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RESEARCH ARTICLE

Performance, Phyto-nutritional and Bio-active substances of Sweet Pepper (*Capsicum annuum*) in response to Soil Applied Organic and Inorganic Sources of N Fertilizers

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Abstract:

Background:

Soil health is an important factor for producing a higher yield and obtaining good quality products. Nitrogen fertilizer is one of the most important and valuable agricultural inputs for increasing crop production.

Objective:

Experiments were conducted in 2017 and 2018 in the cropping seasons to determine the performance and nutritional qualities of sweet pepper in response to organic and inorganic sources of N fertilizers.

Methods:

Ten kilograms (10 kg) capacity black polythene bags were filled with topsoil and were arranged randomly on the field. Treatment combination included: - 0 NPK + 0 PM (T₁), 40 NPK + 0 PM (T₂), 32 NPK + 8 PM (T₃), 24 NPK + 16 PM (T₄), 0 NPK + 40 PM (T₅), 8 NPK + 32 PM (T₆), 16 NPK + 24 PM (T₇) and 20 NPK + 20 PM (T₈). Experiments were laid out in a completely randomized design and were replicated four times. Vegetative, flowering, and quality parameters were collected and analyzed using the GenStat Discovery, 2014 statistical analysis software. Separation of means was determined by the Duncan Multiple Range Test (DMRT) at a probability level of 5%.

Results:

Results indicated that high rates of an organic source of N fertilizer produced higher values for vegetative and yield parameters, which was similar to the sole application of inorganic fertilizer. There was no significant effect of the sole application and combined organic and inorganic sources of N fertilizer on heavy metals and nitrates accumulation, but their effects were able to increase the values for nitrites above the recommended limits as suggested by the Joint FAO/WHO Expert Committee on Food Additives.

Conclusion:

Our results showed that 20 NPK + 20 PM is the best treatment without any health implications in the study area, which also improved the yield and, therefore, can be considered economical.

Keywords: Sweet pepper, Organic N, Inorganic N, Performance, Fruit quality, Phyto-nutritional.

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1. INTRODUCTION

In Nigeria, pepper is regarded as the third most important vegetable after onions and tomatoes [1]. Pepper is a good source of minerals and vitamins, and it also has medicinal

value. Sweet pepper, also called Bell pepper, is unique because it is consumed directly, even in a salad, since it is not peppery [2]. It is the only *Capsicum* that does not produce capsaicin, a lipophilic chemical that can cause a strong burning sensation when it comes in contact with mucous membranes.

It is known that most agricultural lands in Nigeria are of low nutrient status. In order to achieve a high yield in pepper,

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there is a need to augment the nutrient status of the soil to meet the needs of the crops thereby, maintaining the fertility of the soil. This is achievable with adequate nutrient in the soil and their proper management [3, 4]. It was observed that the application of organic materials or their blend with chemical fertilizers increased the availability of NPK in the soil [5].

However, increased use of fertilizer had been reported to cause high concentrations of nitrates in drinking water and plants, especially leafy vegetables [6]. Nitrate aggregation in the plants, due to excessive N-rich fertilizer sources, can lead to the consumption of nitrates, nitrites, and even heavy metals, which are mobilized into different plant parts and have been reported to have negative implications on the health of the consumers, leading to various diseases like methaemoglobinaemia (the reduced ability of the red blood cells to release oxygen (O₂) to the tissues in children) and gastrointestinal cancer (malignant growth) in adults [7].

Heavy metals are not biodegradable, and they have the potential to accumulate in any body part or organ, which can be harmful to human health and physiology [8, 9]. Heavy metals have been reported to have both negative and positive effects on humans [10]. The concentrations of heavy metals in soils are controlled by the parent materials and varied greatly in each area. Thus, the heavy metals content of fruits is affected by the source and level of organic fertilizers. Adding organic manures at different sources (cattle, chicken, and pigeon manures) in the amount of 20 kg every 9 meters line length increased the percentage of N, P, K, Fe, Zn, Mn, Cu, and Ni in pepper fruits [11].

