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Optimizing Nitrogen Rate for Improved Growth and Fruit Yield of Cucumber (*Cucumis sativus L.*) in Guinea Savanna, Nigeria

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Abstract: A randomized complete block design (RCBD) experiment with three replications was conducted at the Federal College of Forestry, Jos, to test the following rates 0, 20, 40, and 60 kg N ha^{-1} on cucumber. The application of 40 kg N ha^{-1} maximized growth and yield, producing the highest total fruit yield (41.50 t ha^{-1}). This rate is therefore recommended to enhance cucumber productivity and support sustainable soil fertility management for smallholder farmers in the Jos Plateau region.

Key words: Nitrogen Fertilizer, Cucumber, RCBD Growth and Yield

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a popular and economically significant vegetable crop cultivated globally for its fruits, which are consumed fresh or processed (Tatli & Mirik, 2017). In Nigeria, the demand for cucumber has increased considerably due to its nutritional value, culinary versatility, and role in supporting diverse livelihoods, particularly among smallholder farmers (Idowu *et al.,* 2021). The Guinea Savanna agro-ecological zone, characterized by its distinct wet and dry seasons and predominantly sandy-loam soils, holds potential for cucumber production to meet this rising demand (Ogbonna *et al.,* 2018). However, this potential is often constrained by low soil fertility, a challenge in the region that limits the growth and productivity of cucumber (Adebayo *et al*., 2019).

Among the essential nutrients, nitrogen (N) is a primary macronutrient critical for vegetative growth, fruit development, and overall yield in cucurbits (Hochmuth, *et al.,* 2018). It is a fundamental component of chlorophyll, amino acids, and nucleic acids, directly influencing photosynthetic capacity and plant metabolism (Marschner, 2012).

Consequently, an inadequate supply of nitrogen leads to stunted growth, chlorosis, and poor fruit set, drastically reducing marketable yield. Conversely, the over-application of nitrogen fertilizers, a common practice in attempts to maximize production, is economically inefficient and poses significant environmental risks, including nitrate leaching into groundwater and the emission of greenhouse gases (Ju *et al.,* 2009). This dual challenge necessitates the optimization of nitrogen fertilizer rates to balance high productivity with environmental and economic sustainability.

While the positive response of cucumber to nitrogen fertilization is well-established, the optimal rate is highly site-specific, varying with climatic conditions, inherent soil properties, and the cultivar used (Swiader *et al*., 2000). In Guinea Savanna zone of Nigeria, where soil organic matter is typically low and rainfall patterns can be erratic, generalized fertilizer recommendations may be inadequate or even detrimental. There is a paucity of location-specific research that defines the precise nitrogen rate required to maximize the growth and fruit yield of cucumber under the unique edaphic and climatic conditions of this agro-ecological zone (Yusuf *et al*., 2020). This knowledge gap often leads to suboptimal fertilizer use, limiting both productivity and profitability for local farmers.

Therefore, this study was conducted to determine the optimum nitrogen fertilizer rate for enhanced growth and fruit yield of cucumber in the Guinea Savanna agro-ecological zone of Nigeria. The research will evaluate the effects of varying nitrogen rates on key agronomic parameters and yield components to establish evidence-based, site-specific fertilizer recommendations for sustainable cucumber production in the region.

Materials and Methods

The field experiment was conducted at the students' demonstration farm of the Federal College of Forestry, Jos, located in Jos North Local Government Area of Plateau State, Nigeria. The site is geographically situated between latitude 9°57' N and longitude 8°05' E, at an altitude of approximately 1200 meters above sea level. The area falls within the Guinea Savanna agro-ecological zone and experiences a mean annual rainfall ranging from 1200 mm to 1500 mm, with a mean annual temperature of 23–25°C. The soils of the region are generally characterized as sandy loam, derived from the basement complex rocks.

