and S2. At Jalingo S3, S4, S5, were significantly different, but S1 and S2 were not significantly different ($P > 0.05$). For combined location, S5 was significantly different from S1, S2, S3, and S4 while S3, and S4, were not different from each other. Also S1 and S2 were not significantly different ($P > 0.05$) from each other. Variety by spacing was also highly (**) significant across locations.

However, at 6 weeks after planting (6WAT), the same trend were observed, the varieties were significantly ($P < 0.05$) different from each other with V3 (7.558cm) recording highest width followed by V1 (4.516cm), and V2 (3.327cm), at Bali location. While Jalingo location also had the largest leaf width V3 (4.995cm), V1 (3.052cm), and the least V2 (2.163cm), at combined locations V3 produced 6.28cm, V1 recorded (3.78cm), and V2 (2.75cm).

For effect of spacing, plant spacing (S1 to S5) exhibited a profound significance ($P < 0.01$) on leaf width, S5 was excellent at Bali, Jalingo and combined locations. At Bali, S5 had 5.771cm of leaf width, S3 and S4 were not significantly different from each other (5.116cm and 5.00cm) respectively while S1 and S2 were also not significantly different from each other (4.86cm and 4.872cm). S5 also produced widest leaf (3.745cm) followed by S4 (3.513cm). S5 maintained its widest leaf at combined location (4.76cm) followed by S3 and S4 (4.24cm and 4.26cm) although the two were not significantly different, S1 and S2 had 4.02cm and 4.07cm but not differs significantly from each other. Variety by spacing was also highly significant from each other.

Table 3: Effect of plant spacing on leaf width of three (3) African nightshade varieties at Bali, Jalingo and combined Locations in 2024 cropping season.

VARIETY/LOCATION	4 WEEKS AFTER PLANTING			6 WEEKS AFTER PLANTING		
	BAL	JAL	COM	BAL	JAL	COM
V1	3.176 b	2.08 b	2.63 b	4.516 b	3.052 b	3.78 b
V2	2.429 c	1.61 c	2.02 c	3.327 c	2.163 c	2.75 c
V3	5.269 a	3.234a	4.25 a	7.558 a	4.995 a	6.28 a
SIG	**	**	**	**	**	**
S.E(±)	0.07	0.05	0.04	0.12	0.02	0.06
L.S.D	0.97	0.13	0.09	1.11	0.057	0.140
SPACING						
S1	3.413 c	2.083d	2.75 c	4.86 c	3.175 d	4.02c
S2	3.421 c	2.167d	2.79 c	4.872 c	3.27 c	4.07 c
S3	3.668 b	2.295 c	2.98 b	5.166 b	3.313 c	4.24 b
S4	3.561 b	2.433 b	3.00 b	5.00 b	3.513 b	4.26 b
S5	4.06 a	2.562 a	3.31 a	5.771 a	3.745 a	4.76 a
SIG	**	**	**	**	**	**
V × S	*	**	**	*	**	**
S.E(±)	0.15	0.03	0.05	0.14	0.03	0.07
L.S.D	0.316	0.1303	0.0949	0.5154	0.0570	0.1487

ns: non – significant, * significant at 5%, ** significant 1%, SE: Standard Error, V1: Mbamga, V2: Mange, V3: Pala Pala. S: Spacing
V× S: Variety by Spacing, V1: 20cm × 30cm, V2: 25cm × 30cm, V3: 30cm × 30cm, V4: 35cm × 30cm, V5: 40cm × 40cm

Table 4: showed that number of leaves per plant was significantly influenced by varietal differences ($p < 0.01$) at both four (4) and six (6) weeks after transplanting (WAT). With Mange (V2) consistently exhibited the highest leaf count per plant, followed by V3, while V1 recorded the least number of leaves across all locations. At four WAT, V2 produced an average of 44.73 leaves in Bali, 31.20 in Jalingo, and 37.97 across locations, significantly outperforming V1 (24.67, 15.99, and 20.33, respectively) and V3 (32.87, 21.43, and 27.15, respectively). By Six WAT, a similar trend persisted, where V2 (63.20, 39.60, 51.40) remained superior to V1 (34.67, 21.80, 28.23) and V3 (46.53, 28.80, 37.67).

