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Growth and Yield Responses of Hot Pepper to Nitrogen Fertilisation in Jos-Plateau, Nigeria

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Abstract
The production of pepper in Nigeria has raised the living standards of many smallholder farmers. The productivity of yellow and red pods is generally low due to poor agronomic practice. There is the need to help smallholder farmers to achieve sustainable production in order to improve and secure their livelihood. This study was aimed to investigate the effects of the rate of Nitrogen fertilisation on growth and yield of pepper in the Jos-Plateau environment. The experiment was 3 x 6 factorial, comprising three varieties of pepper and six levels of N-fertilizer. The treatment-combinations were laid out in the field using the randomised complete block design. Plant height, number of leaves, number of branches, relative growth rate and days to 50% flowering were higher in the variety F_1BT than in the other varieties. Leaf area index, length of fruit and fresh fruit yield were higher in the variety SAFI than in the other varieties. Fruit width and the mean weight of fruit were higher in the Miango Local than in the other varieties. The application of N-fertilizer up to 150 kgN ha^{-1} resulted in significantly higher values in most of the parameters studied. Significant interactions of N-fertilizer rate and variety on plant height, number of leaves per plant, number of branches per plant, leaf area index, relative growth rate, mean weight of fruit and fresh fruit yield were observed. The study recommends the application of N-fertilizer up to 150 kgN ha^{-1} for cultivation of pepper in the Jos-Plateau environment.

Keywords: ***Capsicum*; Growth; N-fertilizer; Productivity; Yield**

Réponses de Croissance et de Rendement du Piment Fort à la Fertilisation Azotée dans le Jos-plateau

Résumé
La production de poivre au Nigéria a élevé le niveau de vie de nombreux petits exploitants agricoles. La productivité des gousses jaunes et rouges est généralement faible en raison de mauvaises pratiques agronomiques. Il est nécessaire d'aider les petits exploitants agricoles à atteindre une production durable afin d'améliorer et de sécuriser leurs moyens de subsistance. Cette étude visait à étudier les effets du taux de fertilisation azotée sur la croissance et le rendement du poivre dans l'environnement du Jos-Plateau.L'expérience était factorielle 3 x 6, comprenant trois variétés de poivre et six niveaux d'engrais azoté. Les combinaisons de traitements ont été disposées sur le terrain à l'aide de la conception randomisée de blocs complets. La hauteur des plantes, le nombre de feuilles, le nombre de branches, le taux de croissance relatif

et les jours de floraison à 50% étaient plus élevés dans la variété F1BT que dans les autres variétés.L'indice de surface foliaire, la longueur des fruits et le rendement en fruits frais étaient plus élevés dans la variété SAFI que dans les autres variétés. La largeur des fruits et le poids moyen des fruits étaient plus élevés dans le Miango Local que dans les autres variétés. L'application d'engrais azotés jusqu'à 150 kgN ha-1 a entraîné des valeurs significativement plus élevées dans la plupart des paramètres étudiés. Des interactions significatives du taux et de la variété d'engrais azotés sur la taille de la plante, le nombre de feuilles par plante, le nombre de branches par plante, l'indice de surface foliaire, le taux de croissance relatif, le poids moyen des fruits et le rendement en fruits frais ont été observées. L'étude recommande l'application d'engrais azotés jusqu'à 150 kgN ha-1 pour la culture du poivre dans l'environnement du Jos-Plateau.

Mots-clés: Capsicum, la croissance, Engrais azoté, la productivité, rendement

Introduction

Pepper is one of the major vegetable crops produced in Nigeria and the country is one of the few developing countries that produce pepper for the export market. It is an important traditional crop valued for its pungency, aroma and colour. It is rich in vitamins, particularly Vitamin A and Vitamin C. One hundred grams of the edible portion of *Capsicum chinesse* contains 24 kCal of energy, 1.3 g of protein, 4.3 g of carbohydrate and 0.3 g of fat (Anonymous, 2001). The crop also serves as a source of income particularly for smallholder farmers in many rural areas (Beyene & David, 2007).

On the basis of the pungency of pepper, *Capsicum* fruits are categorised into non-pungent sweet pepper, moderately pungent or normal hot pepper and very pungent hot pepper, with several intermediate cultivars (Grubben et al*.,* 2004). The pungency of hot pepper is a desirable attribute in many foods.

Habanero pepper is one of the most important vegetables in Nigeria (Beyene & David, 2007). Its production has raised the living standards of many smallholder farmers who produce the crop for commercial purposes. In spite of its importance, the productivity of yellow and red pods has remained at a national average yield of 7.6 t ha^{-1} for red pods and 1.6 t ha^{-1} for yellow pods (PADP, 2006). The decline in the production of *Capsicum* species is attributed to poor varieties, poor cultural practices, and prevalence of fungal (blights), bacterial as well as viral diseases (Fekadu & Dandena, 2006).