Certified seeds of a commonly cultivated cucumber variety (*Cucumis sativus* L.) were procured from a certified agro-service center at Farin Gada Market in Jos. The inorganic fertilizers used in the study, specifically NPK 15:15:15 and Urea (46% N), were sourced from the Plateau State Agricultural Development Program (PADP). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of four nitrogen rates: 0, 20, 40, and 60 kg N ha^{-1}. Each plot measured 3 m × 2 m (6 m^2), with a spacing of 0.75 m between rows and 0.50 m within rows, giving a total of 16 plants per plot. Sowing was done on 26-03-2025, and harvesting commenced forty five days after sowing (45DAS) to fifty five days after sowing (55 DAS).

Soil Analysis

Soil samples were collected from the experimental field at a depth of 0–30 cm using a soil auger in a zigzag pattern to obtain a representative composite sample. The composite sample was air-dried, crushed, and passed through a 2 mm sieve, then analyzed in the laboratory for physical and chemical properties.

Particle size distribution was determined using the hydrometer method as described by Gee and Or (2002). Soil pH was measured in a 1:2.5 soil-water suspension using a digital pH meter following the procedure of Kissel and Sonon (2014). Organic carbon was determined by the Walkley-Black wet oxidation method (FAO, 2021a), while total nitrogen was analyzed using the micro-Kjeldahl digestion and distillation method (FAO, 2021b). Available phosphorus was extracted using the Bray-1 method (FAO, 2021c) and quantified spectrophotometrically. Exchangeable cations (Ca, Mg, K, Na) and cation exchange capacity (CEC) were determined using the ammonium acetate (NH_4OAc) method at pH 7.0 (Hendershot, *et al.*, 2008). Analyses were conducted at the Federal College of Forestry, Jos Soil Science Laboratory.

Agronomic Practices

The experimental field was manually cleared of vegetation and debris using hoes and cutlasses. The land was then tilled, and beds were prepared in each plot according to the dimensions specified in the design. Sowing was done on the same day for all plots on 26-03-2025. Two to three cucumber seeds were sown per hole at a shallow depth of 2-3 cm. A spacing of 0.75 m between rows and 0.50 m within rows was adopted. Seedlings were later thinned to two plants per stand at two weeks after sowing (WAS) to maintain the desired plant population.

Fertilizer application was done in two splits. A basal dose of NPK 15:15:15 was applied at the time of land preparation to supply the phosphorus and potassium needs uniformly across all plots, ensuring that the treatments only varied in nitrogen levels. The first dose of nitrogen, in the form of Urea, was applied immediately after thinning at 2 WAS, while the second and final dose was applied 30 days after the first application, corresponding to the early flowering stage. The exact amount of Urea applied per plot for each treatment was calculated based on the plot area and the treatment-specific N rate.

Weeds were controlled manually by hand-pulling and hoeing at regular intervals to keep the crop weed-free throughout the growing season.

Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatment consisted of four levels of nitrogen fertilizer: 0, 20, 40, and 60 kg N ha^{-1}, designated as T_1 (control), T_2, T_3, and T_4, respectively. Data were collected on growth parameters (vine length, number of leaves, number of branches) and yield parameters (days to 50% flowering, number of flowers, number of fruits, fruit length, fruit weight, total fruit yield and total yield) respectively. Data collected were subjected to Analysis of variance (ANOVA) at 5% level of significance using SPSS 26 version statistical package to test the treatment effects and where significance was declared Duncan multiple range test (DMRT) was used to separate the means.

