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Growth and Yield Responses of Green Pepper (*Capsicum annum L.*) to Manure Rates under Field and High Tunnel Conditions

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Abstract

The present study was conducted to determine growth and yield responses of green pepper to varying manure rates under field and high tunnel conditions. Experiment 1 was a pot experiment to evaluate three rates (0, 5 and 10 t/ha) of poultry manure (PM) on green pepper production under high tunnel and open field conditions. Experiment 2 was to determine the performance of green pepper as influenced by different manure rates (0, 5 and 10 t/ha of PM, 300 kg/ha of NPK, 5 t/ha of PM + 200 kg of NPK and 10 t/ha of PM + 100 kg of NPK) on the field. High tunnel produced about 3.1 fruits/plant that weighted 102.8 g, which was significantly higher than open field experiment in which 1.7 fruits/plant, with a medium weight of 32.3 g were noted. High tunnel enhanced successful production of green pepper during rainy season, whereas the open field production during the same season was near failure. Application of 10 t/ha of PM produced significantly larger fruits in the pot experiment. Good fertilizer effects on growth and yield components were recorded for the field study. Plant height, number of leaves and branches, number and weight of harvested fruit followed similar trend in 5 and 10 t/ha of PM which gave statistically similar results, and provided the best performance during the experiment. Application of 5 t/ha of PM produced the highest total fruits yield.

Keywords: green pepper, high tunnel, growth, open field, poultry manure, yield components

Introduction

Green peppers (*Capsicum annum* L.) are warm season crops grown mainly for their fruits and contain three to six times as much vitamin C as orange (Bosland and Votava, 2007). It requires similar growing conditions as tomatoes and eggplants and performs best in a long, frost free season. Green pepper belongs to the family Solanaceae and it is energy rich source of vitamin A and C. The plants are shrubby perennials, although usually grown as herbaceous annuals in tropic, sub-tropic and temperate regions (Alabi, 2006). Like other vegetable crops, green pepper contributes nutritiously with nutrients that may be lacking in other food supplies hence improve food intake (Grubben, 1997). It is among the most commonly grown crops throughout Africa because of its utilization in soup, stews and salads (Harlen, 1995; Heiser, 1995).

High tunnels are a greenhouse-like structure whereby plants are grown utilizing the soil (Well and Loy, 1993). They are considered to be a less expensive alternative to a true greenhouse and yet can provide some control of the environmental factors that affect plant growth, development and yield. Such control is due to protection against wind, rain, weeds and some insects and diseases. Growing peppers in high tunnels can be advantageous because tunnels extend the growing season, increase opportunities for colour development and can improve the quality of fruit. Green pepper produced in high tunnels may have higher percentage of the first and second quality fruit compared to field grown pepper due to less bacterial rot and sunscald (Reid *et al*., 2010).

Green pepper is cultivated in South-eastern Nigeria, but without the requisite agronomic packages that will ensure optimum yield. Besides, low fertility status of the soils in the region has been advanced as a serious factor limiting crop yield. Maintenance of soil fertility has been established as a prerequisite for sustainable crop production and increase yield, while organic manuring has been reported to play a vital role in this regard (Jablonska, 1990). Thus, studies on agronomic packages to improve growth and yield of green pepper are relevant in agricultural research. Therefore, the objectives of the hereby study were to evaluate the growth and yield responses of green pepper to different manure rates and to determine the effect of high tunnel on growth and yield of green pepper.

Materials and Methods

The site location and the environmental peculiarities

Two experiments were conducted in the Teaching and Research field of Department of Crop Science, University of

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Nigeria, Nsukka. The research field located at latitude 6°51'E, and longitude 7°29'N of 475 m above sea level is characterized by lowland humid condition with bimodal annual rainfall distribution that ranges from 1,155 mm to 1,955 mm, a mean annual temperature of 29 °C to 31 °C and relative humidity that ranges from 69% to 79% (Uguru *et al.,* 2011). The experiment was carried out from April 2014 to July 2015. Monthly rainfall distribution, relative humidity and temperature during the experiment are presented in Table 1.

'Yalo wonder' variety of green pepper was used and was obtained from a seed store in Jos, Plateau State, Nigeria.

Physicochemical properties of the poultry manure used in the research and the soil characterization were determined using the method of Association of Official Analytical chemists (AOAC, 2002).

