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Effects of NPK Fertilizer and Vine Care on Soil Chemical Properties and Cucumber (*Cucumis sativus* L.) Growth and Yield Parameters

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cucumber yield in Nigeria is limited by low soil fertility. Therefore, field fertility and vine care experiments that have ability to moderate yield were conducted in the year 2015 cropping seasons. The experiment was located on farmer's field at Abeokuta, Ogun State, Southwestern Nigeria to study the effects of NPK fertilizer and vine care on soil chemical properties, leaf nutrient content, growth and yield of cucumber (*Cucumis sativus* L.). It was a 4 x 3 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with three replicates. Four levels of NPK nutrient formulations (control, NPK15-15-15, NPK 20-10-10 and NPKMg 12-12-17-2) and three vine care types (unstaked, staked and trellised) were applied. Pre-experiment soil samples and soils from each plot at the end of the experiment were collected for soil chemical analysis. Leaf nutrient contents were determined. Plant growth and yield data were measured. Data collected were subjected to statistical analysis and the interaction between factors combined separated. NPK fertilizers significantly ($P \leq 0.05$) increased soil N, P, K, Ca, Mg and leaf P, K, Ca and Mg

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concentrations, Cucumber fruit yield was increased by NPKMg 12-12-17-2 (90.5%), NPK 15-15-15 (60.4%) and NPK 20-10-10 (30.0%) compared with control. Application of vine care enhanced performance of cucumber, fruit yield was increased by trellised (34.0%) and staked (17.3%) compared with control. Combined application of NPKMg 12-12-17-2 and trellising was found most suitable for cucumber production.

Keywords: NPK fertilizer; vine care; soil chemical properties; yield, quality; cucumber .

1. INTRODUCTION

Cucumber (*Cucumis sativus* L) production in West Africa is fast becoming popular due to its high nutritional and medicinal values, as well as its being a useful component ingredient in the preparation of salad and liquor drinks. Appreciable Cucumber cultivation has been reported in different parts of Nigeria such as Zaria in Kaduna State [1], Nsukka in Enugu State [2], Omoku in Rivers State [3], Ilorin in Kwara State [4] and Ibadan in Oyo State [5]. However, cucumber production in Nigeria is limited by low soil fertility and consumer demand affected by fruit's shape and quality. Traditionally, soil fertility in Nigeria has been maintained through fallow. But intensive cropping, high population pressure and urbanization have shortened the fallow period resulting in low crop yield.

The steady decline in crop production due to reduced length of fallow and subsequent loss in soil fertility is responsible for farmers attempt at amending soil with different materials such as organic and inorganic fertilizers to enhance plant growth and yield [6,4,7]. It has been suggested that organic manure should be used in place of chemical fertilizer to avoid long-term negative effects of mineral fertilizer on the soil [8,9]. However, organic manure is usually bulky and required in large quantity to sustain crop production and may not be available to the small scale farmers [10], hence, the need for inorganic fertilizer. The positive effect of the application of inorganic fertilizers on crop yields and yield improvement have been reported [11,4].

In spite of nutritional and health potentials of cucumber, its production is still mainly in the hands of peasant farmers in Nigeria who lack information on vine care and soil management for optimum crop yield. These farmers allow the vines to trail on the ground with its attendant problems of disease and pest infestation and splash of sand on the marketable fruits. Studies have shown the importance of vine care in crop production [2,12]. Staking avoids overcrowding and allows correct exposure or positioning of cucumber leaves to sunlight for effective photosynthetic activities which enhances fruit yield.

Therefore, the study was carried out to determine the effects of NPK fertilizers and vine care on soil chemical properties, growth and yield parameters of cucumber (*Cucumis sativus* L) and their interactive effects.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was located on farmer's field at 'camp area' (close to the Federal University of Agriculture, Abeokuta, Ogun State). Abeokuta is between 100m to 400m above sea level in the humid tropical rainforest zone of south western Nigeria. The mean annual rainfall is between 1,250 – 2,500 mm with the rainy season occurring between March and November. The rainfall distribution is bimodal with first season beginning from March to July and a dry spell in August followed by second season from September to November. The average monthly relative humidity is 81%. Generally, humidity is higher in rainy season than in dry season. The mean monthly temperature ranges between 25.7^oC–30.2^oC [13]. The soils of the experimental site is gravelly loamy sand derived from pre- cambion basement complex of mainly metamorphic origin classified as Plinthic Kandiudalf [14] or Arenic Lixisol [15]. Alfisol of the region are argillic, well drained and mainly sandy clay, sandy loam and sandy clay loam in texture, they satisfies CEC of 16 cmol (+) or less kg clay and an ECEC of 12 cmol (+) or less kg clay required for profile Kandic horizon designation [16].

2.2 Experimental Layout

The crop was grown on a raised bed in a randomized complete block design with three replicates. The size of the experimental area was

430.36 m^2 (40.6 m x 10.6 m). The size of each block (replicate) was 89.32 m^2. Each block contained 12 plots. Each plot measured 6.16 m^2 (2.8 m x 2.2 m). The plots were separated from one another by 0.5 m space while the blocks (replicates) were separated by 1.0 m alley.

2.3 Experimental Design and Treatment Combinations

The experiment was a 4 x 3 factorial design arranged in a randomized complete block design (RCBD) with three replicates. There were four levels of NPK commercial nutrient formulation (control, NPKMg 12-12-17-2, NPK 15-15-15 and NPK 20-10-10) and three types of vine care methods (unstaked, staked and trellised). This results in twelve (12) treatment factorial combinations.

The twelve treatments were applied at the early raining season planting and residual effect evaluated with a second planting at the late raining season.

