Poultry manure Fertilization Improves the Yield and Capsaicinoid Content of Sweet Pepper (*Capsicum annuum* L.) Cultivars

Comment [R1]: Modify the title

Abstract

To assess the impact of poultry manure fertilization on the yield and capsaicinoid content of sweet pepper cultivars, field experiments were carried out during the 2018 rainy seasons at two locations within the Sudan savanna agro-ecological region: the Teaching and Research Farm Bayero University Kano (l1°58 N, 8°25 E, and altitude 458 m) and Kadawa Irrigation Scheme Bunkure (l1°42 N, 8° 33 E, and altitude 476 m). The experiment was a 4 x 3 factorial laid out in a randomized complete block design with four replicates. The treatments comprised four levels of poultry manure (PM) (0, 1.0, 2.0, and 3.0tha^{-1}) and three cultivars of sweet pepper (Tattasai Dan Damasak, Yolo wonder and Nsukka yellow). The result indicated that the growth, yield and capsaicin content of sweet pepper cultivar was significantly ($p<0.05$) influenced by application of poultry manure. The result of this experiments reveals that plant height, number of branches plant^{-1}, leaf area index and number of plant^{-1} and the capcisinoid content of sweet pepper cultivars were greatly influenced by the application of PM. The application of 3.0 tha^{-1} of PM significantly gave taller plants, more branches plant^{-1}, larger leaves and higher number of fruits plant^{-1}. Similarly, Dan Damasak cultivar significantly produced higher growth characters above except for number of fruits plant^{-1} were Dan Damasak and Yolo wonder cultivars at BUK and Yolo wonder at BKR significantly gave higher number of fruits plant^{-1}. Fresh fruit yield, total fruit yield and capsaicinoid content was significantly higher with application of 3.0 tha^{-1} of PM at both locations. Dan Damasak cultivar resulted in higher yield related characters at both locations. The capsaicinoid content was however significantly higher with Nsukka yellow (17.43 & 18.83 mg kg^{-1}) at BUK and BKR locations, respectively. Thus, the application of 3.0 tha^{-1} PM combined with Dan Damasak culitivar could be suggested to the farmers in the study area for improved growth and fruit yield of sweet pepper. Similarly, the Nsukka Yellow cultivar and the application of 3.0 tha^{-1} PM can also be suggested for greater capsaicinoid concentration.

Comment [R2]: It should not exceed 300 words in length

Key words: Poultry manure, sweet pepper, cultivars, fruit yield, capsaicin

Introduction

Sweet pepper (*Capsicum annuum* L.) belongs to the Solanaceae family and genus Capsicum, which is grown throughout the year around the world, although it’s native to the northern region ofSouth America and southwestern North America (García-Gaytán *et al*., 2017; Aguilar-Meléndez *et al*., 2020).The plant yields berries that are red, green, and yellow in color, and they frequently have a pungent flavor. Within the species, there are about 200 variations, and it also has several popular names and varieties, such as bell pepper, cayenne, jalapeño, chili pepper, and paprika (Zhigila *et al*., 2014).

Out of the roughly 25-200 wild species of capsicum, only five were classified as domesticated species. *C. annuum* L., *C. baccatum* L., *C. chinensis* L., *C. pubescens* L., and *C.*

frutescens L. are the five domesticated species (Roy, 2016; Swamy, 2023). According to Barboza *et al*. (2019), pepper is the second most significant crop among Solanaceous fruits, whereas Tiamiyu *et al*. (2023) placed it third globally in terms of vegetable importance, behind tomato and onion.