The experiment design

Experiment 1 was conducted between April and August 2014 to test the effect of manure rates on the production of green pepper under high tunnel and open field conditions. Healthy seedlings of green pepper were transplanted into the nursery pots containing 15 kg of topsoil. Three treatment of poultry manure (PM) (0, 5 and 10 t/ha) were used and replicated 10 times. The experiment was laid out in completely randomized design (CRD) with a split-plot arrangement. The main plot treatments were the tunnel and open field conditions, while the three manure rates made up the subplot treatments. There were 60 experimental pots; 30 pots were used inside the high tunnel, while the other 30 were used outside the tunnel, each containing 3 seedlings. Manure was applied at 2 weeks after transplanting (2 WAT). Data were taken at 2 weeks interval starting from 3 WAT. Five pots were used as sampling unit; from the sampling unit, 2 plants per pot were used thus data were taken from 10 representative plants per manure rate. Average of 2 plants per pot and 5 pots per treatment were used for data analysis.

Experiment 2 was carried out from November 2014 to March 2015 in an open field to evaluate the effect of poultry manure and inorganic fertilizer on the growth and yield of green pepper. The treatments were six manure rates (0, 5 and 10 t/ha of PM, 300 kg/ha of NPK 15:15:15, 5 t/ha of PM + 200 kg/ha of NPK 15:15:15 and 10 t/ha of PM + 100 kg/ha of NPK 15:15:15). Treatments were laid out in a randomized complete block design (RCBD) with 3 replications. Data were collected from the three middle row plants in each plot, on the following growth and yield parameters: number of leaves, number of branches, plant height (cm), number of fruits, weight of fruits (g) for both experiments.

Statistical analyses

Data collected were subjected to analysis of variance following the procedure outline for split-plot in CRD for experiment 1, while that of experiment 2 were subjected to analysis of variance for randomized complete block design (RCBD) procedures using Genstat Release 10.3DE Discovery Edition 4 (GenStat, 2011) software.

Results

The result of physical and chemical properties of the soil (Table 2) indicated that the soil of the study area before the application of poultry manure (PM) was acidic (pH 4.8 and 4.4 in water and potassium chloride, respectively), and that of poultry manure was slightly above neutral (pH 7.8 and 7.6 in water and potassium chloride, respectively). The soil textural class was a sandy loam, containing 18% clay, 5% silt, 36% fine sand, 41% coarse sand. Total organic matter and total nitrogen contents were found to be 2.55% and 0.14% for soil, while those of PM where 45.74% and 1.54%, respectively.

Data in Table 3 revealed that the environment significantly influenced plant height. In almost all cases, high tunnel outperformed open field. High tunnel produced the tallest plant at 5, 7, 9 and 11 weeks after transplanting (WAT) with an average plant height of 28.6 cm compared to open field that produced 16.3 cm at 11 WAT. Manure rate had a significant effect on plant height; the application of 10 t/ha of PM produced the tallest plant at 3, 5, 7, 9 and 11 WAT. At 11 WAT 10 t/ha of PM produced the tallest plant (26.6 cm) followed by 5 t/ha of PM (23.6 cm), while the least was obtained in 0 t/ha (17.1 cm). Number of leaves significantly varied between open field and high tunnel at 3, 9 and 11 WAT. Open field had the highest number of leaves at

Table 1. Site meteorological data (January-December, 2014 and January-July, 2015)

Month	2014					2015				
	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Temperature (°C)		Relative humidity (%)	
		Min	Max	10 am	4 pm		Min	Max	10 am	4 pm
January	0.0	19.3	31.7	62.1	61.4	0.0	20.5	30.3	61.4	59.6
February	0.0	22.0	33.3	67.9	54.1	56.6	22.7	32.0	70.1	64.2
March	14.2	22.5	31.7	72.8	65.6	34.8	22.6	32.3	70.6	70.2
April	105.2	22.3	31.3	69.9	70.5	39.6	22.4	31.5	71.0	67.7
May	241.1	21.1	28.3	72.3	72.3	267.9	21.8	30.7	71.7	71.4
June	271.8	20.9	29.1	72.0	72.0	121.4	21.2	29.1	76.0	76.0
July	195.8	20.9	27.7	72.2	72.2	110.5	20.6	27.9	76.0	76.0
August	92.4	20.7	27.3	73.0	73.0					
September	401.9	20.3	27.9	73.0	73.0					
October	211.1	20.8	28.9	73.0	72.8					
November	77.2	21.0	30.1	73.8	71.9					
December	4.8	19.0	30.7	70.6	70.1					
Total	1533.6	210.8	297.3	707.1	685.5	630.9	151.8	213.8	496.8	485.1
Mean	153.4	21.1	29.7	70.7	68.6	90.1	21.6	30.5	70.9	69.3