Table1: Physicochemical properties of the experimental soil (0–30 cm depth; n = 1 composite sample)

Parameter	Value	Method Reference
Physical Properties		
Sand (g kg^{-1})	74.08	Gee and Or (2002)
Silt (g kg^{-1})	15.28	Gee and Or (2002)
Clay (g kg^{-1})	10.64	Gee and Or (2002)
Texture	Sandy loam	Gee and Or (2002)
Chemical Properties		
pH (H_2O) (1:2.5)	6.75	Kissel and Sonon (2014)
pH ($CaCl_2$) (1:2.5)	6.17	Kissel and Sonon (2014)
Organic carbon (g kg^{-1})	0.658	FAO (2021a)
Total nitrogen (g kg^{-1})	0.035	FAO (2021b)
Available phosphorus (mg kg^{-1})	47.524	FAO (2021c)
Electrical conductivity (dS m^{-1})	0.089	Soil Survey Staff. 2014
Exchangeable Cations (cmol kg^{-1})		
Ca^{2+}	2.367	Hendershot *et al.* (2008)
Mg^{2+}	1.718	Hendershot *et al.* (2008)
K^{+}	1.503	Hendershot *et al.* (2008)
Na^{+}	0.39	Hendershot *et al.* (2008)
CEC (cmol kg^{-1})	7.241	Hendershot *et al.* (2008)

RESULTS

The results of soil analysis are presented in Table 1. The results indicated that soil at the experimental site was textured sandy loam with moderate water holding capacity. The pHs (H_2O) of the soil were 6.11 and 6.75, which is within the range of 6.0 to 7.0 suitable for cucumber production (Kissel and Sonon, 2014). The organic carbon (OC) content was 0.658%. The cation exchange capacity (CEC) of the soil was 7.241cmol kg^{-1}, could be considered as low according to Nweke *et al.* (2013) who rated CEC value as 12.8cmol kg^{-1} from soil analysis conducted. The total Nitrogen of the soil was 0.035 % which could be considered as low, this is as stated by Nweke *et al.* (2013) who rated total N below 0.05 % as low.

The result of nitrogen application significantly increased growth parameters. The results on vine length across the trend indicated that there was increase at all growth stages from 4 to 12 Weeks After Sowing (WAS) and T_3 (40 kg N ha^{-1}) consistently produced the longest vines, peaking at (218.00 cm) at 12 WAS table 2. Similarly, T_3 (40 kg N ha^{-1}) produced the highest number of branches at all growth stages, reaching (17.00 branches/plant) at 12 WAS as shown in table 3. In table 4 again, T_3 (40 kg N ha^{-1}) gave the highest leaf count at all stages, with 95 leaves/plant at 12 WAS. T_4 (60 kg N ha^{-1}) application recorded the lowest mean value for growth parameters (vine length, number of branches and number of leaves) as shown in table 2, 3 and 4 respectively.

Table 2: Mean effects of Nitrogen rates on Vine Length (cm)

Treatment(kg/ha)	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS
T1= (0 Kg N ha^{-1})	12.33	54.00^c	92.33^c	126.67^c	154.00^c	175.67^c
T2=(20Kg N ha^{-1})	12.86	72.00^b	102.00^b	144.00^b	166.33^b	202.00^b
T3=(40 Kg N ha^{-1})	13.66	85.00a	131.67^a	162.67^a	185.00^a	218.00^a
T4 =(60Kg N $ha-^{1}$)	12.33	35.00^d	47.33^d	57.67^d	73.00^d	82.67^d
SE	0.846	1.633	2.257	4.196	3.325	3.475
p – value	0.416^{NS}	$< 0.001^{**}$	$< 0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), WAS = Weeks after Sowing, SE = Standard Error, NS = **Not significant at 5%,** ** = Significant at 1%

Table 3: Mean effects of Nitrogen rates on Number of Branches-

Treatment (kg/ha)	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS
T1= (0 Kg N ha^{-1})	1.33	3.33^c	6.00^b	8.33^c	10.67^c	12.33^b
T2=(20Kg N ha^{-1})	1.67	4.33^b	7.33^b	10.67^b	13.00^b	13.67^b
T3=(40 Kg N ha^{-1})	2.00	5.33^a	10.00^a	13.00^a	16.33^a	17.00^a
T4 =(60Kg N ha^{-1})	1.00	2.33^d	4.33^c	5.67^d	7.33^d	8.67^c
SE	0.385	0.408	0.680	0.561	0.733	0.561
p – value	0.156^{NS}	$<0.002^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), **WAS** = Weeks after Sowing, **SE** = Standard Error, **NS** = Not significant at 5%, ** = Significant at 1%