Due to its vulnerability to frost, pepper is typically planted as an annual crop, although in tropical conditions, it is actually a herbaceous perennial that can live and produce for several years (Gruda and Tanny, 2014; Anitha and Hore, 2018; Bhattacharya, 2022). Due to its high nutrient content which could be missing in other dietary items, it enhances the flavor and palatability of food, aiding in digestion and absorption (Olatunji and Afolayan, 2018; García-Gaytán *et al*., 2017).To boost crop yields and food security, the current system of producing capsicum spp. mainly relies on chemical fertilizers. Nevertheless, this has resulted in soil degradation, decreased agricultural output, loss of soil fertility, and deterioration of the environment (Martey *et al*., 2019). Substantial use of chemical fertilizers containing only one or two nutrient components affected the availability of micronutrients (Zn, Mn, Fe, B, and Cu) and secondary nutrients (S and Ca), endangering food security and raising severe concerns for the sustainable production system (Penuelas *et al*., 2023).

Farmers can easily obtain organic manure at a lower cost as compared to inorganic fertilizer. Additionally, it delivers macro and micronutrients to the soil, boosts the microbial population, which improves soil health, and replenishes soil organic matter in the form of humus (EL-Shimi *et al*., 2015; Alhrout, 2017). Additionally, these manures can enhance the qualities of the soil in terms of aeration, moisture retention, and nutrient conservation.In addition to enhancing the physical and chemical characteristics of soil, poultry manure can boost crop output and growth. According to Bade *et al*. (2017), it also has higher levels of NPK than other kinds of manures. This manure can increase the soil's organic matter content, microbial activity, anion and cation exchange capacity, and carbon content (Masocha & Dikinya, 2022). This work was designed to assess the effects of chicken manure levels on sweet pepper types' yield and capsaicicoid content in an effort to improve the development of capsicum varieties with high capsaicin content.

Comment [R3]: How Poultry manure Fertilization Improves the Yield

MATERIALS AND METHODS.

Experimental site

Two field trials were carried out at the Faculty of Agriculture Research and Teaching Farm, Bayero University Kano, and Kadawa Irrigation Scheme, Bunkure local government area, Kano State (Fig. 1). The BUK research farm was located in the northern part of Kano at a latitude of $11^{o}58^{'}$N and a longitude of 8^{o} 25' E, and Bunkure Farm was located in the southern part of Kano at a latitude of $11^{o}42^{'}$N and a longitude of 8^{o} $33^{'}$E. All of the research sites were situated in the Sudan Savanna agro-ecological zone of Nigeria, which is characterized by a monomodal rainfall pattern with a mean annual rainfall of 739.80 mm and a daily range of temperature between 17.89^{o}C to 31.83^{o}C.

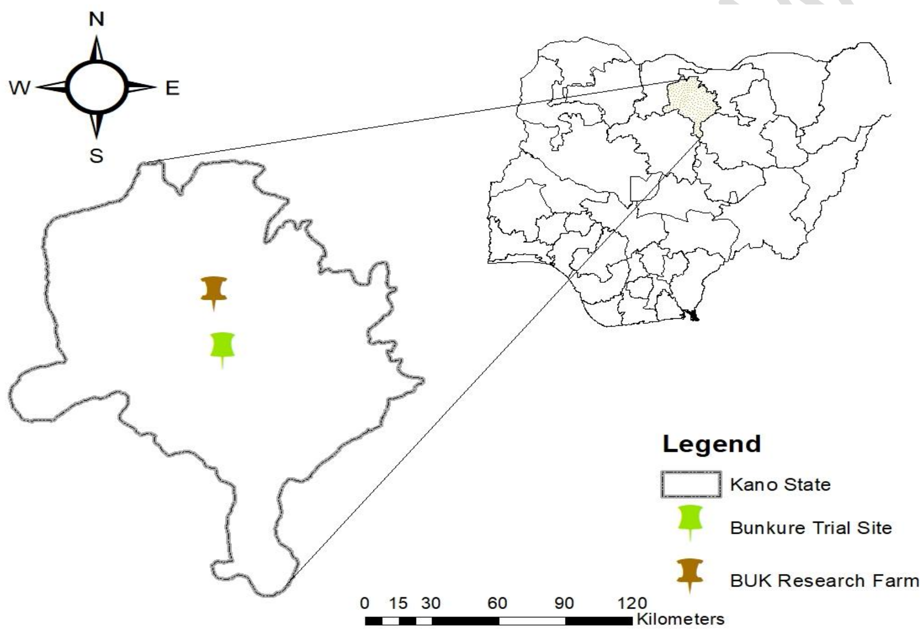

Fig. 1: Map Showing the Study Sites

Treatments and Experimental design

The treatments consisted of three varieties of sweet pepper (Tattasai Dan Damasak, Nsukka Yellow, and Yolo Wonder) and four levels of poultry manure (0.0, 1.0, 2.0, and 3.0 t ha^{-1}) which were factorially combined and laid out in a Randomized Complete Block design with four replications.