Source: Meteorological Station, Department of Crop Science, University of Nigeria, Nsukka

Table 2. Physical and chemical characteristics of the soil and poultry manure used in the experiment

Physio-chemical properties	Soil	Poultry manure
Clay	18	_
Silt	5	_
Fine Sand	36	_
Coarse Sand	41	_
Textured Class	Sandy loam	
Soil pH (in H2O)	4.8	7.8
Soil pH (in KCL)	4.4	7.6
Total Carbon %	1.48	26.53
Total Organic Matter %	2.55	45.74
Total Nitrogen %	0.14	1.541
Exchangeable Sodium (meq/100 g of soil)	0.04	0.02
Exchangeable Potassium (meq/100 g of soil)	0.11	0.09
Exchangeable Calcium (meq/100 g of soil)	2.2	14.4
Exchangeable Magnesium (meq/100 g of soil)	2.2	47.2
Exchangeable Aluminum (meq/100 g of soil)	_	_
Exchangeable Hydrogen (meq/100 g of soil)	1.6	_
Cation Exchangeable Capacity (meq/100 g of soil)	9.6	_
Base Saturation %	47.4	_
Available Phosphorus (ppm)	30.76	1.06

Table 3. The main effect of environment and manure rate on plant height, number of leaves and number of branches of green pepper

Environment	Plant height					Number of leaves					Number of branches				
	Weeks after transplanting (WAT)														
	3	5	7	9	11	3	5	7	9	11	3	5	7	9	11
Tunnel	8.9	15.1	19.6	25.6	28.6	5.6	10.5	15.9	23.6	27.3	0.0	0.7	2.8	3.5	4.7
Open field	11.6	13.8	15.6	16.0	16.3	6.7	12.6	17.6	18.0	17.0	0.1	0.9	2.2	2.5	2.6
LSD (0.05)	0.8	1.1	1.9	5.2	5.0	0.9	ns	ns	5.3	5.0	ns	ns	ns	ns	1.2
Manure (t/ha)															
0	10.0	12.7	13.9	15.8	17.1	5.1	7.9	12.0	13.7	16.0	0.0	0.2	1.3	1.7	2.1
5	9.6	13.9	17.2	21.2	23.6	6.0	11.1	15.6	19.6	21.5	0.0	0.9	2.1	2.6	4.0
10	11.2	16.8	21.8	25.3	26.6	7.4	15.7	22.8	29.1	29.1	0.2	1.5	3.9	4.7	4.8
LSD (0.05)	0.9	1.4	2.4	6.3	6.3	1.2	3.7	3.9	6.5	6.2	ns	0.7	1.2	1.2	1.4

Table 4. The main effect of environment and manure rate on number of fruits and fruit yield (g/pot) of green pepper

Environment	Number of fruit	Weight of fruits (g)
Tunnel	3.1	102.8
Open field	1.7	32.3
LSD (0.05)	0.7	32.1
Manure (t/ha)		
0	1.3	24.7
5	3.0	77.2
10	2.9	100.7
LSD (0.05)	0.9	39.3

3 WAT, but at 9 and 11 WAT it was high tunnel that produced the highest number of leaves of 23.6 and 27.3, respectively. Manure rate significantly influenced plant performance throughout the experimental period. The application of 10 t/ha of PM produced the highest number of leaves, while 0 t/ha of PM produced the least number of leaves.

Number of branches did not vary significantly between the environments at 3, 5, 7 and 9 WAT, except at 11 WAT when high tunnel produced the highest number of branches, which was significantly higher than open field. Among manure rates, there was significant difference at 5, 7, 9, and 11 WAT. Application of 10 t/ha of PM produced the highest number of branches and non-application of PM produced the least number of branches at 11 WAT.

Table 4 showed that the number of fruits harvested and the weight the fruits varied significantly between high tunnel and open field planting. High tunnel gave the highest number of fruits and fruit weight per plant (of 3.1 and 102.8 g respectively). Among manure rates, application of 5 t/ha of PM gave the highest number of fruits (3.0) followed by 10 t/ha of PM (2.9). For weight of fruits, 10 t/ha of PM gave the highest fruits weight, followed by 5 t/ha of PM.