Table 4: Effect of plant spacing on number of leaves of three (3) African nightshade varieties at Bali, Jalingo and combined Locations in 2024 cropping season.

VARIETY/LOCATION	4 WEEKS AFTER PLANTING			6 WEEKS AFTER PLANTING		
	BAL	JAL	COM	BAL	JAL	COM
V1	24.667 c	15.99 c	20.33 c	34.667 c	21.80 c	28.23 c
V2	44.733 a	31.20 a	37.97 a	63.200 a	39.60 a	51.4 a
V3	32.867 b	21.425 b	27.15 b	46.533 b	28.80 b	37.67 b
SIG	**	**	**	**	*	**
S.E(±)	0.13	0.091	0.07	0.35	0.12	0.18
L.S.D	5.87	0.24	0.177	6.76	4.21	0.406
SPACING						
S1	27.000e	17.33e	22.17 e	38.111 e	23.67 e	30.89 e
S2	31.222d	22.50d	26.86 d	44 d	27.33 d	35.67 d
S3	35.000c	23.275c	29.14 c	49.556 c	31.00 c	40.28 c
S4	37.000b	24.833b	30.92 b	52.222 b	32.67 b	42.44 b
S5	40.222a	26.417a	33.32a	56.778 a	35.67 a	46.22 a
SIG	**	**	**	**	**	**
V × S	**	**	**	**	**	**
S.E(±)	0.18	0.14	0.11	0.23	0.19	0.11
L.S.D	0.628	0.2395	0.2267	0.8043	0.76	0.2262

ns: non – significant, * significant at 5%, ** significant 1%, SE: Standard Error, V1: Mbamga, V2: Mange, V3: Pala Pala. S: Spacing
V× S: Variety by Spacing, V1: 20cm × 30cm, V2: 25cm × 30cm, V3: 30cm × 30cm, V4: 35cm × 30cm, V5: 40cm × 40cm

The three African nightshade varieties (V1, V2, and V3) exhibited statistically significant differences ($p < 0.01$) in the number of branches per plant across both locations and combined analysis (Table 5). At four weeks, V2 demonstrated superior branching performance, with 7.20 followed by V3 (4.53) and V1 (3.627) at Bali location, Jalingo location also had V2 (5.745) being the best, next was V3 (3.165) and V1 (2.580). The same trend followed at combined with V2 (6.47), V3 (3.85) and V1 (3.10).

More so, Spacing effect was significantly different at $P < 0.01$ level with S5 (40×40cm) had highest number (6.556) followed by S4 (5.778), S3 (5.222), S2 (4.500) and S1 (3.544). Variety by spacing was significant at $P < 0.01$.

At 6 weeks after transplanting (6WAT), Bali, Jalingo, and Combined locations followed the same pattern with V2 producing the highest number of branches recording 9.91, 6.515 and 8.21, followed by V3 (6.93, 4.155 and 5.54), the next was V1 (4.897, 2.83 and 3.86) at Bali, Jalingo and Combined respectively.

Spacing effect was also significant ($P < 0.01$), S5 was superior with 8.883, 5.508 and 7.20, next S4 was 8.322, 4.992, 6.66, S3 had 7.278, 4.558 and 5.92 while S2 had 6.194, 4.042 and 5.12. The least was S1 (5.556, 3.40 and 4.48) at Bali, Jalingo and Combined. Variety by spacing was highly significant at $P < 0.01$ across locations. The results indicate significant differences ($p < 0.01$) among the three African nightshade varieties (V1, V2, and V3) in terms of plant height at both the fourth and sixth weeks after transplanting across Bali, Jalingo, and combined locations.

Table 5: Effect of plant spacing on number of branches of three (3) African nightshade varieties at Bali, Jalingo and combined Locations in 2024 cropping season.