Table 4: Mean effects of Nitrogen rates on Number of Leaves

Treatment (kg/ha)	2WAS	4WAS	6WAS	8WAS	10WAS	12WAS
T1= (0 Kg N ha-1)	2.67^{ab}	5.67^c	20.00^c	40.33^c	57.67^c	66.67^c
T2=(20Kg N ha-1)	3.67^a	9.00^b	29.67^b	56.33^b	71.33^b	80.67^b
T3=(40 Kg N ha-1)	4.00^a	10.33^a	39.67^a	82.33^a	81.33^a	95.00^a
T4 =(60Kg N ha-1)	2.00^b	3.33^d	11.00^d	22.00^d	31.67^d	39.67^d
SE	0.539	0.451	0.757	3.937	3.336	2.867
p – value	0.049^{*}	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$	$<0.001^{**}$

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test **(DMRT)**, **WAS** = Weeks after Sowing, **SE** = Standard Error, ** = Significant at 1%

The results of nitrogen rates on yield parameters in table 5, 6, 7, 8, 9 and 10 below shows that significant difference were observed with treatments and T3 (40 kg N ha^{-1}) recording the Earliest flowering (37.00) days and the delayed flowering was recorded in T4 (60 kg N ha^{-1}) (52.33 days) as presented in table 5. On number of flowers per plant presented in table 6, T2 (20 kg N ha^{-1}) produced the most flowers (11.33), followed closely by T3 (9.67) and T4 (60 kg N ha^{-1}) produced the fewest flowers (5.67), significantly lower than the control. The results on number of fruits per plant showed significant difference was observed and T3 (40 kg N ha^{-1}) produced the highest number of fruits (32.67 fruits/plant). T4 (60 kg N ha^{-1}) however, had drastically reduced fruit number (8.33 fruits/plant) shown in table 7.

Fruit length per plant, fruit weight per plant and total fruit yield in kg /ha^{-1} presented in table 8,9 and 10 indicated that significant difference was recorded and T3 (40 kg N ha^{-1}) recorded the highest fruit length (19.33 cm), fruit weight (2.00 kg) and total fruit yield kg/ha (41.50 t ha^{-1}) the least values of the parameters mentioned above were recorded in T4 (60 kg N ha^{-1}) as shown on the tables.

Table 5: Mean effects of Nitrogen rates on Days to 50% Flowering

Treatment	Days to 50% Flowering
T1= (0 Kg/ha)	42.67^{b}
T2= (20Kg/ha)	41.67^{b}
T3= (40Kg/ha)	37.00^{c}
T4= (60 Kg/ha)	52.33^{a}
SE	1.521
p – value	<0.001**

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), SE = Standard Error, ** = Significant at 1%

Table 6: Mean effects of Nitrogen rates on Number of Flowers Per Plant

Treatment	Number of Flowers Per Plant
T1= (0 Kg N ha^{-1})	8.33^{c}
T2= (20 Kg N ha^{-1})	11.33^{a}
T3 = (40 Kg N ha^{-1})	9.67^{b}
T4 = (60 Kg N ha^{-1})	5.67^{d}
SE	0.544
p – value	<0.001**

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), SE = Standard Error, ** = Significant at 1%

Table 7: Mean effects of Nitrogen rates on Number of Fruits Per Plant

Treatment (kg/ha)	Number of Fruits Per Plant
T1= (0 Kg N ha^{-1})	23.33^{b}
T2 = (20 Kg N ha^{-1})	26.33^{b}
T3 =(40Kg N ha^{-1})	32.67^{a}
T4 = (60 Kg N ha^{-1})	8.33^{c}
SE	1.986
p – value	<0.001**