2.4 Treatment Application

The fertilizers and vine care treatments were applied simultaneously at 2 weeks after planting. The NPK fertilizers were applied as single dose of 400 kg ha^{-1} at early raining season planting by ring application method. Vine care treatments were carried out; bamboo sticks were used as stakes while lines attached to erected bamboo were used as trellises with the emergence of tendrils, control treatment was also established.

2.5 Growth and Yield Data

Six plants were randomly selected and tagged for measurement. Growth data were collected bi-weekly. Vine length was measured as the lateral distance from the base of the shoot to the tip of the lateral main vine by flexible tape rule, number of leaves and number of branches per plant were counted, number of harvested fruits per plant was counted at every harvest. The cumulative weights of the entire harvests were summed up for data analysis; fruit length was measured at every harvest by a flexible tape rule, fruit diameter was measured by cutting the fruit transversely into two equal halves and the diameter measured by a flexible tape rule and fruit yield per hectare was calculated.

2.6 Soil Sampling and Analysis

At the beginning of the experiment, soil samples were randomly collected from the field while post-harvest soil samples were collected per plot at the end of the experiment and analyzed in the laboratory (as described by [17]). The soil was air dried, crushed and sieved with a 2 mm sieve mesh. It was then analyzed in the laboratory as follows: Particle size distribution was determined by the hydrometer method [18]. Soil pH was determined in 1.2 (soil: water) ratio using digital electronic pH meter. Organic carbon (OC) was determined by Walkey and Black dichromate digestion method [19]. Total nitrogen (N) content was determined by the Kjeldahal digestion procedure (Bremner 1996). Available phosphorus was determined using Bray I method and colour was developed in soil extracts using the ascorbic and acid blue colour method as outlined in Frank *et. al,* [20]. Exchangeable bases (Na, K, Ca and Mg) were determined after leaching with 1 N ammonium acetate (NH_4OAC). Ca and Mg were read from the atomic absorption spectrophotometer while K and Na were read from the flame photometer [21].

2.7 Leaf Analysis

Cucumber leaf (leaves and petioles) samples were collected per plot oven dried to constant weight, milled and analyzed for P, Ca, Mg and K according to standard method [22]. P was determined by colorimetry, K was determined by flame photometry. Mg and Ca were determined by atomic absorption spectrophotometry.

2.8 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using the Genstat statistical package [23] to determine the effects of treatments on chemical properties of soil, leaf nutrient content, growth and yield components of cucumber. Duncan Multiple Range Test (DMRT) was used to compare treatments when ANOVA has shown significant differences among means.

3. RESULTS

3.1 Pre-Planting Physical and Chemical Properties of the Soil

The pre-trial physical and chemical properties of the soils at the experimental site are summarized in Table1. The texture is loamy sands**;** pH (6.77) of the soil is within the optimum pH range for vegetable production [24]. Total N (1.20 g kg^1) is below the critical level of < 1.80 g kg^{-1} for cucumber production [25], available P (13.66 mg kg^{-1}) is moderate, OC (11.80 g kg^{-1}) is below the critical range (14 – 20 g kg^{-1}), exchangeable K (0.27 cmol kg^{-1}) is below the critical level (< 0.31 cmol kg^{-1}), exchangeable Mg (2.32 cmol kg^{-1}) is greater than the critical level (< 1.01 cmol kg^{-1}) and exchangeable Ca (6.13 cmol kg^{-1}) is higher than the critical level (< 6.0 cmolkg^{-1}) recommended for vegetable production in Ogun State [24].

3.2 Effect of NPK Fertilizer on Soil Chemical Properties for Early and Late Rain (Residual) Cucumber Cultivation

The effect of NPK fertilizer treatments (control, NPKMg 12-12-17-2, NPK 15-15-15 and NPK 20-10-10) on soil chemical properties for early and late rain (residual) cucumber cultivation are presented in Table 2. There were no significant ($P \leq 0.05$) differences in soil pH across early and late rain (residual) cultivations for all NPK treatments considered. Acidity increased in value within each of the cultivation period in the order NPK 20-10-10>NPK15-15-15>NPKMg12-12-17-2. In late rain (residual) cultivation, only NPKMg 12-12-17-2 significantly ($P \leq 0.05$) increased soil K, while soil K values of NPK 15-15-15 and NPK 20-10-10 treated plots showed no statistical difference between each other. Also, NPKMg 12-12-17-2 significantly ($P \leq 0.05$) increased soil Mg while NPK 15-15-15 and NPK 20-10-10 showed no significant difference in soil Mg compared with control at both cultivations. There were 23, 24, 17, 24 and 26% decrease in Soil OC, N, P, K and Ca respectively from early to late rain (residual) cultivation for NPKMg 12-12-17-2 treatment, likewise 30, 22, 20, 33 and 22% decrease for NPK 15-15-15 treatment and 38, 38, 40, 31 and 17% decrease in soil OC, N, P, K and Ca from early to late rain (residual) cultivation with N-P-K 20:10:10 treatment.

3.3 Effect of NPK Fertilizers on Cucumber Leaf Nutrient Content for Early and Late Rain (Residual) Cultivation

The effect of NPK fertilizers on cucumber leaf nutrient content for early and late rain cucumber cultivation is presented in Table 3a. Generally, all the blends of NPK fertilizers significantly ($P \leq 0.05$) increased leaf P, K, Ca and Mg contents of cucumber compared with the control at early and late rain (residual) cultivations. NPKMg 12-12-17-2 and NPK 15-15-15 treated plots were similar in the values of their leaf P and K but were significantly ($P \leq 0.05$) higher than the values for NPK 20-10-10 treated plots at early and late rain cultivations. However, NPKMg 12-12-17-2 fertilized plots were significantly ($P \leq 0.05$) superior to NPK 15-15-15 and NPK 20-10-10 treated plots in leaf Ca and Mg at both cultivations. Similarly NPK 20-10-10 fertilized plants significantly ($P \leq 0.05$) produced higher values of leaf Ca and Mg than NPK 15-15-15 treated plots except at early rain where leaf Mg values were statistically the same.