	4 WEEKS AFTER PLANTING			6 WEEKS AFTER PLANTING		
VARIETY/LOCATION	BAL	JAL	COM	BAL	JAL	COM
V1	3.627 c	2.58 c	3.10 c	4.897 c	2.83 c	3.86 c
V2	7.200 a	5.745 a	6.47 a	9.91 a	6.515 a	8.21 a
V3	4.533 b	3.165 b	3.85 b	6.933 b	4.155 b	5.54 b
SIG	**	**	**	**	**	**
S.E(±)	0.21	0.02	0.11	0.12	0.031	0.14
L.S.D	0.58	0.07	0.2447	0.33	0.07	0.24
SPACING						
S1	3.544 e	2.667 e	3.11 e	5.556 e	3.400e	4.48e
S2	4.500 d	3.517 d	4.01 d	6.194 d	4.042d	5.12d
S3	5.222 c	3.792 c	4.51 c	7.278 c	4.558c	5.92c
S4	5.778 b	4.392 b	5.09 b	8.322 b	4.992b	6.66b
S5	6.556 a	4.783 a	5.67 a	8.883 a	5.508a	7.20a
SIG	**	**	**	**	**	**
V × S	*	**	**	**	**	**
S.E(±)	0.16	0.05	0.09	0.12	0.04	0.17
L.S.D	0.5891	0.0683	0.1746	0.4189	0.0743	0.1252

ns: non – significant, * significant at 5%, ** significant 1%, SE: Standard Error, V1: Mbamga, V2: Mange, V3: Pala Pala. S: Spacing
V× S: Variety by Spacing, V1: 20cm × 30cm, V2: 25cm × 30cm, V3: 30cm × 30cm, V4: 35cm × 30cm, V5: 40cm × 40cm

Table 6: V2 exhibited the highest plant height (24.87 cm at 4 WAT and 35.55 cm at 6 WAT in combined data), followed by V1 (18.39 cm at 4 WAT and 27.03 cm at 6 WAT), while V3 recorded the lowest plant height (16.89 cm at 4 WAT and 24.63 cm at 6 WAT). Plant spacing also significantly influenced plant height across all locations. Wider spacing (S5) resulted in the tallest plants (22.4 cm at 4 WAT and 32.59 cm at 6 WAT in combined data), while the narrowest spacing (S1) produced the shortest plants (17.43 cm at 4 WAT and 25.46 cm at 6 WAT). The significant interaction between variety and spacing ($p < 0.01$) indicates that plant height responses to spacing among the three varieties. V2 exhibited the highest plant height across all spacing treatments, with maximum values recorded at the widest spacing S5 (40cm×40cm).

Table 6: Effect of plant spacing on plant height of three (3) African nightshade varieties at Bali, Jalingo and combined Locations in 2024 cropping season.

VARIETY/LOCATION	4 WEEKS AFTER PLANTING			6 WEEKS AFTER PLANTING		
	BAL	JAL	COM	BAL	JAL	COM
V1	22.541 b	14.234 b	18.39 b	32.149 b	21.915 b	27.03 b
V2	29.603 a	20.144 a	24.87 a	42.286 a	28.822 a	35.55 a
V3	20.553 c	13.232 c	16.89 c	29.384 c	19.881 c	24.63 c
SIG	**	**	**	**	**	**
S.E(±)	0.04	0.141	0.07	0.08	0.07	0.05
L.S.D	0.03	0.3953	0.1679	0.153	0.1668	0.1134
SPACING						
S1	21.382 e	13.47 d	17.43 e	30.528 e	20.398 e	25.46 e
S2	22.413 d	15.07 c	18.74 d	32.056 d	21.627 d	26.84 d
S3	24.694 c	16.403 b	20.55 c	35.276 c	24.00 c	29.64 c
S4	25.609 b	16.667 b	21.14 b	36.529 b	25.142 b	30.84 b
S5	27.062 a	17.74 a	22.4 a	38.643 a	26.53 a	32.59 a
SIG	**	**	**	**	**	**
V × S	**	**	**	**	**	**
S.E(±)	0.13	0.10	0.10	0.18	0.16	0.09
L.S.D	0.4481	0.3389	0.2077	0.6281	0.1397	0.1893

ns: non – significant, * significant at 5%, ** significant 1%, SE: Standard Error, V1: Mbamga, V2: Mange, V3: Pala Pala. S: Spacing
V× S: Variety by Spacing, V1: 20cm × 30cm, V2: 25cm × 30cm, V3: 30cm × 30cm, V4: 35cm × 30cm, V5: 40cm × 40cm