Pepper is a long-season crop which requires both quick and steady supply of nutrients during growth. The crop responds to both organic and inorganic fertilizers, which may be applied single or in combination (Aliyu & Kuchinda, 2002). The productivity of pepper is enhanced when it is cultivated on fertile soils with a pH ranging from 5.5-7.0 (Hartmann *et al*., 1981). In Nigeria, hot pepper is usually grown as a rain-fed crop and occasionally under irrigation during the dry season in lowland areas (Muhammad, 1989).

The amount of fertilizer applied depends on soil fertility, fertilizer recovery rate, organic matter, soil mineralisation of nitrogen and soil leaching (Berke *et al*., 2005). The nutrients used on peppers are nitrogen and phosphorus (Bosland & Votava, 2000). Nitrogen enhances crop growth and fruit-set in most vegetable crops. This is attributed to the increased photosynthetic surface and increased physiological activities, resulting in the production of more assimilates which are converted to high fruit yield (Paul & Votava, 2000; Aliyu, 2000; Aliyu & Kuchinda, 2002). Excessive application of N-fertilizer can, however, over-stimulate growth, resulting in large plants with few early fruits, or delayed maturity with a high risk of plant or pod rots (Bosland & Votava, 2000). Fertilizer requirements vary with soil type and previous crop history. A balanced nutrient level is, therefore, required for maximum productivity. In Nigeria, the recommended fertilizer rate for the hot pepper is 200 kg ha^{-1} Diammonium phosphate (DAP) and 100 kg ha^{-1} of urea (EARO, 2004). Alemu and Erimias (2000) reported interactions between nitrogen and different varieties of Habanero pepper (*Capsicum chinesse*).

In the Jos-Plateau, Toro and Zaria in Plateau, Bauchi and Kaduna States, respectively, where fruit pepper is cultivated on a commercial scale, there are limited hot pepper varieties, including indigenous and exotic species. Consequently, varietal information for the improvement of the crop for high yield and quality in the existing agro-ecologies is scanty. There is, therefore, the need to evaluate the growth and yield performance of the cultivated varieties to enable the growers select the best-performing ones in the study area. There is also the need to determine the optimum level of fertilizer application for the cultivation of pepper in the Jos-Plateau environment. The present study was, therefore, aimed to examine the growth and yield responses of two exotic species of Habanero pepper and a local check to different rates of N-fertilizer application in the Jos-Plateau environment in Nigeria.

Materials and Methods

The field study was carried out during the rainy season of 2018 at the Federal College of Forestry Jos, Nigeria; the site is located at latitude 09^0 57'N, longitude 08^0 53'E and at an altitude of 1,159 m above sea level. Composite soil samples were collected from three points at a depth of 0-15 cm and analysed for soil physico-chemical properties. The pH was determined using the glass electrode meter. Bray-P-1 extractant was used to extract available P. Organic C and total N were determined by Walkey Black oxidation and Kjedahl digestion techniques, respectively. Exchangeable bases (K, Ca and Na) were extracted by neutral normal acetate; K, Ca and Na were determined by flame photometry while Mg was determined by the atomic absorption spectrophotometry. Effective cation exchange capacity (CEC) was obtained by summation method (i.e. sum of K, Ca, Mg, Na and exchangeable) (Danbaba & Fogah, 2017). Particle size distribution was done by the hydrometer method of soil mechanical analysis outlined by Bouycous (1951) as reported by Danbaba & Fogah (2017). The result of the soil analysis is shown in Table 1.

The experiment was 3 x 6 factorial, comprising three varieties of *Capsicum* (two exotic and one local check) and six rates of Nitrogen fertilizer (0, 30, 60, 90, 120 and 150

Table 1: Physico-chemical properties of the top soil used for the experiment

Property	Value
Texture class	Sandy Loam
pH (H_2O)	6.0
Nitrogen (g kg^{-1})	2.30
Organic carbon (g kg^{-1})	17.81
Phosphorus (mg kg^{-1})	9.98
Potassium (cmol kg^{-1})	0.19
Sodium (g kg^{-1})	0.11
Calcium (g kg^{-1})	2.91
Magnesium (g kg^{-1})	0.512
Cation exchange capacity (CEC) (g kg^{-1})	3.722

kg ha^{-1}). The treatment-combinations were laid out in the field using the randomised complete block design in three replicates. The agronomic characteristics of the varieties used in the study are as shown in Table 2.