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), SE = Standard Error, ** = Significant at 1%

Table 8: Mean effects of Nitrogen rates on Fruit Length Per Plant

Treatment (kg/ha)	Fruit Length Per Plant (cm)
T1= (0 Kg N ha^{-1})	15.33^{b}
T2 = (20 Kg N ha^{-1})	16.67^{b}
T3 =(40Kg N ha^{-1})	19.33^{a}
T4 = (60 Kg N ha^{-1})	11.00^{c}
SE	0.990
p – value	<0.001**

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), SE = Standard Error, ** = Significant at 1%

Table 9: Mean effects of Nitrogen rates on Fruit Weight Per Plant

Treatment (kg/ha)	Fruit Weight Per Plant (kg)
T1= (0 Kg N ha^{-1})	1.10^{c}
T2 = (20 Kg N ha^{-1})	1.60^{b}
T3 =(40Kg N ha^{-1})	2.00^{a}
T4 = (60 Kg N ha^{-1})	0.63^{d}
SE	0.097
p – value	<0.001**

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), SE = Standard Error, ** = Significant at 1%

Table10: Mean effects of Nitrogen rates on Total Fruit Yield

Treatment	t ha^{-1}
T1= (0 Kg N ha^{-1})	24.36^{c}
T2 = (20 Kg N ha^{-1})	34.53^{b}
T3 =(40Kg N ha^{-1})	41.50^{a}
T4 = (60 Kg N ha^{-1})	15.50^{d}
SE	2.129
p – value	<0.001**

Means within a column having different letters are significant at 5% probability level using Duncan Multiple Range Test (DMRT), **SE** = Standard Error, ** = Significant at 1%

Discussion

The results of this study unequivocally demonstrate that nitrogen (N) fertilization has a profound and statistically significant ($p \leq 0.05$) effect on both the growth and yield of cucumber in the Jos Plateau environment. The consistent improvement in all measured parameters with N application up to 40 kg ha^{-1} underscores the critical role of this nutrient in cucumber production, especially in soils with inherently low total nitrogen content, as was the case in this study. The results on the effects of nitrogen on growth parameters presented in tables 2,3 and 4 below shows significant increase in vine length, number of branches, and number of leaves with increasing N rates (up to 40 kg ha^{-1}) aligns with the role of nitrogen which is a component of chlorophyll, amino acids, and proteins. Nitrogen encouraged vigorous vegetative growth by enhancing photosynthetic capacity and cell division, the longer vines and greater leaf area at T3 (40 kg N ha^{-1})

provided a larger photosynthetic capacity enabling the plant to produce more assimilates for subsequent reproductive development. This evidence corroborates the findings of Uwah, *et al.* (2011) and Ahmed *et al.* (2007), who reported that increased N supply significantly enhanced vine length and leaf production in cucumber. Conversely, the control plants (T1) exhibited stunted growth and smaller leaves, this is evident that nitrogen is deficient therefore, limited their photosynthetic potential and overall biomass accumulation.

The reduction in growth observed at the highest N rate of 60 kg ha^{-1} (T4) compared to T3 is an important finding, though, not statistically significant for all growth parameters as seen in the tables above , suggests a slight negative effect from excessive nitrogen. This observation can be explained that while nitrogen promotes vegetative growth, it excessiveness can lead to a state of "luxury consumption," where the plants grows in abundance foliage at the expense of reproductive growth. Furthermore, excessively high N levels can create physiological imbalances or increase the plant's susceptibility to certain stresses, which may subtly suppress optimal growth.