Table 1. Pre-Planting Properties of Soils of the Experimental Site

Soil Property	Value
Mechanical Analysis (g kg^{-1})	
Sand	796
Silt	100
Clay	104
Textural Class	**Loamy Sand**
pH (1:2) (H_2O)	6.77
Org. C (g kg^{-1})	11.8
Total N (g kg^{-1})	1.20
Available P (Bray –1- P) (mg kg^{-1})	13.69
Exchangeable Bases (cmol kg^{-1})	
K	0.27
Ca	6.13
Mg	2.32
Na	0.37

Table 2. Effect of NPK Fertilizers on Soil Chemical Properties for Early and Late Rain (Residual) Cucumber Cultivation

NPK Fertilizers	pH 1:2	Org. C	N	P	K	Ca	Mg
	H_2O	← gkg^{-1} →		mgkg^{-1}	← cmolkg^{-1} →		
	Early Rain Cultivation						
Control	6.97a	11.13c	0.98c	6.34c	0.23c	4.97d	2.06b
NPKMg 12- 12-17- 2	6.68a	20.10a	1.76a	12.67a	0.45a	8.32a	3.05a
NPK 15 -15 -15	6.64a	19.12ab	1.66ab	12.09ab	0.39b	7.05b	2.25b
NPK 20 - 10 -10	6.60a	19.60b	1.69b	12.06b	0.36b	6.26c	2.40b
	Late Rain Cultivation (Residual Effect)						
Control	6.68a	7.40c	0.63c	3.56c	0.22b	4.66c	1.92b
NPKMg 12-12- 17- 2	6.28a	15.44a	1.33a	10.48a	0.34a	6.17a	4.46a
NPK 15 - 15 – 15	6.17a	14.91ab	1.30ab	9.62ab	0.26b	5.50b	2.20b
NPK 20 - 10 – 10	6.28a	12.10b	1.04b	7.27b	0.25b	5.19b	2.29b

Means within same column having the same letters are not significantly different at $P \leq 0.05$ by DMRT

3.4 Effect of Vine Care on Cucumber Leaf Nutrient Content at Early and Late Rain (Residual) Cultivation

The effect of vine care (staked and trellised) on cucumber leaf nutrient content at early and late rain (residual) cucumber cultivation is presented in Table 3b. Vine care methods significantly ($P \leq 0.05$) increased leaf nutrient contents of cucumber more than the unstaked at both cultivations. Trellised method significantly ($P \leq 0.05$) produced higher leaf P, K, Ca and Mg contents than staked at both cultivations except in leaf Mg (early rain) and leaf P (late rain) where no significant differences were observed between the two vine care methods.

3.5 Interactive Effect of NPK Fertilizers and Vine Care (Staked and Trellised) on Cucumber Leaf Nutrient Content at Early and Late Rain (Residual) Cultivation

The interactive effect of NPK fertilizers and vine care (staked and trellised) on cucumber leaf nutrient content at early and late rain (residual) cultivation is presented in Table 3c. Significant ($P \leq 0.05$) interaction of NPK fertilizer and vine care were observed in respect of leaf P, K, Ca and Mg at both cultivations. Fertilizers + Trellised generally performed better than fertilizers + staked with regards to leaf nutrient contents most of the time. In early rain cultivation, NPKMg 12-12-17-2 + trellised produced the highest leaf P and K (10.30 gkg^{-1}, 29.50 gkg^{-1}), whereas NPKMg 12-12-17-2 + staked produced the highest leaf Ca and Mg (20.10 gkg^{-1}, 23.67 gkg^{-1}) while control produced the least leaf P, K, Ca and Mg (6.20 g kg^{-1}, 11.77 g kg^{-1}, 4.87 g kg^{-1}, 6.90 g kg^{-1}) respectively. In the late rain cultivation, NPKMg 12-12-17-2 + staked treatment produced the highest leaf P and Ca (9.00 g kg^{-1}, 20.0 g kg^{-1}) but NPKMg 12-12-17-2 + trellised produced the highest leaf Mg (25.07 gkg-1) whereas NPK 15-15-15 + trellised produced the highest leaf K (38.00 gkg^{-1}) while control produced the least leaf K, Ca and Mg (7.30 g kg^{-1}, 5.80 g kg^{-1}, 10.00 g kg^{-1}) respectively.