Seedlings were raised in nursery beds, which measured 1.5 m × 2.0 m. Seeds of each variety were drilled 5 cm deep, lightly covered with soil and planted in their respective beds on July 4, 2018. The beds were then mulched with dry grass and lightly watered until they germinated. Regular watering and weeding were done until the seedlings were ready for transplanting on August 11, 2018. The seedlings were transplanted at inter- and intra-row spacing of 0.30 m and 1 m, respectively, to give a total of 33, 333 plants per hectare. The N-fertilizer in the form of urea was applied two weeks after transplanting at the specified rates using the dibbling method.

Plant height, number of leaves per plant and number of branches per plant were taken at 3, 6 and 9 weeks after transplanting (WAT). Plant height was obtained by measuring 5 tagged plants from the ground level to the tip of the plant using a metre rule. The number of leaves per plant was taken by physically counting the total number of fully expanded leaves on 5 tagged plants. The number of branches per plant was determined by counting the total number of branches of 5 tagged plants, and dividing by five.

Leaf area was measured by using the tracing method. Leaf area index, which is the assimilatory surface per unit of ground area covered by the sampled plant, was calculated using the method of Watson (1958) as cited by

Table 2. The Agronomic characteristics of the varieties of pepper used in the experiment

Variety	Agronomic Characteristics
F_1BT	It is a newly introduced Habanero pepper (*Capsicum chinesse*) variety from ZAC Actparc de Jumelles, France. It was imported into Nigeria through Technisem Seed Company. F_1 is a high-yielding variety recommended for any cropping season in the Sudan Savannah in Nigeria. It has elongated wrinkled fruits with pointed ends. It matures 80 days after transplanting. It is very pungent and aromatic. Fruits are light-green to vivid yellow in colour. It is suitable for cropping in the open field.
SAFI	It is also a newly introduced Habanero pepper (*Capsicum chinesse*) variety by Technisem Seed Company in Jos, Plateau State. It is a high-yielding variety with light-green to deep-red fruits which are globular, wrinkled and medium-sized. It matures 80 days after transplanting, with very good export quality. It is very pungent and aromatic.
Miango local	It is a land race of the hot pepper grown locally in Miango Local Government Area of Plateau State, Nigeria. It is globular with wrinkled shape, medium-green turning to deep red at full maturity. It is very hot and aromatic and matures 90 days after transplanting (PADP, 2008).

Namo (2005):

$$LAI = \frac{\text{Total leaf area}}{\text{Area of land covered by the sampled plant}}$$

The relative growth rate was calculated on the basis of increase in dry weight of the plant parts over a fixed period of time using the formula:

$$RGR = \frac{InW_2 - InW_1}{t_2 - t_1}$$

Where,
W_2 and W_1 are total dry weight at times t_1 and t_2
The net assimilation rate (NAR), defined as the rate of increase in dry weight per unit leaf area, was calculated from the data obtained on dry weight of plants using the method by Gregory (1918) as cited by Namo (2005):

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \text{ x } \frac{(\log_e L_2 - \log_e L_1)}{(L_2 - L_1)}$$

Where,
W_1 and W_2 are total plant dry matter at times t_1 and t_2; L_1 and L_2 are leaf areaat time t_1 and t_2.

The number of days taken by the *Capsicum* species to attain 50% flowering after transplanting was counted and recorded. The total number of fruits harvested per plot was divided by the number of tagged plants to give the mean number of fruits per plant. Fruit length was measured using the Vernier caliper. Five fruits were sampled from each plot the length of each of which was measured.The mean was used for the statistical analysis. The fruits used for the measurement of the fruit length were also used for the measurement of the fruit width, using the Vernier caliper. All the fruits harvested from each plot were counted and weighed. The weight of the fruits was divided by the total number of fruits harvested from each plot to give the mean fruit weight. All the fruits harvested from each plot were weighed and the weight was converted to the equivalent in kilograms per hectare before the statistical analysis.
Data collected were subjected to two-way analysis of variance as described by Snedecor & Cochran (1967), using the Statistical Analysis System (SAS Version 9.0). Differences between means were compared using the least significant difference at 5% level of probability.