Varietal seed source and their characteristics

1. Nsukka Yellow pepper is an aromatic pepper grown mostly in specific rural areas located in southeastern Nigeria. Ripe fruits are predominantly yellow and are exported to Nigerian

cities, where they command a premium price. The seeds were sourced from Techni Seeds Ltd., Hadejia Road, Kano State. This cultivar has a yield potential of up to 9 t ha^{-1}

2. Yolo wonder pepper is one of the most frequently seen sweet peppers; it is predominantly green in color. It is a very productive variety with good leaf cover to reduce sun scald. The seeds were sourced from Abubakar Rimi Market (Yan Kura), Kano. This variety has a yield potential of up to 11 t ha^{-1}

3. Tattasai Dan Damasak is among the most popular local cultivars. It is very productive, and the fruits ripen to red quickly. The seeds were sourced from the local farmers at Kura Market, Kano State. This cultivar has a yield potential of up to 11 t ha^{-1}

Field Preparation and Crop husbandry

Adequate land preparation for good sweet pepper production in the form of plowing and harrowing in order to bring the soil to a fine tilth was carried out, while a portion was reserved for the nursery establishment. Three nursery seed beds were prepared for the three varieties of pepper for the purpose of producing good pepper seedlings to be used for the experiment. The seeds were drilled in rows of 10 cm apart in nursery beds separately. The seed beds were covered with rice straw to avoid the displacement of the seeds and keep the soil moist. Watering was carried out every day in the morning and in the afternoon. The nursery lasted for 39 days.The land for the experiment was further ridged following the initial ploughing and harrowing and then plots were laid out as per the specifications quoted in the experimental design. Pegs were used to mark out the field according to the experimental design. All these were carried out a week before the transplanting of seedlings into the field. The gross plot was 3 x 4 m (12 m^2) while the net plot size was 1.5 m x 3 m (4.5 m^2) with a discard of 0.5 m between the plots and 1.0 m between replications.

Poultry manure was incorporated into the field as per the treatment at a depth of 5 cm and 8 cm away from the spots where the seedlings would be transplanted a week before transplanting. However, the sample poultry manure used for the experiment was collected and analyzed for mineral content before the commencement of the experiment. Similarly, soil samples from the experimental sites were collected at a depth of 0–15 cm and 15–30 cm and analyzed for the physico-chemical properties of the soils.All other agronomic practices of weed control, pest control, and disease control were duly carried out as and when due.

Harvesting was done manually at the physiological maturity stage of the crop through hand picking.

DATA COLLECTION AND DATA ANALYSIS

Data were collected on plant height, number of branches plant^{-1}, leaf area index, number of fruits plant^{-1}, fresh fruit weight and total fruit yield. Also, the capsaicin content of the varieties was also analysed using the Liquid-Chromatography-electro-spray/time of flight mass Spectrometry according to standard method as described by Graces *et al*.(2006). Data collected was subjected to Analysis of variance (ANOVA) using Genstat (17th edition). Significant means were separated using Student's New Man's Kuel at 5% probability level.