New consumption patterns and their accompanying agronomic practices are the current issues that have an influence on humans' health. Intensive inorganic fertilizer usage in agriculture may cause many health problems and unrecoverable environmental pollution [12]. Moreover, the accumulation of nitrate and nitrite ions in vegetables and fruits can cause cancer of the guts. The following research was carried out to analyze if the accumulation of heavy metals, nitrates, and nitrites in pepper can be moderated or avoided through the use of different levels of organic and inorganic sources of N fertilizer.

Sweet Pepper is considered an excellent source of bioactive nutrients. Ascorbic acid (Vitamin C), carotenoids, and phenolic compounds are their main antioxidant constituents [13]. The levels of Vitamin C, carotenoids, and phenolic compounds in peppers and other vegetables depend on several factors, including cultivar, agricultural practice (organic or conventional), maturity and storage conditions [14].

It is expedient to study the health implication and quality of food. Nitrate and nitrite are naturally occurring inorganic ions present in our environment. The decomposition of organic materials in soil releases ammonia, which oxidizes to form nitrate and nitrite. These ions become detrimental and pose a threat to human health if their concentration is high in the soil.

In order to optimise yield, farmers always apply excess manure (organic and/or inorganic) to both leafy and fruit vegetables, thereby increasing their concentration of heavy metals, nitrate, and nitrite. Hence, an appropriate ratio of the

two sources of N should be identified by providing optimum N requirement for Sweet Pepper, and suggesting the superiority of the organic source of N over the inorganic source of N fertilizer in the study area. Therefore, this study determined the influence of different ratios of two sources of N fertilizers on the performance of sweet pepper, as well as the accumulation of nitrate, nitrite, and heavy metals in sweet pepper. This study hypothesized that the overall performance in terms of yield, and phyto-nutritional qualities of sweet pepper would be affected differently by the different ratios of two sources of N fertilizer. In order to validate this working hypothesis, experiments were conducted to determine which ratio would have the greatest effect on the performance, nitrate, nitrite, heavy metals accumulation, variation in proximate composition, and Vitamin C content in sweet pepper.

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The experiment was carried out during the 2017 and 2018 cropping season at the Teaching and Research Farm of Landmark University, Omu-Aran, Kwara state (latitude 8°8'N and longitude 5°6'E), located in the transitional rainforest area with rainfall extending between April and October. Annual rainfall of 600 mm – 1500 mm is predominant, following a dry season between November and March.

2.2. Potting, Treatment Combination and Experimental Design

Ten kilograms (10 kg) capacity black polythene bags were filled with topsoil collected from the Teaching and research farm, Landmark University, Nigeria. The amendments, 40, 32, 24, 16 and 8 kg/ha which was obtained from inorganic fertilizer (NPK 20:10:10) and 40, 32, 24, 16 and 8 kg/ha which was obtained from organic manure (poultry manure) were combined and arranged randomly on the field as follows: - 0 NPK + 0 PM (T₁), 40 NPK + 0 PM (T₂), 32 NPK + 8 PM (T₃), 24 NPK + 16 PM (T₄), 0 NPK + 40 PM (T₅), 8 NPK + 32 PM (T₆), 16 NPK + 24 PM (T₇) and 20 NPK + 20 PM (T₈). Experiments were, therefore, laid out in a completely randomized design and replicated four times.

2.3. Pre-cropping Soil Analysis

Soil samples were randomly collected from different pots that were already filled with soil collected from the Teaching and Research farm, bulked to obtain a composite sample for laboratory routine analysis. N was determined by the micro-Kjeldahl digestion method. Ground samples were digested with nitric-perchloric-sulphuric acid mixture for the determination of P, K, Ca, and Mg. Phosphorus was determined colorimetrically using the vanadomolybdate method, K was determined using a flame photometer, and Ca and Mg were determined by the EDTA titration method [15]. The percentage of organic carbon in the sample was determined by the Walkley and Black procedure using the dichromate wet oxidation method [16]. Sample pH was determined by using a soil-water medium at a ratio of 1:2 using Jenway digital electronic pH meter model 3520 [17].