Results
Plant height increased with time up to 9 weeks after transplanting (9 WAT) in all the varieties and at all levels of N-fertilizer application. At all sampling dates, plant height differed significantly ($p<0.05$) amongst the varieties, being highest in the variety F_1BT and lowest in the Miango Local (Table 3). The application of N- fertilizer at 150 kg ha $^{-1}$ resulted in a significantly higher plant height ($p < 0.05$) than at the other levels of application at all sampling dates. The interaction of N-fertilizer rate and variety on plant height at 9 WAT was significant (Table 4). Across the varieties, plant height increased with increasing rate of N-fertilizer. The interaction of F_1BT with N-fertilizer rate resulted in the highest plant height at 150 kgN ha$^{-1.}$

Table 5 shows the mean number of leaves per plant at different stages of growth. The number of leaves per plant increased with time up to 9 WAT in all the varieties and at all levels of N-fertilizer application. The highest number of leaves was observed in the variety F_1BT at all sampling dates, while the lowest was observed in the Miango Local. The varieties differed significantly ($p < 0.05$) in the number of leaves per plant at all sampling dates. The number of leaves per plant was highest at 150 kgN ha^{-1} and lowest at 0 kgN ha^{-1}

at all but 3 WAT. Table 6 shows the interaction of Nitrogen fertilizer and variety on the number of leaves per plant at 6 WAT. The highest mean number of leaves (84.3) was observed in the variety F_1BT at 150 kgN ha^{-1} while the lowest (24.7) was observed in the Miango Local at 0 kgN ha$^{-1.}$

The mean number of branches per plant increased with time throughout the sampling period in all the varieties and at all levels of N-fertilizer application. At 6 and 9 WAT, the number of branches per plant was significantly higher in the variety F_1BT than in the other two varieties. At 6 and 9 WAT, the number of branches per plant was highest at 150 kg N ha^{-1} and lowest at 0 kg N ha^{-1} (Table 7). The interaction of N-fertilizer rate and variety on the number of branches per plant was significant at 6 WAT (Table 8). In the variety F_1BT, the number of branches per plant increased with increasing N-fertilizer rate; the trend was, however, different in the other two varieties.

The leaf area index was generally higher in the variety SAFI than in the other two varieties except at 9 WAT (Table 9). The interaction of N-rate and variety on LAI was significant at 3, 6 and 9 WAT. At 3 WAT, the LAI increased with increasing N-rate up to 90 kgN ha-^{1} and thereafter decreased in the Miango Local; the trend was different in the other two varieties (Table 10). At 6 WAT, the LAI increased with increasing N-rate up to 150 kgN ha^{-1} in both varieties F_1BT and SAFI. The trend was, however, different in the variety Miango Local (Table 11). At 9 WAT, the interaction of N-rate and the variety SAFI resulted in the highest LAI value of 1.63 at 150 kgN ha$^{-1.}$ The lowest LAI value of 0.61 was observed in the variety SAFI at 0 kgN ha^{-1} (Table 12).

The relative growth rate (RGR) decreased with time in varieties F_1BT and SAFI; in the variety Miango Local, the RGR increased with time throughout the sampling period. At 6 WAT, the RGR decreased with increasing N-fertilizer rate, whereas at 9 WAT, the RGR was highest at 150 kgN ha^{-1} and lowest at 120 kgN ha^{-1} (Table 13). The interaction of N-rate and variety on the RGR was significant at 6 and 9 WAT. At 6 WAT, the RGR values in both varieties F_1BT and the Miango Local decreased with increasing N-rate. In the variety SAFI, the RGR increased with increase in the N-rate up to 30 kgN ha^{-1} and thereafter decreased (Table 14). At 9 WAT, the RGR decreased with increasing N-rate in both varieties SAFI and Miango Local. However, in the variety F_1BT, the RGR increased as the N-rate increased up to 30 kgN ha^{-1} and thereafter decreased (Table 15).

The net assimilation rate (NAR) increased with time up to 9 WAT in all the varieties, but these did not differ significantly at 9 WAT. Across the N-rates, the NAR increased with time up to 9 WAT. At 6 WAT, the NAR decreased as the N-rate increased, whereas at 9 WAT the NAR increased as the N-rate increased but the differences ($p>0.05$) were not significant (Table 16).

The number of days to 50% flowering was significantly higher in the variety F_1BT than in the other two varieties. The number of days to 50% flowering decreased with increasing N- fertilizer rate, being highest at 0 kg N ha^{-1} and lowest at 150 kg N ha^{-1}(Table 17).

The mean number of fruits per plant ranged from 44.3 in the Miango Local to 46.3 in the variety F_1BT, although the difference ($p > 0.05$) was not significant. The mean number of fruits per plant was significantly higher at 150 kgN ha^{-1} than at the other levels of N-fertilizer application (Table 17).

The mean length of fruit was highest in the Miango Local (12.8 cm) and lowest in the variety F_1BT (10.0 cm). The length of fruit increased with increasing N- fertilizer rate, ranging from 9.6 cm at 0 kg N ha^{-1} to 13.6 cm at 150 kg N ha^{-1} (Table 18). The mean width of fruit was highest in the Miango Local (11.1 cm) and lowest in the variety F_1BT (9.7 cm); it was similar at 120 and 150 kgN ha^1, both of which differed significantly from the other levels of N-application (Table 18).