Table 3a. Effect of NPK Fertilizers on Cucumber Leaf Nutrient Content at Early and Late Rain (Residual) Cultivation

NPK Fertilizers	P	K	Ca	Mg
	←	gkg^{-1}		→
	Early Rain Cultivation			
Control	6.77c	16.14c	8.30c	10.82c
NPKMg 12-12-17- 2	8.98a	19.10a	16.92a	18.44a
NPK 15 - 15 -15	8.33a	22.30a	13.84b	16.73b
NPK 20- 10 – 10	7.79b	18.73b	15.94a	16.62b
	Late Rain Cultivation (Residual Effect)			
Control	6.07c	32.12b	8.67c	12.17d
NPKMg 12- 12- 17- 2	7.19a	39.24a	17.61a	20.26a
NPK 15 - 15 -15	7.03b	39.27a	9.51c	16.83c
NPK 20- 10- 10	7.08ab	36.50ab	11.69b	19.14b

Means within same column having the same letters are not significantly different at $P \leq 0.05$ by DMRT

Table 3b. Effect of Vine Care on Leaf Nutrient Content at Early and Late Rain (Residual) Cucumber Cultivation

Vine Care	P	K	Ca	Mg
	←	gkg^{-1}		→
	Early Rain Cultivation			
Unstaked	7.38b	14.91d	10.66bc	11.73c
Staked	7.54b	16.47d	14.15ab	17.15b
Trellised	8.98a	25.83c	16.45a	18.08b
	Late Rain (Residual Effect)			
Unstaked	6.35c	28.04c	8.87c	11.89c
Staked	7.36b	36.28b	12.83b	17.97b
Trellised	7.36b	46.03a	13.92ab	21.44a

Means within same column having the same letters are not significantly different at $P \leq 0.05$ by DMRT

Table 3c. Interactive Effect of NPK Fertilizer and Vine Care on Leaf Nutrient Content at Early and Late Rain (Residual) Cucumber Cultivation

Treatment	Combination	P	K	Ca	Mg
		←	gKg^{-1}		→
		Early Rain Cultivation			
NPK Fertilizer	Vine Care				
Control	Unstaked	6.20f	11.77f	4.87e	6.90e
	Staked	6.57ef	13.87e	8.27 de	11.13d
	Trellised	7.53cde	22.80b	11.77 cd	14.43d
NPKMg 12-12-17- 2	Unstaked	8.53bc	13.70e	12.27 cd	12.70e
	Staked	8.10cd	14.10e	20.10 a	23.67a
	Trellised	10.30a	29.50a	18.40 a	18.97b
NPK 15 -15-15	Unstaked	7.70cde	18.57c	12.40 cd	12.17ed
	Staked	7.90cd	19.17c	12.27 cd	17.17c
	Trellised	9.40ab	29.17a	16.87 ab	20.87a
NPK 20-10-10	Unstaked	7.07def	15.60 d	13.10 bc	15.17d
	Staked	7.60cde	18.73c	15.97 abc	16.63c
	Trellised	8.70bc	21.87b	18.77 a	18.07bc
NPK *	Vine Care	**	**	*	**
		Late Rain Cultivation (Residual Effect)			
NPK Fertilizer	Vine Care				
Control	Unstaked	6.07def	7.30f	5.80 f	10.00g
	Staked	5.20f	13.20e	7.90 ef	12.07ef
	Trellised	6.93cde	15.87e	12.30 cd	14.43d
NPKMg 12-12-17- 2	Unstaked	6.47def	20.57d	14.87 bc	12.70g
	Staked	9.00a	31.37b	20.03 a	23.00b
	Trellised	6.10def	35.80a	17.93 ab	25.07a
NPK 15- 15-15	Unstaked	5.63ef	24.33cd	4.90 f	11.50f
	Staked	7.07bcd	25.47c	10.37 de	16.50c
	Trellised	8.40ab	38.00a	13.27 cd	22.50b
NPK 20-10-10	Unstaked	7.23bcd	19.97d	9.90 de	13.37de
	Staked	8.17abc	25.07c	13.00 cd	20.30c
	Trellised	8.00abc	34.47ab	12.17 cd	23.77ab
NPK *	Vine Care	**	**	*	**

Means within same columns having same letters are not significantly different at P ≤ 0.05 by DMRT
*Ns = non-significant, ** = significant at 1%, * = significant at 5% level of probability*

3.6 Effect of NPK Fertilizer at Two (2) Weeks Intervals on Growth Traits of Cucumber at Early and Late Rain (Residual) Cultivation

Application of NPK fertilizers significantly (P ≤ 0.05) increased vine length, number of leaves per plant and number of branches per plant of cucumber compared with the control at different stages of growth at both early and late rain (residual) cultivations (Table 4a). At early rain, the vine length of all the blends of NPK (NPKMg 12-12-17-2, NPK 15-15-15 and NPK 20-10-10) fertilized plants were statistically the same but at the late rain the vine length of NPKMg 12-12-17-2 and NPK 15-15-15 treated plants were significantly (P ≤ 0.05) longer than that of NPK 20-10-10. Also, there were no significant differences (P ≤ 0.05) among the blends of NPK fertilizers (NPKMg 12-12-17-2, NPK 15-15-15 and NPK 20-10-10) applied in their number of leaves per plant throughout their stages of growth but early rain plants significantly (P ≤ 0.05) produced higher number of leaves per plant than their late rain counterpart. Moreover, at the early rain and early stage of growth (4WAP) NPKMg 12-12-17-2 fertilized plants significantly (P ≤ 0.05) produced more number of branches per plant than those of NPK 15-15-15 and NPK 20-10-10 fertilized plants but at the late rain cultivation NPKMg 12-12-17-2 and NPK 20-10-10 fertilized plants were similar in their values of the number of branches per plant.

3.7 Effect of Vine Care at Two (2) Weeks Intervals on Growth Traits of Cucumber at Early and Late Rain (Residual) Cultivation

The vine care methods (staked and trellised) significantly ($P \le 0.05$) increased vine length and number of leaves per plant of cucumber compared with the unstaked at both early rain and late rain cultivations (Table 4b). Throughout the stages of growth the vine length, number of leaves per plant and number of branches per plant of staked and trellised plants were statistically the same at both early and late rains except at 4 WAP and 6WAP where trellised plants significantly ($P \le 0.05$) produced higher number of leaves per plant than staked plants at early rain and at late rain cultivations respectively. Closer observation shows that trellised plants consistently produced longer vines , higher numbers of leaves per plant and branches per plant than the staked ones (Table 6b).