The effects of nitrogen rates on yield parameters and yield is presented in tables 5,6,7,8,9 and 10. The results showed that application of nitrogen also significantly influenced the reproductive phases of the crop. Plants in the T3 treatment reached 50% flowering earlier (37.00 days) than those in the T4 treatment (52.33 days). This indicates that adequate nitrogen nutrition increases crop development which inadvertently can lead to earlier harvests and allows for more cropping cycles per year. Nitrogen deficiency, as seen in the control treatment, slows down all metabolic processes, including the transition to the flowering stage.

The highest number of fruits per plant, fruit length, fruit weight per plant, and total fruit yield in kg /ha were all recorded at the 40 kg N ha^{-1} rate. The T3 treatment produced a remarkable total yield of 41.50 t ha^{-1}, which was significantly higher than both the control (15.50 t ha^{-1}) and the 20 kg N ha^{-1} rate, and also higher than the 60 kg N ha^{-1} rate. This result is a direct consequence of the improved vegetative growth, which provided the necessary photosynthates to support a greater number of developing fruits. The superior fruit characteristics at T3 aligns with the findings of Jilani *et al.* (2008) and Waseem, *et al.* (2008), who reported that optimal nitrogen levels maximize fruit weight, length, and overall yield. The response of fruit number and weight to N can be attributed to several factors: enhanced flower production, improved fruit set due to better nutrient availability, and reduced flower and fruit abortion. The decrease in total yield at the highest N rate (60 kg ha^{-1}) in this study is consistent with the findings of Uwah, *et al.* (2011), who observed that while 150 kg N/ha promoted vegetative growth, it did not translate to the highest fruit yield, suggesting that a more moderate rate was optimal for economic yield. This reinforces the principle that the relationship between N input and crop yield is not linear but follows a curve where an optimum rate exists beyond which additional inputs provide no further benefit or can even be detrimental.

The results of this study clearly showed that 40 kg N ha^{-1} (T3) is the optimal nitrogen rate for cucumber production under the conditions of this experiment. This rate successfully balanced vigorous vegetative growth with a highly efficient conversion of that growth into marketable fruit yield, outperforming both lower and higher N levels. This finding provides a valuable, location-specific recommendation that can help farmers on the Jos Plateau maximize their productivity and profitability while avoiding the unnecessary costs and potential environmental risks associated with the over-application of nitrogen fertilizers.

CONCLUSION

This study demonstrates that nitrogen fertilization is very crucial for optimizing cucumber growth and yield in the Guinea Savanna zone of Nigeria. The application of 40 kg N ha^{-1} (T3) was identified as the optimal rate, producing the most vigorous plants, earliest flowering, and highest marketable yield (41.50 t ha^{-1}), while the 60 kg N ha^{-1} rate was detrimental to productivity. Therefore, the application of 40 kg N ha^{-1} is strongly recommended for cucumber production in the Jos Plateau and similar environments. However, multi-location and multi-year trials are recommended to validate these findings.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest

REFERENCES

Adebayo, O. S., Fagbami, T. A., & Ojeniyi, S. O. (2019). Fertility status of soils under continuous cultivation in the Southern Guinea Savanna of Nigeria. *Nigerian Journal of Soil Science, 29*(2), 112–120.

Ahmed, N., Baloch, M. H., Haleem, A., Ejaz, M., & Ahmed, N. (2007). Effect of different levels of nitrogen on the growth and production of cucumber. *Life Science International Journal, 1*(1), 99–102.

FAO. (2021a). *Standard operating procedure for soil organic carbon Walkley-Black method titration and colorimetric method*. Rome.

FAO. (2021b). *Standard operating procedure for soil nitrogen* - Kjeldahl method. Rome.

FAO. (2021c). *Standard operating procedure for soil available phosphorus, Bray I and Bray II method*. Rome.

Gee, G.W & Or, D.C. (2002). Particle -size analysis. In J.H. Dane & G.C. Topp (Eds.), Methods of soil analysis part 4. *physical methods* Pp 255-293. Soil science society of America. DOI: 10.2136/sssabookser 5.4.C12

Hendershot, W. H., Lalande, H., & Duquette, M. (2008). Ion exchange and exchangeable cations. In M. R. Carter & E. G. Gregorich (Eds.), *Soil sampling and methods of analysis* (2nd ed., pp. 197–206). Canadian Society of Soil Science, CRC Press & Taylor & Francis Group.