The mean weight of fruit in the variety Miango Local (7.17 g) was significantly different from the variety F_1BT (5.98 g). The mean weight of fruit at 120 and 150 kgN ha^1 was similar but both differed significantly from the other levels of N-fertilizer application (Table 19). The total fresh fruit yield was similar in varieties SAFI and Miango Local but both differed significantly from the variety F_1BT. Fresh fruit yield increased with increasing N- fertilizer rate from 383.9 kg ha^{-1} at 0 kg N ha^{-1} to 1,375.1 kg ha^{-1} at 150 kg N ha^{-1} (Table 19).

The interaction of N-rate and variety on the mean weight of fruit was significant. In both varieties F_1BT and SAFI, the mean weight of fruit increased with increasing N-fertilizer rate up to 150 kgN ha^{-1}; in the variety Miango Local, however, the highest mean weight of fruit of 30.8 g was observed at 120 kgN ha_{-1} and the lowest (28.1 g) at 30 kgN ha^{-1} (Table 20). A significant interaction of N-rate and variety on fresh fruit yield was observed. In all the varieties, fresh fruit yield increased with increasing N-rate. However, whereas the highest fruit yield of 1, 679.5 kg ha^{-1} was observed in the variety SAFI at 150 kgN ha^{-1}, the lowest yield (362.8 kg ha^{-1}) was observed in the variety F_1BT at the zero level of N-fertilizer application (Table 21).

The analysis of variance showed that significant differences were observed for all the growth and yield attributes studied except the net assimilation rate at 9 WAT. The increase in growth and yield attributes with increasing N-rate as observed in this study corroborated earlier reports of Paul & Votava (2000) that nitrogen enhances crop growth rate and fruit-set in most vegetable crops. Nitrogen has been reported to enhance photosynthetic activity and physiological processes resulting in increased production of assimilates, and consequently high fruit yield (Aliyu, 2000; Aliyu & Kuchinda, 2002). Excessive nitrogen application should, however, be avoided as this may result in prolonged vegetative growth, few fruits and pod rots (Bosland & Votava, 2000). A balanced nutrient application is, therefore, required for optimum productivity. To improve high yield in crops, the application of a complete fertilizer to supply about 100-150 kg ha^{-1} of nitrogen and 50 kg ha^{-1} of phosphoric acid and potash is commonly recommended (Hartmann *et al*., 1988). In Nigeria, the recommended fertilizer rate for hot pepper is 200 kg ha^{-1} of Diammonium phosphate (DAP) and 100 kg ha^{-1} of urea (EARO, 2004). Alemu and Erimias (2000) reported significant interactions between nitrogen and different varieties of Habanero pepper (*Capsicum chinesse).* In this study, significant interactions of N-fertilizer and variety were observed on plant height, number of leaves per plant, number of branches per plant, leaf area index, relative growth rate, mean weight of fruit and fresh fruit yield, suggesting that these attributes are influenced by the genotype and environment.
The varieties used in this study showed differences in the number of days to 50% flowering. The variety F_1BT, an exotic variety, took the longest time to flower, compared to the local check (Miango Local). The varieties did not differ significantly in the number of fruits per plant, which, however, varied with the rate of N-fertilizer application. This result suggests that N-fertilizer enhances crop growth and fruit-set in pepper, as reported by Aliyu and Kuchinda (2002). The

Table 3: Main effects of Nitrogen rate and variety on plant height (cm) at 3, 6 and 9 weeks after transplanting of pepper in Jos in 2018

Treatment	Growth Stage (weeks after transplanting)		
	3	6	9
Variety			
F_1BT	13.20[a]	21.36[a]	28.29[a]
SAFI	12.02[b]	17.17[b]	21.46[b]
MIANGO LOCAL	11.18[b]	14,87[c]	19.75[c]
SIGNIFICANCE	*	**	**
L.S.D (0.05)	1.10	0.97	1.28
Nitrogen (Kg ha^{-1})			
0	9.37[d]	12.90[e]	17.50[f]
30	10.82[cd]	14.50[d]	19.50[e]
60	12.13[bc]	16.70[c]	21.16[d]
90	12.94[ab]	19.43[b]	24.11[c]
120	13.94[a]	21.60[a]	25.98[b]
150	13.64[ab]	21.73[a]	30.80[a]
Significance	**	**	**
L.S.D (0.05)	1.55	1.37	1.28
Interaction			
N × V	NS	NS	**
CV%	13.30	7.90	8.05