3.8 Interactive Effect of NPK Fertilizer and Vine Care at Two (2) Weeks Intervals on Growth Traits of Cucumber at Early and Late Rain (Residual) Cultivation

Significant ($P \le 0.05$) interaction of NPK fertilizer and vine care were obtained in vine length, number of leaves per plant and number of branches per plant at 6 and 8 WAP (Table 4c). At 6 WAP treatment combination of NPKMg 12-12-12-17-2 + trellised produced the longest vines (146.33cm) while control produced the shortest vines (80.13cm) at early rain cultivation. Similar trend was observed at late rain cultivation. At 8 WAP, treatment combinations of NPKMg 12-12-12-17-2 + trellised and NPK 20-10-10 + trellised produced longest vines (189.14cm and 189.38 cm) at early rain cultivation and (169.42 cm and 174.64cm) at the late rain cultivation while control, still produced the shortest vines (early rain 108.83 cm and late rain 85.32 cm) respectively. However, at 6 and 8 WAP, treatment combination of NPK 20-10-10 + trellised produced the highest number of leaves per plant (32.67, 52.60) at early rain whereas it was NPKMg 12-12-12-17-2 + staked that produced the highest number of leaves per plant (22.42, 43.0) at late rain while control produced the least number of leaves per plant (20.69, 30.32) at early rain and (12.58, 25.31) at late rain cultivation. In addition, at the early rain cultivation, the highest number of branches per plant was produced by NPK 20-10-10 + staked (8.46) at 6 WAP and NPKMg 12-12-12-17-2 + trellised (8.96) at 8 WAP while the least number of branches per plant was produced by the control (4.42, 6.25) at the same period. Similar trend was recorded at the late rain cultivation.

3.9 Effect of NPK Fertilizers on Yield and Yield Components of Cucumber at Early Rain and Late Rain (Residual) Cultivation

Cucumber yield and its components in terms of the number of: fruits per plant, weight of fruits per plant, fruit length, fruit diameter and fruit yield per hectare as influenced by blends of NPK fertilizer and vine care (training) application are presented in Table 5a. NPK fertilization significantly ($P \le 0.05$) increased number and weight of fruits per plant, fruit length, fruit diameter and total fruit yield per hectare of cucumber compared with the control at both early and late rain cultivations. At early rain cultivation, all the NPK treatments were virtually uniform in their fruit length and diameter but NPK 15-15-15 fertilized plants consistently produced higher number and weight of fruit per plant and fruit yield per hectare than NPKMg 12-12-17-2 and NPK 20-10-10 treated plants. However, at late rain cultivation NPKMg 12- 12-17-2 significantly ($P \le 0.05$) produced higher number and weight of fruits per plant, fruit length, fruit diameter and total fruit yield per hectare than both NPK 15-15-15 and NPK 20-10-10 fertilized plants. Using the mean of both early rain and late rain cultivations NPKMg 12-12-17-2 increased fruit yield by 90 %, NPK 15-15-15 by 60 % and NPK 20-10-10 by 30 % compared with control respectively.

3.10 Effect of Vine Care on Yield and Yield Components of Cucumber at Early Rain and Late Rain (Residual) Cultivation

Cucumber yield and its components in terms of the number of: fruits per plant, weight of fruits per plant, fruit length, fruit diameter and fruit yield per

Table 4a. Effect of NPK Fertilizer at Two (2) Weeks Intervals on Growth Traits of Cucumber at Early and Late Rain (Residual) Cultivation

NPK Fertilizers	Vine Length (cm)			Number of Leaves per Plant			Number of Branches per Plant		
	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
				Early Rain Cultivation					
Control	17.42b	98.32b	139.50b	7.25b	24.09b	34.55b	4.55c	10.96b	14.44b
NPKMg 12-12-17- 2	24.43a	131.33a	180.80a	8.73a	27.84a	46.60a	6.57a	13.00a	16.51a
NPK 15-15-15	24.05a	130.28a	168.09a	7.90ab	27.70a	45.88a	5.17b	12.81a	16.15a
NPK 20-10 -10	25.64a	126.40ab	176.07a	8.16a	27.61a	46.38a	4.68b	12.41a	16.27a
				Late Rain Cultivation (Residual Effect)					
Control	18.07b	85.15b	113.56c	5.75c	14.24c	28.18b	3.55c	13.09b	15.50b
NPKMg 12- 12-17- 2	28.46a	127.49a	164.05a	8.45a	24.32a	42.74a	5.96a	15.19a	17.97a
NPK 15 -15 -15	24.77a	117.90a	149.95b	7.59b	21.34b	40.09a	5.03b	15.08a	17.50a
NPK 20-10-10	28.48a	114.59ab	151.86b	8.73a	23.73b	40.63a	6.31a	15.56a	17.69a

Means within same columns with same letters are not significantly different at P ≤ 0.05 by DMRT

Table 4b. Effect of Vine Care at Two (2) Weeks Intervals on Growth Traits of Cucumber at Early and Late Rain (Residual) Cultivation.