The analysis of variance indicates significant differences ($p < 0.01$) in leaf yield per plot among the three African nightshade varieties (V1, V2, and V3) across Bali, Jalingo, and combined locations (Table 7). Varieties V2 and V3 exhibited the highest yields (2599.8 g and 2613.9 g in Bali; 1739.0 g and 1735.13 g in Jalingo), whereas V1 had the lowest yield (1475.00 g in Bali, 971.25 g in Jalingo). The combined analysis also confirmed the superior performance of V2 (2169.4 g) and V3 (2174.5 g), significantly out yielding V1 (1223.1 g). These differences highlight the genetic potential of V2 and V3 for higher productivity. Plant spacing significantly ($p < 0.01$) influenced leaf yield per plot. The widest spacing (S1) resulted in the highest leaf yield (2775.8 g in Bali; 1834.23 g in Jalingo), whereas the narrowest spacing (S5) led to the lowest yield (1718.4 g in Bali; 1151.15 g in Jalingo). A significant interaction ($p < 0.01$) between variety and spacing was observed across locations. The best-performing combinations were V2 and V3 at wider spacing (S1 and S2).

Table 7: Effect of plant spacing on leaf yield of three (3) African nightshade varieties at Bali, Jalingo and combined Locations in 2024 cropping season.

VARIETY/LOCATION	BAL	JAL	COM
V1	1475.00 a	971.25 a	1223.1 b
V2	2599.8 b	1739.00 a	2169.4 a
V3	2613.9 b	1735.13 b	2174.5 a
SIG	**	*	**
S.E(±)	21.07	11.23	10.53
L.S.D	58.49	812.22	24.29
SPACING			
S1	2775.8 a	1834.23 a	2305 a
S2	2590.5 b	1721.64 b	2156.1 b
S3	2163.9 c	1436.97 c	1800.4 c
S4	1899.3 d	1264.97 d	1582.2 d
S5	1718.4 d	1151.15 e	1434.8 e
SIG	**	**	**
V × S	**	**	**
S.E(±)	21.24	11.67	10.62
L.S.D	75.94	67.89	21.36

ns: non – significant, * significant at 5%, ** significant 1%, SE: Standard Error, V1: Mbamga, V2: Mange, V3: Pala Pala. S: Spacing V× S: Variety by Spacing, V1: 20cm × 30cm, V2: 25cm × 30cm, V3: 30cm × 30cm, V4: 35cm × 30cm, V5: 40cm × 40cm

5. CONCLUSION AND RECOMMENDATIONS

This study conclusively demonstrates that both varietal selection and plant spacing are critical factors influencing the growth, reproductive development, and overall yield of African nightshade. The findings provide valuable, data-driven insights that can be leveraged to optimize cultivation practices in Taraba State, Nigeria, and other regions sharing similar agro-ecological characteristics.

Based on the empirical evidence gathered, the following recommendations are proposed:

For farmers prioritizing the maximization of leaf yield per unit area, a closer plant spacing of 20×30 cm is recommended, particularly when cultivating the Mange (V2) and Pala Pala (V3) varieties.

Given the significant impact of environmental conditions observed between the two locations, it is crucial to emphasize that site-specific recommendations are paramount for successful and high-yielding African nightshade cultivation.

Further research is warranted to delve deeper into the physiological mechanisms underlying the varied responses of African nightshade varieties to different spacing regimes. Additionally, exploring other complementary agronomic practices could further enhance the overall productivity and sustainability of this important indigenous vegetable.

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