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 4: Interaction of Nitrogen rate and variety on plant height (cm) at 9 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	20.27d	24.40c	25.90bc	29.20b	31.50b	38.47a
SAFI	16.70e	17.31de	19.00d	22.30cd	24.00c	29.41b
MIANGO LOCAL	15.41e	16.70e	18.50d	20.80d	22.51cd	24.60c
LSD (0.05)			2.495			

Table 5: Main effects of Nitrogen rate and variety on number of leaves per plant at 3, 6 and 9 weeks after transplanting of pepper in Jos in 2018

Treatment	Growth Stage (weeks after transplanting)		
	3	6	9
Variety			
F_1BT	20.78[a]	54.78[a]	80.89[a]
SAFI	19.39[ab]	38.06[b]	59.39[b]
MIANGO LOCAL	18.50[b]	34.06[c]	54.00[c]
SIGNIFICANCE	NS	**	**
L.S.D (0.05)	2.64	2.14	2.10
Nitrogen (Kg ha^{-1})			
0	15.44[c]	28.78[e]	52.11[d]
30	16.67[c]	34.00[d]	56.33[c]
60	18.78[c]	37.11[c]	59.00[c]
90	18.44[c]	39.78[c]	69.33[b]
120	27.78[a]	50.89[b]	74.22[a]
150	23.22[b]	63.22[a]	77.56[a]
Significance	**	**	**
L.S.D (0.05)	3.74	3.03	2.97
Interaction			
N × V	NS	**	NS
CV%	19.87	7.46	4.76

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 6: Interaction of Nitrogen rate and variety on number of leaves per plant at 6 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	36.00g	43.67de	47.33de	51.33d	69.33b	84.33a
SAFI	25.67i	32.01h	33.00h	36.10g	46.02e	55.70c
MIANGO LOCAL	24.70i	26.30i	31.01h	35.30g	39.00f	49.71d
LSD (0.05)			2.545			

Table 7: Main effects of Nitrogen rate and variety on number of branches per plant at 3, 6 and 9 weeks after transplanting of pepper in Jos in 2018

Treatment	Growth Stage (weeks after transplanting)		
	3	6	9
Variety			
F_1BT	9.78^{a}	22.17^{a}	35.61^{a}
SAFI	8.28^{a}	14.94^{c}	24.17^{b}
MIANGO LOCAL	8.56^{a}	17.22^{b}	23.56^{b}
SIGNIFICANCE	NS	**	*
L.S.D (0.05)	1.90	1.22	0.87
Nitrogen (Kg ha^{-1})			
0	6.67^{b}	15.36^{c}	22.56^{e}
30	7.89^{b}	15.56^{c}	24.00^{d}
60	7.33^{b}	16.78^{bc}	26.33^{c}
90	7.89^{b}	17.67^{b}	26.33^{c}
120	12.22^{a}	20.89^{a}	31.78^{b}
150	11.22^{a}	22.44^{a}	35.78^{a}
Significance	**	**	**
L.S.D (0.05)	2.69	1.72	1.23
Interaction			
N × V	NS	**	NS
CV%	31.52	7.20	0.91

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 8: Interaction of Nitrogen rate and variety on number of branches per plant at 6 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	13.00h	418.33e	21.67cd	23.01c	27.33b	29.67a
SAFI	12.31h	15.70f	14.32g	16.00ef	17.00e	21.10d
MIANGO LOCAL	12.60h	12.71hi	14.31g	15.70f	13.31gh	20.60d
LSD (0.05)			1.180			

Table 9: Main effects of Nitrogen rate and variety on leaf area index at 3, 6 and 9 weeks after transplanting of pepper in Jos in 2018

Treatment	Growth Stage (weeks after transplanting)		
	3	6	9
Variety			
F_1BT	0.57^c	0.73^c	0.86^b
SAFI	0.70^a	0.94^a	0.08^c
MIANGO LOCAL	0.61^b	0.80^b	0.92^a
SIGNIFICANCE	**	**	**
L.S.D (0.05)	0.01	0.02	0.03
Nitrogen (Kg ha^{-1})			
0	0.43^f	0.57^e	0.62^d
30	0.51^e	0.68^d	0.78^c
60	0.57^c	0.83^c	0.84^a
90	0.67^c	0.90^b	0.92^a
120	0.73^b	0.96^a	0.22^f
150	0.85^a	0.01^f	0.35^e
Significance	**	**	**
L.S.D (0.05)	0.03	0.03	0.03
Interaction			
N × V	**	**	**
CV%	4.66	4.28	2.18

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 10: Interaction of Nitrogen rate and variety on leaf area index at 3 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	0.45f	0.43f	0.49f	0.63d	0.66d	0.76c
SAFI	0.41f	0.57e	0.63d	0.76c	0.85c	1.01b
MIANGO LOCAL	0.44f	0.54ef	0.58e	1.44a	0.67d	0.79c
LSD (0.05)			1.180			