Vine Care	Vine Length (cm)			Number of Leaves per Plant			Number of Branches per Plant		
	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
				Early Rain Cultivation					
Unstaked	19.94b	111.89b	150.77b	6.98c	24.44b	38.97bc	4.50a	11.08c	14.65c
Staked	22.96ab	120.94ab	168.98ab	8.44ab	26.61b	43.97a	5.00a	12.21bc	15.85bc
Trellised	25.77a	131.92a	178.59a	8.61a	29.37a	47.12a	6.23a	13.59ab	17.02ab
				Late Rain Cultivation (Residual Effect)					
Control	22.48b	101.76b	124.03c	7.79abc	20.16c	36.35c	4.76a	13.00b	15.46bc
Staked	25.79a	111.38b	149.29b	7.6aabc	20.82c	37.64c	5.43a	15.36a	17.45a
Trellised	26.57a	120.72ab	161.24ab	7.43bc	21.75bc	39.49b	5.45a	15.83a	18.59a

Means within same columns with same letters are not significantly different at P ≤ 0.05 by DMRT

Table 4c. Interactive Effect of NPK Fertilizer and Vine Care at Two (2) Weeks Intervals on Growth Traits of Cucumber at Early and Late Rain (Residual) Cultivation

Treatment	Combination	VineLength (cm)		Number of Leaves per Plant		Number of Branches per Plant	
		6 WAP	8 WAP	6 WAP	8 WAP	6 WAP	8 WAP
		Early Rain Cultivation					
NPK Fertilizer	Vine Care						
Control	Unstaked	80.13 b	108.83c	20.69c	30.32e	4.42c	6.25b
	Staked	100.97 ab	146.33cd	25.44 bc	35.85de	5.04bc	7.07ab
	Trellised	113.88 ab	163.34 bc	26.13bc	37.48de	6.98ab	8.33ab
NPKMg 12-12-17- 2	Unstaked	121.33 ab	172.84 ab	26.64 ab	42.33bc	5.92abc	7.54a
	Staked	126.33 ab	180.42ab	27.89 ab	48.12ab	6.46ab	8.31ab
	Trellised	146.33a	189.14a	29.00 ab	49.36ab	7.13a	8.92a
NPK 15 -15-15	Unstaked	127.54 ab	159.22 c	25.56bc	41.40bc	6.29abc	7.95ab
	Staked	130.18 ab	172.55 ab	27.87ab	47.19bc	6.38abc	7.86ab
	Trellised	133.12 ab	172.50 ab	29.66ab	49.04ab	6.54ab	8.42a
NPK 20-10-10	Unstaked	118.55 ab	162.19 bc	24.90 bc	41.82bc	5.54abc	7.57ab
	Staked	126.28 ab	176.63ab	25.25 bc	44.72bc	6.54ab	8.46a
	Trellised	134.37ab	189.38a	32.67a	52.60a	6.53a	8.38ab
NPK *	Vine Care	*	*	*	*	*	*
		Late Rain Cultivation (Residual Effect)					
NPK Fertilizer	Vine Care						
Control	Unstaked	71.85 c	85.32e	12.58c	25.31c	5.17c	6.28f
	Staked	87.34 bc	122.69de	12.03c	26.58c	7.10b	8.45cde
	Trellised	96.2 abc	132.67abd	18.11b	32.64b	7.38ab	8.53cde
NPKMg 12-12-17- 2	Unstaked	128.87 a	155.14 abcd	24.42 a	42.46 a	6.83b	8.12de
	Staked	123.34 ab	167.58 abc	24.22 a	43.00a	7.58ab	8.96bcd
	Trellised	130.28 a	169.42 ab	24.33 a	42.75 a	8.38a	9.88a
NPK 15- 15-15	Unstaked	105.93 abc	130.47bcd	18.89 ab	37.60ab	7.13b	7.96e
	Staked	116.64 ab	151.13abd	23.58 ab	41.96ab	7.58ab	8.79bcde
	Trellised	130.14 a	168.25 ab	21.56 ab	40.72ab	7.92ab	9.50ab
NPK 20-10-10	Unstaked	100.39 abc	125.17cd	24.75 a	40.03ab	6.88b	8.56cde
	Staked	118.18 ab	155.77abd	23.44 ab	39.71ab	8.46a	8.71bcde
	Trellised	125.18 ab	174.64a	23.00 ab	41.83ab	8.00ab	9.28abc
NPK *	Vine Care	*	*	*	*	*	*

*Means within same columns with same letters are not significantly different at P ≤ 0.05 by DMRTNs = non-significant ** = significant at 1% * = significant at 5% level of probability*

hectare as influenced by vine care (vine training) application are presented in Table 5b. The vine care methods (staked and trellised) significantly (P ≤ 0.05) increased yield and yield components of cucumber compared with unstaked at both plantings but with different pattern. At early rain cultivation staked and trellised plants were similar in fruit diameter and total fruit yield per hectare but significantly (P ≤ 0.05) different from unstaked. Other parameters were statistically the same in unstaked, staked and trellised methods. Whereas, at late rain cultivation, number of fruits per plant, fruit length, fruit diameter and total fruit yield per hectare were comparable in both staked and trellised plants but significantly (P ≤ 0.05) higher compared with the unstaked. Using the mean of both early rain and late rain cultivations, fruit yield of cucumber was increased by trellising method 34% and staking method by 17%. compared with unstaked.