2.4. Laboratory Analysis of Poultry Manure

The used poultry manure was analysed for nutrient composition after being air-dried using warm air (18 – 21°C) in the poultry house for 7 days. The dried poultry manure was crushed and passed through a 2-mm sieve. Analysis was done for Organic Carbon (OC), and the total concentration of N, P, K, Ca, Mg, Cu, Mn, Zn, and Na [15].

2.5. Sources of Materials

The poultry manure used for the study was collected from the poultry house of Landmark University, Omu-Aran, while NPK 20:10:10 fertilizer was purchased from the local market. The poultry manure was cured for two weeks before application.

2.6. Seed Source and Fruit Characteristics

The pepper seed (California Wonder) used for the experiment was obtained from Landmark University Teaching and Research Farm. It is a classic heirloom Bell pepper variety that was introduced in 1928. It has 4 lobes each, is sweet and crispy, also freezes well, and is ready for harvesting in 80 days after sowing. The color of matured fruits ranges from green to red.

2.7. Nursery Preparation and Seedling Transplanting

The seedlings were prepared in the screen house of Landmark University Teaching and Research Farm in a tray of sandy loam soil. The soil was sieved and covered with polythene to enhance uniform and accelerated germination. At 4 WAS (weeks after sowing), seedlings were hardened off by the reduction of the amount of water supplied and shade removal, while at 5 WAS, seedlings were transplanted into the prepared potting bags.

2.8. Application of Amendments and Weed Control

The N status of the soil was low in both years of the experiment, and it was upgraded with 40 kg N ha⁻¹, either from organic or inorganic sources or from the combination of both except for the control. Organic source of N fertilizer (poultry manure) was applied two weeks before seedling transplantation to allow for its mineralization and release of nutrients, while the inorganic source of N fertilizer (NPK 20:10:10) was applied two weeks after seedling transplantation based on treatment combinations. Weed control was done by handpicking weeds inside the potting bags and around the experimental site.

2.9. Observation and Data Collection

The following parameters were taken in both years of the experiment: plant height at transplantation (cm), plant height at 50% flowering (cm), number of leaves at 50% flowering, number of branches at 50% flowering, number of days taken for 50% flowering, number of days taken for 50% fruiting, number of days between flowering and fruiting, yield, heavy metals concentration, nitrates and nitrites accumulation, proximate composition, and Vit. C content.

2.10. Laboratory Analysis of Nutritional Composition of Sweet Pepper Fruits

Fresh samples of Sweet pepper were harvested based on treatments and were taken to the laboratory for the determination of nitrates, nitrites, heavy metals (Cu, Cd, Ar, and Zn), vitamin-C contents, and proximate composition (crude protein, crude fat, crude fiber, and ash contents).

2.10.1. Determination of Nitrate and Nitrite

About 10 ml of the filtrate from ash was pipetted into a 50 ml flask containing 2 ml Brucine, then 10 ml of concentrated H₂SO₄ were added rapidly, mixed well, and allowed to stand for 10 min before reading the values spectrophotometrically at 470 nm [18]. The nitrate values from the machine were calculated using:

$$\text{Nitrate (mg/kg)} = \frac{\text{Instrument reading} \times \text{slope reading} \times \text{volume of extract}}{\text{Weight of material}}$$

Nitrite was determined by pipetting 10 ml of the filtrate from ash into 50 ml flask with the 2 ml of 2 N HCl added and diluted to about 30 ml with water, then 2 ml of sulphanic acid was added and stirred for about 5 min and allowed to cool. A 10 ml of alpha nathylamine was then added and stirred for about 10 mins before the absorbance was read at 520 nm [18].