Table 11: Interaction of Nitrogen rate and variety on leaf area index at 6 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-[1])					
Variety	0	30	60	90	120	150
F_1BT	0.54g	0.59f	0.67e	0.82d	0.86d	0.91c
SAFI	0.63e	0.80d	0.95c	1.03b	1.07b	1.14a
MIANGO LOCAL	0.55f	0.64e	0.86d	0.84d	0.96c	0.98c
LSD (0.05)			0.055			

Table 12: Interaction of Nitrogen rate and variety on leaf area index at 9 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-[1])					
Variety	0	30	60	90	120	150
F_1BT	0.61k	0.69j	0.77h	0.84f	1.13c	1.13c
SAFI	0.73i	0.86f	0.95d	1.01cd	1.37b	1.63a
MIANGO LOCAL	0.62k	0.76h	0.81g	0.90de	1.15c	1.28bc
LSD (0.05)			0.020			

Table 13: Main effects of Nitrogen rate and variety on relative growth rate (gg^{-1} $week^{-1}$) ($x10^{-1}$) at 6 and 9 Weeks after transplanting of pepper in Jos in 2018

Treatment	Growth Stage (weeks after transplanting)	
	3	6
Variety		
F_1BT	0.028^{a}	0.022^{a}
SAFI	0.023^{c}	0.018^{a}
MIANGO LOCAL	0.025^{b}	0.030^{a}
SIGNIFICANCE	**	**
L.S.D (0.05)	0.003	0.016
Nitrogen (Kg ha^{-1})		
0	0.034^{a}	0.027^{c}
30	0.030^{b}	0.026^{c}
60	0.026^{c}	0.021^{c}
90	0.024^{c}	0.038^{bc}
120	0.020^{de}	0.016^{c}
150	0.019^{e}	0.053^{a}
Significance	**	*
L.S.D (0.05)	0.004	0.023
Interaction		
N × V	**	**
CV%	5.30	12.81

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 14: Interaction of Nitrogen rate and variety on relative growth rate (gg^{-1} week) ($\times10^{-1}$) at 6 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	0.034a	0.025d	0.022e	0.019g	0.018h	0.021f
SAFI	0.033ab	0.050a	0.025d	0.024d	0.021f	0.016i
MIANGO LOCAL	0.034a	0.030b	0.024d	0.023de	0.021f	0.020g
LSD (0.05)			0.020			

Table 15: Interaction of Nitrogen rate and variety on relative growth rate (gg^{-1} week) (×10-1) at 9 weeks after transplanting of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	0.019de	0.027ab	0.024bc	0.017ef	0.014h	0.017ef
SAFI	0.025b	0.021d	0.021d	0.019de	0.016g	0.013h
MIANGO LOCAL	0.028a	0.025b	0.021d	0.018e	0.016g	0.015gh
LSD (0.05)			0.001			

Table 16: Main effects of Nitrogen rate and variety on net assimilation rate (gg^{-1} $week^{-1}$) ($x10^{-1}$) at 6 and 9 weeks after transplanting of pepper in Jos in 2018

Treatment	Growth Stage (weeks after transplanting)	
	6	9
Variety		
F_1BT	0.063^{b}	0.085^{a}
SAFI	0.079^{a}	0.142^{a}
MIANGO LOCAL	0.078^{a}	0.104^{a}
SIGNIFICANCE	*	NS
L.S.D (0.05)	0.007	0.061
Nitrogen (Kg ha^{-1})		
0	0.087^{a}	0.160^{a}
30	0.086^{a}	0.086^{a}
60	0.073^{b}	0.086^{a}
90	0.066^{bc}	0.095^{a}
120	0.061^{c}	0.083^{a}
150	0.069^{bc}	0.154^{a}
Significance	**	NS
L.S.D (0.05)	0.010	0.086
Interaction		
N × V	NS	NS
CV%	14.76	18.90

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 17: Main effects of Nitrogen rate and variety on days to 50% flowering and mean number of fruits per plant of pepper grown in Jos in 2018

Treatment	Days of flowering	Mean number of fruits per plant
Variety		
F_1BT	69.17[a]	46.33[a]
SAFI	65.28[b]	44.83[a]
MIANGO LOCAL	65.56[b]	44.33[a]
SIGNIFICANCE	*	NS
L.S.D (0.05)	1.12	3.89
Nitrogen (Kg ha^{-1})		
0	71.22[a]	29.00[d]
30	66.56[b]	38.56[c]
60	66.11[b]	43.67[bc]
90	66.00[b]	47.00[b]
120	65.11[b]	53.78[a]
150	65.00[b]	59.00[a]
Significance	**	**
L.S.D (0.05)	1.59	5.50
Interaction		
N × V	NS	NS
CV%	2.47	12.65