Table 5a. Effect of NPK fertilizer on yield and yield components of cucumber at Early Rain and Late Rain (Residual) Cultivation

NPK Fertilizers	No of Fruits per Plant	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Yield per Plant (kg plant^{-1})	Fruit Yield per Hectare (t ha^{-1})
		Early Rain Cultivation			
Control	5.71c	18.52b	5.02b	0.91c	22.43b
NPKMg 12-12-17- 2	7.18ab	19.63a	5.40a	1.21ab	30.04ab
NPK 15 -15-15	8.24a	19.68a	5.41a	1.41a	35.28a
NPK 20-10-10	6.84b	19.79a	5.32ab	1.14b	27.13ab
		Late Rain Cultivation (Residual Effect)			
Control	2.27c	16.93c	4.54c	0.44c	8.40b
NPKMg 12-12-17- 2	4.61a	18.84a	5.14a	1.18a	28.97a
NPK 15-15-15	3.64b	16.24bc	4.62c	0.61b	14.16b
NPK 20-10-10	4.20ab	17.40b	4.98b	0.54bc	12.96b

Means within same columns with same letters are not significantly different at P ≤ 0.05 by DMRT

Table 5b. Effect of vine care on yield and yield components of cucumber at Early Rain and Late Rain (Residual) Cultivation

Vine Care	No of Fruits per Plant	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Yield per Plant (kg plant^{-1})	Fruit Yield per Hectare (t ha^{-1})
		Early Rain Cultivation			
Unstaked	6.72a	18.57b	5.08b	1.01a	24.79b
Staked	6.88a	19.75a	5.33a	1.16a	29.12ab
Trellised	7.38a	19.90a	5.47a	1.34a	32.26a
		Late Rain Cultivation (Residual Effect)			
Unstaked	2.51c	16.19b	4.53b	0.59a	13.43b
Staked	4.30b	17.77ab	4.98a	0.69a	15.71ab
Trellised	4.23b	18.11a	4.95a	0.79a	19.23a

Means within same columns with same letters are not significantly different at P ≤ 0.05 by DMRT

Table 5c. Interactive effect of NPK fertilizers and vine care on yield and yield components of cucumber at Early Rain and Late Rain (Residual) Cultivation

Treatment	Combination	No of Fruits per Plant	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Yield per Plant (kg plant^{-1})	Fruit Yield per Hectare (t ha^{-1})
				Early Rain Cultivation		
NPK Fertilizer	Vine Care					
Control	Unstaked	5.13b	17.53b	4.60 a	0.73b	18.03b
	Staked	6.07 ab	18.87ab	5.27a	0.96ab	23.70ab
	Trellised	5.93 ab	19.17ab	5.20 a	1.04ab	25.57ab
NPKMg 12-12-17- 2	Unstaked	7.33ab	18.90ab	5.17a	1.13ab	27.53 ab
	Staked	6.40 ab	19.70a	5.40a	1.14 ab	29.03 ab
	Trellised	7.80ab	20.30a	5.63a	1.36 ab	33.57ab
NPK 15 -15-15	Unstaked	8.00ab	19.30ab	5.37a	1.25 ab	30.87 ab
	Staked	8.67a	20.07a	5.47a	1.36ab	34.70ab
	Trellised	8.07ab	19.67a	5.40a	1.63a	40.27a
NPK 20-10-10	Unstaked	6.40 ab	18.53ab	5.07 a	0.92 ab	22.73 ab
	Staked	6.40 ab	20.37a	5.27 a	1.18 ab	29.03 ab
	Trellised	7.73ab	20.47a	5.63a	1.31 ab	29.63 ab
NPK *	Vine Care	*	*	Ns	*	*
				Late Rain Cultivation (Residual Effect)		
NPK Fertilizer	Vine Care					
Control	Unstaked	1.67d	16.80b	4.10d	0.36c	5.31c
	Staked	2.27d	16.33ab	4.57 bcd	0.3c	5.56c
	Trellised	2.87cd	17.67ab	4.97 ab	0.58 c	14.32 bc
NPKMg 12-12-17- 2	Unstaked	3.03bcd	17.83ab	4.87 abc	1.13 ab	27.78 ab
	Staked	4.20 abcd	19.77a	5.43a	1.12 ab	27.66 ab
	Trellised	6.60 a	18.93ab	5.13 ab	1.28 a	31.48a
NPK 15- 15-15	Unstaked	2.40d	13.37c	4.23cd	0.37c	8.28c
	Staked	5.27 abc	17.70ab	5.03 ab	0.74 bc	16.54 abc
	Trellised	3.27 bcd	17.67ab	4.60bcd	0.72bc	17.66 abc
NPK 20-10-10	Unstaked	2.93bcd	16.77ab	4.93 abc	0.50 c	12.35 bc
	Staked	5.47 ab	17.27ab	4.90 abc	0.53 c	13.09 bc
	Trellised	4.20 abcd	18.17ab	5.10 ab	0.58 c	13.46 bc
NPK *	Vine Care	*	Ns	Ns	*	*

Means within same columns with same letters are not significantly different at P ≤ 0.05 by DMRT
*Ns = non-significant, ** = significant at 1%, * = significant at 5% level of probability*

3.11 Interactive Effect of NPK Fertilizer and Vine Care on Cucumber Yield and Yield Components at Early Rain and Late Rain (Residual) Cultivation

The combination of NPK fertilization with vine training significantly influenced the performance of cucumber yield and yield components (Table 5c). Significant interaction of NPK fertilizer and vine care was observed in number and weight of fruits per plant, fruit length and diameter and fruit yield per hectare. At early rain cultivation, treatment combination of NPK 15-15-15 + staked produced the highest number of fruits per plant (8.67), weight of fruits per plant (1.63 kgplant^{-1}) and fruit yield per hectare (40.27 t ha^{-1}) while control produced the least number of fruits per plant (5.13), weight of fruits per plant (0.73 kg plant^{-1}) and fruit yield per hectare (18.03 t ha^{-1}). However, at late rain cultivation treatment combination of NPKMg 12-12-17-2, + trellised produced the highest number of fruits (6.60), weight of fruits per plant (1.02 kg $plant^{-1}$) and fruit yield per hectare (31.48 t ha^{-1}) while control produced the least number of fruits per plant (1.67), weight of fruits per plant (0.36 kg $plant^{-1}$) and fruit yield per hectare (5.31 t ha^{-1}) respectively.