RESULTS

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Result and discussion should not be written separate
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Plant height, Number of branches plant^{-1}, Leaf area index and Number offruits plant^{-1}of Sweet Pepper was Influenced by cultivar and Poultry manure rates at BUK and Bunkure. Dan damasak cultivar significantly ($p < 0.05$) produced the tallest plants, number of branches plant^{-1}, and leaf area index at both locations while number of fruits plant^{-1} was higher with Dan Damasak and Yolo wonder in BUK and Yolo wonder in Bunkure. Similarly, the application of 3 t ha^{-1} of poultry manure significantly resulted in higher characters compared to other rates under investigation. The interaction between cultivar and PM on plant height was highly significant at BUK where application of 3 tha^{-1} of PM in Dandamasak cultivar significantly produced the tallest plant compared with the rest of the interaction effects. Interaction of cultivar and PM on number of branches plant^{-1} was significant ($p<0.05$) at BUK and highly significant ($p<0.01$) at BKR, where the application of 3 tha^{-1} of PM in Dan Damasak at BUK and 2 & 3 tha^{-1} of PM at BKR resulted in producing a greater number of branches plant^{-1} than the rest of the interaction effects. The highly significant ($p < 0.01$) interaction obtained between cultivar and PM (Table 5) in both locations reveals that the application of 3 tha^{-1} in Dan Damasak and Yolo wonder significantly produced larger leaves compared with the rest of the interaction effects at BUK and BKR, respectively.

Fresh fruit weight and total fruit yield of sweet pepper as influenced by cultivar and poultry manure at BUK and Bunkure are presented in Table 6. Results show that the fresh fruit weight per plant and total fruit output of the Dan Damasak cultivar were found to be higher than those of other cultivars; Yolo Wonder trailed closely behind, while Nsukka Yellow gave the lowest values at the BUK and BKR locations, respectively. The application of 3 tha^{-1} PM significantly produced the highest fresh fruit weight plant^{-1} and fresh fruit yield compared with the rest of the PM rates. However, 0 tha^{-1} resulted in the lowest yield characters at both locations, respectively. There was no interaction observed between cultivar and PM on the measured characters across the locations.

The capsaicin content of sweet pepper as influenced by cultivar and PM is shown in Table 7. The Nsukka yellow significantly produced a higher capsaicin content, which was closely followed by Dan Damasak, while Yolo Wonder produced the lowest content at BUK and BKR, respectively. Application of PM at 3.0 t ha^{-1} significantly resulted in higher capsaicin content compared with other rates at both locations, respectively. The interaction between cultivar and PM (Table 8) was highly significant ($p < 0.01$), where the application of 3 tha^{-1} of PM in Nsukka yellow yielded the highest capsaicin content compared with the rest of the interaction effects.

DISCUSSION

The significant differences observed in some growth characters, yield and yield component as well as the capsaicin content among the tested sweet pepper varieties could be attributed to the variations in the genetic constitution of the cultivars. A crop variety has the ability to outyield other varieties in terms of growth and yield attributes owing to its genetic potentials. Similar finding was reported by Kavhiza *et al*. (2022) on increase in crop yield by the adoption of improve cultivars.The ability of Dan Damasak cultivar at both experimental locations to outperformed other cultivars might be attributed to its genotypic makeup. Similarly, Shahein *et al.* (2015) reported that the growth differences between two pepper hybrids might be correlated with gene action of the tested hybrid, as well as the adaptability to agro-ecological conditions of the variety to the study areas. The little variations in the capsaicin content observed between two locations of the experiment could be due to some differences in the environmental factors of the locations. This also corroborates the finding of Das*et al.* (2016) who reported that the environmental factors especially the climate, light intensity, soil type, moisture level, fertilization and temperature during plant growth, is considered to have an impact on capsaicinoids level, as does the age of the fruits.Oh and Koh (2019) reported similar findings on the quality of hot pepper owing to variation in temperature regimes.

The results obtained from these experiments clearly shown that the poultry manure used in the trails substantially increased the yield and chemical composition of sweet pepper fruits across the two locations. These effects of poultry manure could be attributed to the fact that it contains essential elements needed by the crop plant. Farhad *et al*. (2018) observed that poultry manure contains essential nutrient elements associated with high photosynthetic activities, and they stimulate the roots and vegetative growthsof vegetable maize. The improved tuber output and nutritional uptake of potatoes were noted by Oustani *et al*. (2015). Releasing nutrient elements into the soils was also noted by Adekiya*et al*. (2018) and Sajid *et al*. (2023), who found that this improved other soil chemical and physical qualities that support crop growth and development in Amaranthus hybridus and Curcuma longa, respectively.