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 18: Main effects of Nitrogen rate and variety on fruit length and fruit width of pepper grown in Jos in 2018

Treatment	Fruit length (cm)	Fruit width (cm)
Variety		
F_1BT	10.01^{b}	9.69^{b}
SAFI	13.01^{a}	10.96^{a}
MIANGO LOCAL	12.77^{a}	11.07^{a}
SIGNIFICANCE	*	*
L.S.D (0.05)	0.87	0.78
Nitrogen (Kg ha^{-1})		
0	9.63^{c}	8.54^{c}
30	10.90^{b}	9.37^{c}
60	11.27^{b}	10.72^{b}
90	13.22^{a}	11.09^{b}
120	13.16^{a}	12.51^{a}
150	13.59^{a}	11.20^{a}
Significance	**	**
L.S.D (0.05)	1.23	1.20
Interaction		
N × V	NS	NS
CV%	10.68	10.78

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 19: Main effects of Nitrogen rate and variety on mean fruit weight and total fruit yield of pepper grown in Jos in 2018

Treatment	Mean fruit weight (cm)	Total fruit yield (kg ha^{-1})
Variety		
F_1BT	9.24^{b}	622.66^{b}
SAFI	9.97^{ab}	972.55^{a}
MIANGO LOCAL	9.85^{a}	897.49^{a}
SIGNIFICANCE	*	*
L.S.D (0.05)	1.19	103.85
Nitrogen (Kg ha^{-1})		
0	9.23^{b}	383.93^{f}
30	9.19^{b}	500.67^{e}
60	9.62^{b}	726.12^{d}
90	9.87^{b}	892.66^{c}
120	10.01^{a}	$1,106.90^{b}$
150	10.30^{a}	$1,375.09^{a}$
Significance	*	**
L.S.D (0.05)	3.93	146.87
Interaction		
N × V	**	**
CV%	23.94	2.04

Means with the same letter(s) within the same column are not significantly different at 5% level of probability

Table 20: Interaction of Nitrogen rate and variety on mean weight of fruit weight (g) of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	25.51f	26.51e	27.70de	28.10d	28.51d	30.10bc
SAFI	27.08e	28.10d	29.30c	30.30bc	31.00b	33.10a
MIANGO LOCAL	30.20bc	28.10d	29.09cd	29.90c	30.80b	29.40c
LSD (0.05)			0.832			

Table 21: Interaction of Nitrogen rate and variety on fresh fruit yield (kg ha^{-1}) of pepper in Jos in 2018

	Nitrogen rate (kg ha-^{1})					
Variety	0	30	60	90	120	150
F_1BT	362.77k	415.93i	550.41hi	667.30gh	806.07f	924.15e
SAFI	405.81j	567.65hi	838.93f	1026.26de	1313.57c	1679.45a
MIANGO LOCAL	372.4kj	518.32i	788.93g	974.96e	1200.93de	1519.19b
LSD (0.05)			06.437			

number of fruits is believed to be influenced by the rate of flower abortion and genotype. In the big-fruit genotypes, more flowers are aborted to allow for the maturation of other fruits, while in small-fruit genotypes, plants may develop several fruits per cluster (Perez, 2003; Marcelis *et al.,* 2004; Rodriques, 2005; Michael, 2011).

Length of fruit, width of fruit and mean weight of fruit varied with variety and the rate of N-fertilizer application, suggesting that these traits are genotypically and environmentally influenced (MARC, 2005). These attributes have been reported to be major yield components in pepper (Bosland & Votava, 2000).

Fresh fruit yield varied with variety and N-fertilizer rate, being highest in the variety SAFI and at 150 kg ha^{-1}. The result suggests that fruit yield in pepper is influenced by genotype and environment, as has been reported by Cankaya *et al.* (2010). Fruit yield is dependent on the number of flowers produced and the proportion that develops into mature fruits. Plant heights, the number of branches per plant, leaf area and dry matter have also been reported as yield-contributing components (Bosland & Votava, 2000; Sam-Aggrey & Bereke-Tsehai, 2005).

Conclusion

Generally, the highest values in the growth and yield attributes studied were observed at 150 kgN ha^{-1} with the lowest at 0 kgN ha^{-1}. The local check (Miango Local) and the variety SAFI have demonstrated potentials for high productivity in the Jos-Plateau environment. The application of Nitrogen fertilizer resulted in the highest fresh fruit yield, and is, therefore, recommended for the cultivation of hot pepper in the Jos-Plateau environment.

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Conflict of interest

The authors declare no conflict of interest.

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