The growth (plant height, number of branches and number of leaves) responses of green pepper to manure and fertilizer application in the field experiment are shown in Table 5. Application of 5 t/ha of PM produced the tallest plant (39.4 cm) and the shortest was obtained in 300 kg/ha of NPK at 11 WAT. Similarly, application of 10 t/ha of PM produced the highest number of branches, while the least number of branches was obtained in 300 kg/ha of NPK at 11 WAT. Number of leaves was significantly different at 9 WAT. It was the application of 10 t/ha of PM + 100 kg of NPK that produced the highest number of leaves and the least number of leaves was observed in 300 kg/ha of N P K (54.7). Variation in number of leaves was not significant at 11 WAT, although the application of 5 t/ha of PM had the highest number of leaves while 300 kg/ha of NPK produced the least number of leaves.

Fig. 1 showed that the total number of fruits per plot peaked at 10, 12 and 16 WAT; the highest peak have been registered at 16 WAT and 10 t/ha of PM was found to be on top of these peaks. Table 6 showed that total fruit weight was significantly affected by manure rate. Application of 5 t/ha of

Table 5. Growth responses of green pepper to manure and fertilizer application

Manure/fertilizer	Plant height (cm)					Number of branches					Number of leaves				
	Weeks after transplanting (WAT)														
Rate (kg/ha)	3	5	7	9	11	3	5	7	9	11	3	5	7	9	11
0 t/ha	15.0	19.2	22.9	25.7	28.1	3.0	6.2	7.8	9.8	13.1	21.1	43.7	53	72.3	86.7
5 t/ha	17.4	21.8	27.4	34.7	39.4	4.1	8.4	10.0	12.8	18.1	24.9	47.2	65.7	89.8	121.4
10 t/ha	18.3	21.4	27.9	32.4	37.7	4.7	8.3	10.8	13.7	18.1	26.0	44.6	74.6	87.5	118.1
300 kg NPK	9.4	11.9	15.4	17.3	21.2	1.6	4.3	5.4	5.8	7.7	12.3	26.2	39.4	41.4	54.7
5 t/ha+ 200 NPK	15.6	18.6	23.3	29.4	34.8	3.9	6.9	8.3	11.3	14.5	21.9	46	56.9	81.9	108.3
10 t/ha+100 NPK	14.2	16.6	24.9	31.6	36.8	4.0	8.1	10.8	12.6	15.8	23.1	59.2	70.3	92.9	108.3
LSD (0.05)	5.4	4.5	4.4	5.9	7.3	ns	2.8	3.6	5.0	ns	ns	ns	ns	32.8	ns

Table 6. Fruit weight (g) of green pepper in response to manure and fertilizer application

Manure/fertilizer rate (kg/ha)	TFW (g/plot)	TFW (t/ha)
0 t/ha	678.0	1.8
5 t/ha	944.0	2.5
10 t/ha	834.0	2.2
300 kg NPK	424.0	1.1
5 t/ha + 200 NPK	766.0	2.0
10 t/ha +100 NPK	833.0	2.2
LSD (0.05)	234.0	0.6

TFW=Total fruits weight

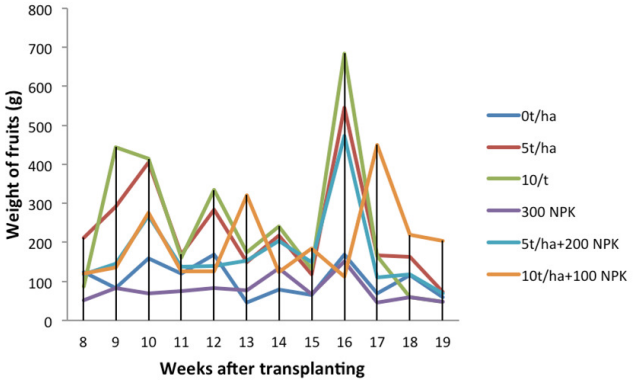

Fig. 2. Fruit weight (g/plot) of green pepper in response to manure and fertilizer application

PM had the highest fruit weight (944.0 g) and the least was obtained in 300 kg/ha of NPK. Total fruits weight (t/ha) was significantly affected by treatments, the highest was obtained in 5 t/ha of PM and the least in 300 kg/ha of NPK. Fig. 2 showed the weight of fruits per plots peaked at 9, 10, 12, 13, 14, 16 and 17 WAT; the highest peak have been noted at 16 WAT and 10 t/ha of PM was on top of the peak at 9, 10, 12, 14 and 16 WAT. Although at 13 and 17 WAT, 10 t/ha of PM + 100 kg of NPK was on top of the peaks.