Comment [R5]: Tables & figures should be placed inside the text. Tables and figures should be presented as per their appearance in the text.

CONCLUSION

The outcomes of these studies show that the application of PM significantly affected the capcisinoid content, number of branches per plant, leaf area index, number of plants per plant, and plant height of sweet pepper cultivars. Taller plants, more branches, larger leaves, and more fruits per plant^{-1} were the notable results of applying 3.0 tha^{-1} of PM.Similarly, the Dan Damasak cultivar significantly produced higher growth characters mentioned above except for the number of fruits plant^{-1}. The Dan Damasak and Yollow Wonder cultivars at BUK and Yolo wonder at BKR significantly gave a higher number of fruits plant^{-1}. Fresh fruit yield, total fruit yield, and capsaicinoid content were significantly higher with the application of 3.0 tha^{-1} of PM at both locations. The Dan Damasak cultivar resulted in higher yield-related traits at both locations.However, the Nsukka Yello cultivar has a noticeably higher capsaicinoid concentration at both locations when compared to other cultivars. Therefore, farmers in the study region may be advised to apply 3.0 tha^{-1} PM combined with Dan Damasakcultivar. Similarly, the Nsukka yellow cultivar and the application of 3.0 tha^{-1} PM can also be suggested for greater capsaicinoidconcentration.

Comment [R6]: Add Acknowledgments
Competing Interests
AUTHORS' CONTRIBUTIONS

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Table 1:Plant height, Number of branches plant^{-1}, Leaf area index and Number offruits plant^{-1}of Sweet Pepper as Influenced by cultivar and Poultry manure rates at BUK and Bunkure during 2018 rainyseason

Treatment	Plant height (cm)		Number of branches plant^{-1}		Leaf area index		Number of fruits plant^{-1}	
	BUK	Bunkure	BUK	Bunkure	BUK	Bunkure	BUK	Bunkure
Cultivar (C)								
Dan Damasak	28.95a	28.87a	4.19a	4.13a	0.94a	0.92a	12.12a	13.15b
Nsukka yellow	24.37c	23.95c	3.09c	3.09c	0.79c	0.81c	10.84b	11.73c
Yolo wonder	25.22b	25.23b	3.51b	3.51b	0.89b	0.88b	12.34a	14.14a
SE±	0.076	0.463	0.063	0.052	0.003	0.0048	0.308	0.347
Poultry Manure (PM)(t ha^{-1})								
0	21.93d	22.49d	2.72d	2.72d	0.58d	0.58d	5.67d	6.58d
1	24.68c	24.37c	3.19c	3.15c	0.79c	0.78c	10.35c	11.58c
2	28.10b	27.96b	4.09b	4.12b	0.99b	0.98b	14.67b	15.58b
3	29.99a	29.26a	4.38a	4.32a	1.12a	1.13a	16.38a	18.27a
SE±	0.087	0.534	0.073	0.060	0.0035	0.0055	0.355	0.401
Interaction								
C x PM	<0.001	0.663	0.021	<0.001	<0.001	<0.001	0.949	0.965

Means followed by the same letters in a column are not significantly different at p<0.05 using Student Newman Keuls (SNK)

Table 2: Interaction between Cultivar and Poultry manure on plant height at BUK during 2018 Rainy Season

	Poultry manure (t ha^{-1})			
Cultivar	0	1	2	3
Dan Damasak	23.97f	27.95d	30.78b	33.10a
Nsukka yellow	20.24j	22.62h	26.58e	28.04d
Yolo wonder	21.59i	23.47g	26.96e	28.86c
SE±		0.152		

Table3: Interaction between Cultivar and Poultry manure on Number of branches $plant^{-1}$ at BUK and Bunkure during 2018 Rainy Season