4. DISCUSSION

NPK fertilizer application Increase in soil OC, N, P, K and Ca compared with the control, this was expected because the soil fertility was low (table 1) (FMRD, 2012), this is consistent with the work of Okonwu and Mensah [26] who reported increase in post-harvest soil N, P, K, Ca, Na and Mg at Abiriba, Abia State, south east Nigeria due to the application of NPK 15-15-15 fertilizer at the rate of 400 $kgha^{-1}$ in pumpkin cultivation. Increase in soil acidity due to NPK fertilizer formulation application is consistent with the result of Omotosho [27], conversion of ammonium to nitrite results in release of four molecules of hydrogen that is implicated in soil acidity due to fertilizer application. The higher values of soil K and Mg of NPKMg 12-12-17-2 compared with NPK 15-15-15 and NPK 20-10-10 could be adduced to the initial commercial formulations of the NPK fertilizers that have higher K and Mg fortified.

Observed Increase in leaf P, K, Ca and Mg content of cucumber due fertilizer application is consistent with the result of Ayeni and Ezeh [28] that reported higher values of leaf N, P, K, Ca and Mg when NPK 20-10-10 was applied to tomato in South West Nigeria. Increase in cucumber growth and fruit production could also be ascribed to increased availability of soil nutrients occasioned by NPK Fertilizer application. The result corroborates Hakeem [4] who obtained significant growth and yield responses when three cucumber varieties (Marketer, Marketmore and Poinsett) were fertilized with100 $kgha^{-1}$ NPK 15-15-15 at Ilorin in the southern guinea savannah zone of Nigeria. The early rain yield of NPK 15-15-15 was higher than NPKMg 12-12-17-2 but the combined early and late rain yield of NPKMg 12-12-17-2 was greater than both NPK 15-15-15 and NPK 20-10-10. Superior performance of NPKMg 12-12-17-2 have also been documented in cowpea [29].

There were significant responses to the different vine care methods applied. Without vine caring (training) vine length, number of leaves per plant and number of branches per plant of cucumber were much less. Application of vine care irrespective of the nutrient source significantly increased vine length, number of leaves per plant and number branches per plant of cucumber. Similar responses of cucumber, watermelon and fluted pumpkin to staking have been reported by Nweke *et. al.* [2] and Ekwu *et. al.* [12]. The observed increase in vegetative growth could be due to upward training of cucumber vines that increased net photosynthesis. Nweke *et. al.* [2] also reported that the number of branches, number of leaves, vine length and leaf area were higher in staked cucumber (*Cucumis sativus* L.) than the unstaked plants in Enugu, south eastern Nigeria. They suggested that the leaves on the staked plants were all exposed to greater light interception leading to a higher accumulation of photosynthates for vegetative growth.

Results of this study revealed that significant fruit yield increases were obtained by vertical training of cucumber plants this could be attributed to reduction in unmarketable fruits arising from fruit rot, crocked fruit, misshapen fruits, etc. Staked and trellised vine care methods significantly increased number and weight of fruits, increased length and diameter of fruit and gave higher fruit yield per hectare compared with unstaked. The reason for this could be that vine training facilitated exposure of branches and leaves for aeration and effective light reception as a result number of marketable fruits increased. Alam *et. al*. [30] also found that staking increased fruit yield, reduced the proportion of unmarketable fruit, and enhanced the production of high quality fruits of cucumber and tomato. Ekwu *et. al*., [12] also obtained higher number of marketable fruits in staked cucumber at Abakaliki, Southeastern Nigeria. Therefore, researchers recommended staking of crops for higher yield of quality fruits. The higher performance of trellising over staking of the present study corroborates the work of Nair *et. al*., [31] who reported that trellising cucumbers in high tunnel production systems affects fruit length and yield higher number of marketable fruits as compared to non-trellised systems. Chukwudi *et. al*., [32] also reported that Trellising improved the vegetative phase, flowering and yield of *Telfairia occidentalis* in Nsukka, Enugu State, southeastern Nigeria. They claimed that trellising allows for better air movement and heat dissipation and reduces the occurrence of fungal and bacterial diseases.

Hence, trellising allowed continuous and correct positioning of cucumber leaves to sunlight for effective photosynthetic activities that enhanced increased fruit yield. The significant fertilizer*vine care interaction for yield may indicate that yield increase was influenced by frequent vine training if additional NPK was available to maintain higher soil fertility.

5. SUMMARY AND CONCLUSION

Application of different NPK formulations increased soil OC, N, P, K, Ca, Mg, leaf P, K, Ca and Mg concentrations, growth and fruit yield of cucumber compared with the control. Results indicated that NPKMg 12-12-17-2 produced significantly higher fruit yield of cucumber than NPK 15-15-15 and NPK 20-10-10. The higher yield was attributed to higher K and Mg content of NPK 12-12-17-2 fertilizer. Also, the application of cultural technique of vine care (training) further enhanced production of higher fruit yield. The study further revealed that trellised plants produced significantly higher fruit yield than staked plants. The increase in yield was credited to trellising vine care method used that allowed constant and correct positioning of cucumber leaves to sunlight for effective photosynthetic activities that consequently increased fruit yield. The combination of NPKMg 12-12-17-2 + trellised vine care method was found suitable for optimum cucumber production. Therefore, combined application of 400 $kgha^{-1}$ NPKMg 12-12-17-2 fertilizer and trellised vine care method in cucumber production is recommended in the study area. Future research should consider split dosage application of NPKMg 12-12-17-2 fertilizer and cost implication of trellising cucumber.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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