Hochmuth, G., Maynard, D., Vavrina, C., Hanlon, E., & Simonne, E. (2018). *Plant tissue analysis and interpretation for vegetable crops in Florida* (HS964). University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/HS964

Idowu, M. K., Akinboye, O. A., & Oyedele, D. J. (2021). Assessment of cucumber production and marketing among smallholder farmers in Southwestern Nigeria.

*Journal of Agricultural Extension and Rural Development, 13(*1), 15–24. https://doi.org/10.5897/JAERD2020.1189

Jilani, H., Murtaza, G., & Ali, H. (2008). *Cucumis sativus* L. (cucumber): A potential vegetable crop in the tropics. *Journal of Food Science and Technology, 45 (*5), 290–293.

Ju, X. T., Xing, G. X., Chen, X. P., Zhang, S. L., Zhang, L. J., Liu, X. J., Cui, Z. L., Yin, B., Christie, P., Zhu, Z. L., & Zhang, F. S. (2009). Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proceedings of the National Academy of Sciences, 106 (*9), 3041–3046. https://doi.org/10.1073/pnas.0813417106

Kissel, D. E., & Sonon, L. (2014). Single addition of $Ca(OH)_2$ for lime requirement. In F. J. Sikora (Ed.), *Soil test methods from the southeastern United States* (Southern Cooperative Series Bulletin No. 419, pp. 54–58). Southern Extension and Research Activity Information Exchange Group-6.

Marschner, P. (Ed.). (2012). *Marschner's mineral nutrition of higher plants* (3rd ed.). Academic Press.

Nweke, I. A., & Emeh, H. O. (2013). The response of bambara groundnut (*Vigna subterranea* (L.) Verdc.) to phosphate fertilizer levels in Igbariam, South East Nigeria. *IOSR Journal of Agriculture and Veterinary Science, 2 (*4), 28–34. https://doi.org/10.9790/2380-0242834

Ogbonna, P. E., Nwosu, C. J., & Umar, H. S. (2018). Assessment of agricultural practices and constraints to vegetable production in the Guinea Savanna zone of Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology , 25* (3), 1–9. https://doi.org/10.9734/AJAEES/2018/42656

Soil Survey Staff. (2014). *Soil survey field and laboratory methods manual* (Soil Survey Investigations Report No. 51, Version 2.0). R. Burt & Soil Survey Staff (Eds.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Swiader, J. M., Sipp, S. K., & Brown, R. E. (2000). *Pumpkin production: Fertilizer management* (Report No. 2000-03). Illinois State Water Survey.

Tatli, H. İ., & Mirik, M. (2017). Determination of yield and quality characteristics of some cucumber (*Cucumis sativus* L.) genotypes under open field conditions. *Derim , 34* (1), 41–48. https://doi.org/10.16882/derim.2017.305420

Uwah, D. F., Effa, E. B., & Agbanyim, I. K. (2011). Influence of nitrogen and phosphorus on the growth and yield of cucumber (*Cucumis sativus* L.). *Journal of Science, Engineering and Technology , 18* (3), 10248–10260.

Waseem, K., Kamran, Q. M., & Jilani, M. S. (2008). Effect of different levels of nitrogen on the growth and yield of cucumber (*Cucumis sativus* L.). *Journal of Agricultural Research, 46*(3), 259–266.

Yusuf, A. A., Iwuafor, E. N., & Eniola, H. T. (2020). Response of cucumber (*Cucumis sativus* L.) to nitrogen fertilization in the Northern Guinea Savanna of Nigeria. *Journal of Agriculture and Environment* , *16*(2), 78–86.