	Poultry manure (tha^{-1})			
	0	1	2	3
Cultivar		BUK		
Dan Damasak	2.90f	3.58c	4.88b	5.40a
Nsukka yellow	2.30g	2.90f	3.40e	3.75d
Yolo wonder	2.95f	3.10f	4.00c	4.00c
SE±		0.127		
		Bunkure		
Dan Damasak	2.90e	3.50cd	4.95a	5.20a
Nsukka yellow	2.30f	2.90e	3.40d	3.75c
Yolo wonder	2.95e	3.10de	4.00b	4.00b
SE±		0.105		

Means followed by different letter(s) in a column and row differ significantly at P≤ 0.05 using Student Newman Keuls (SNK)

Table 4: Interaction between Cultivar and Poultry Manure on Leaf area index at BUK and Bunkure during 2018 rainyseason

	Poultry Manure (t ha^{-1})			
	0	1	2	3
		BUK		
Cultivar				
Dan Damasak	0.63g	0.84e	1.10c	1.21a
Nsukka yellow	0.53h	0.72f	0.92d	1.02b
Yolo wonder	0.58h	0.84e	0.98c	1.13a
SE±		0.006		
		Bunkure		
Dan Damasak	0.61g	0.83e	1.07b	1.18a
Nsukka yellow	0.56h	0.71f	0.91d	1.06b
Yolo wonder	0.57h	0.82e	0.97c	1.16a
SE±		0.0095		

Means followed by different letter(s) in a column and row differ significantly at p≤ 0.05 using Student Newman Keuls (SNK)

Table 5:Fresh fruit weight and Total ffruitsyieldof Sweet Pepper as Influenced by cultivar and Poultry manurerates at BUK and Bunkure during 2018 Rainy Season

Treatment	Fresh fruitweight plant^{-1}(g)		Total fruit yield ha^{-1} (kg ha^{-1})	
	BUK	Bunkure	BUK	Bunkure
Cultivar (C)				
Dan Damasak	369.80a	377.10a	9861.00a	10063.00a
Nsukka yellow	270.00c	278.60c	7199.00c	7430.00c
Yolo wonder	341.70b	371.70b	9113.00b	9912.00b
SE±	8.850	13.310	236.100	353.000
Poultry Manure (PM)(t ha^{-1})				
0	81.70d	86.80d	2178.00d	2313.00d
1	239.10c	252.90c	6375.00c	6743.00c
2	457.10b	461.70b	12191.00b	12324.00b
3	530.80a	568.50a	14154.00a	15160.00a
SE±	10.220	15.370	272.600	407.600
Interaction				
C x PM	0.397	0.648	0.392	0.684

Means followed by the same letters in a column are not significantly different at P <0.05 using Student Newman Keuls (SNK)

Table 6: Capsaicin ccontent of Sweet pepper as Influenced by Cultivar and Poultry Manure at BUK and Bunkure in 2018 rainyseason

Treatment	Capsaicin content (mg kg^{-1})	
	BUK	Bunkure
Cultivar (C)		
Dan Damasak	15.87b	16.89b
Nsukka yellow	17.43a	18.83a
Yolo wonder	11.78c	12.69c
SE±	0.122	0.170
Poultry Manure (PM)(t ha^{-1})		
0	10.59d	11.33d
1	13.66c	14.81c
2	16.57b	18.58b
3	19.29a	19.83a
SE±	0.141	0.196
Interaction		
C x PM	<0.001	0.194

Means followed by the same letters in a column are not significantly different at p<0.05 using Student Newman Keuls (SNK)

Table 7:Cultivar and Poultry manure interaction on Capsaicin Content (mg kg^{-1}) of Sweet Pepper at BUK during 2018 rainyseason

	Poultry manure (t ha^{-1})			
Cultivar	0	1	2	3
Dan Damasak	11.32j	14.64g	17.25d	20.28b
Nsukka yellow	12.25i	16.15e	19.09c	22.23a
Yolo wonder	8.20l	10.20k	13.36h	15.36f
SE±		0.244		

Means followed by different letter(s) in a column and row differ significantly at p≤ 0.05 using Student Newman Keuls (SNK)