Discussion

The high tunnels can be warmer than the ambient outside air temperature during the day. This temperature increase allows peppers to be planted some weeks earlier than outside plantings in some locations. Growing pepper in high tunnels can be beneficial because its shield the plants from wind, control moisture inflow, reduced nutrient leaching and make the plant to remain productive for a longer time (Maughan and Drost, 2012). A convinced example in this way might be the failed field experiment that was carried out in July-August 2014, which was the pick of the rain in the region. The results

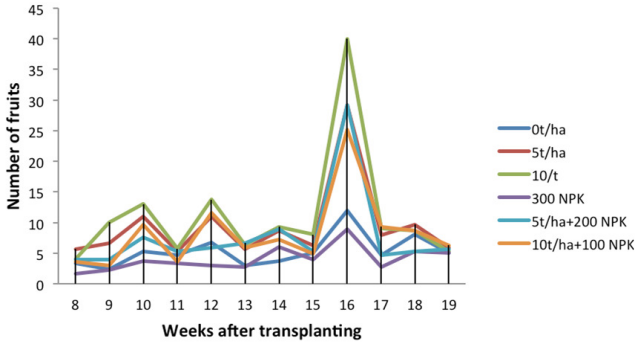

Fig. 1. Number of fruits harvested per plot over the experiment

obtained from analysis of variance for the main effect of environment on growth and yield of green pepper revealed that high tunnel was significantly higher than open field in all the parameters measured, especially from the later growing stage of the plant. This could probably be as a result of good growing conditions offered by high tunnel. These results are in agreement with the findings of Wien (1997) and Halim and Islam (2013) who reported that a little shade in tropics might benefit pepper growth. Also, Singh *et al.* (2013) reported that low poly tunnel significantly increased the growth and yield attributes of green pepper when compared with an open field grown green pepper.

Main effect of poultry manure rates on growth and yield of green pepper showed a significant difference, whereas application of 10 t/ha of PM was found to be significantly higher than other manure rates in plant height, number of leaves and number of branches. This result is in accordance with the findings of Ikeh *et al.* (2012) who observed that application of 10 t/ha of PM was significantly higher than 0 t/ha and 4 t/ha of PM on plant height, number of leaves, number of branches and leaf area of pepper. For number of fruits, 5 t/ha of PM performed significantly better than 0 t/ha and statistically was the same with 10 t/ha of PM. For weight of fruits, 10 t/ha of PM was significantly higher than 0 t/ha and was statistically the same with 5 t/ha of PM. Ikeh *et al.* (2012) earlier reported similar results and concluded that application of 10 t/ha and 6 t/ha of PM were statistically the same on the fresh fruit yield (t/ha) in pepper.

The results obtained from field experiment on growth responses of green pepper to fertilizer application clearly showed that PM used in the hereby experiment substantially increased the growth and yield performance of green pepper and application of 5 t/ha of PM performed the best. Application of PM probably reflected high release of essential nutrients, especially nitrogen and phosphorus. Reports from other researchers have shown that organic-amended of soil have twice the level of nitrogen as conventional soil (Burger and

Jackson, 2003; Dauda *et al*., 2005; Funsho *et al*., 2015). Poultry manure has been reported to possess essential nutrient elements associated with high photosynthesis activities and thus promoted roots and vegetative growth (John *et al.,* 2004). However, this result disagreed with the findings of Ikeh *et al.* (2012) who observed that increase in PM rate increased the number of leaves, plant height and number of branches of pepper as the application of 5 t/ha of PM was better when compared to 10 t/ha of PM on the mentioned traits.

Conclusions

It was clearly evident from the collected data that high rainfall limited the growth and yield performances of green pepper. Thus, the high tunnel supported production of more than 100% fruit increase over the open field cultivation during the heavy tropical rainfall season. Besides, green pepper had a positive response to fertilization regime and organic manure (poultry droppings) gave better results in regard to pepper yield than the inorganic (NPK 15:15:15) fertilizer.

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