2.10.2. Determination of Heavy Metals

Dry ashing of the collected fruit samples was carried out as described in a study [19]. A portion of each plant sample (1 g) was weighed into a 50 ml porcelain crucible and placed in the muffle furnace at 550°C for about 5 hours, and was allowed to cool. The obtained cooled ash was dissolved in 5 ml portion of 2 N Hydrochloric Acid (HCl) and mixed thoroughly with a plastic rod for 15 minutes. Then it was mixed with 50 ml of distilled water and allowed to stand for 30 min before using the supernatant (after filtering through Whatman No. 42 filter paper) for analyzing the heavy metals (Cd, Cu, Zn, and Ar) using the Atomic absorption spectrometry (AAS) as described in the methods of Association of Official Analytical Chemists [15]. Heavy metals (Cd, Pb, Cu, Zn, and Ar) were calculated using:

$$\text{Heavy metals (mg/kg)} = \frac{\text{Titre value} \times \text{volume used}}{\text{Molar mass of HCl}}$$

2.10.3. Determination of Vitamin C and Proximate Compositions of Sweet Pepper

Vitamin C content was determined by using the indophenol dye method [20]. Proximate analysis of sweet pepper was carried out at the central laboratory, Landmark University, Nigeria. Samples were grinded and analyzed for their proximate composition under the Parten D analyzer. The samples were then analyzed to determine the crude fiber content, protein content, ash content, and Fat content.

2.11. Statistical Analysis

The data collected were analyzed using the methodology of a previous study [21]. Separation of means was performed by Duncan Multiple Range Test (DMRT) at a probability level of 5%.

Table 1. The physical and chemical properties of soil prior to planting (0 - 15 cm) in 2017 and 2018 Cropping Seasons.

Parameter	2017	2018
Ph (H ₂ O) 1:1	4.25	4.49
Total nitrogen	0.109	0.104
Organic carbon	3.24	3.36
K (cmol/kg)	0.23	0.25
Ca (cmol/kg)	3.95	4.00
Mg (cmol/kg)	1.32	1.33
Available phosphorus (mg/kg)	20.15	21.12

3. RESULTS

3.1. Soil and Poultry Manure Analysis

Laboratory analysis of the experimental soil revealed that the soil was sandy loam, low in N, and contained some essential nutrients needed for plant growth and development (Table 1). Analysis of the poultry manure used in the experiment also showed that poultry manure had higher concentrations of N, P, K, Ca, and Mg and micronutrients (Table 2).

Table 2. Chemical composition of poultry manure.

Nutrients %	O. C	N	C/N	P	K	Ca	Mg	Cu	Mn	Zn	Na
Value	20.9	2.80	7.5	1.28	1.65	0.82	0.55	0.34	0.20	0.23	0.26

3.2. Meteorological Data of the Experimental Site for 2017 and 2018

The meteorological data for the periods of the experiment is shown in Table 3. The rainfall for the 2017 cropping season was lower than that of the 2018 cropping season.

Table 3. Meteorological data of the study area.

-	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	-	-	-	-	-	-	-	-	-	-	-	-
Rainfall (mm)	0	0	97.3	92.46	158.3	174.5	71.1	179.3	231.4	119.9	0	114.0
Relative humidity (%)	54.1	44.9	69.7	81.0	85.3	89.9	91.9	93.4	92.3	85.2	71.3	56.9
Mean temp (°C)	29.1	31.2	31.9	29.9	28.9	27.9	26.9	26.3	26.5	27.8	29.9	28.4
2018	-	-	-	-	-	-	-	-	-	-	-	-
Rainfall (mm)	0	12.19	157.7	96.3	214.9	228.6	160.0	95.3	248.7	195.1	19.6	0
Relative humidity (%)	34.3	63.7	78.8	85.2	87.5	90.2	92.7	92.7	91.3	88.4	76.4	47.1
Mean Temp (°C)	26.6	29.6	29.3	29.2	28.1	27.7	26.4	26.2	26.4	27.5	28.8	28.9

Source: Meteorological unit, Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State, Nigeria

Table 4. Effects of sole and combined application of organic and inorganic sources of N fertilizers on the vegetative parameters of sweet pepper in 2017 and 2018 cropping seasons.

Treatments (kg ha ⁻¹)	Plant Height at one week After Transplanting		Plant Height at 50% Flowering		Number of Leaves at 50% Flowering		Number of Branches at 50% Flowering	
	2017	2018	2017	2018	2017	2018	2017	2018
-	2017	2018	2017	2018	2017	2018	2017	2018
0 NPK + 0 PM (T ₁)	9.27a	9.30a	25.20c	26.00c	35.00c	37.15c	12.00c	12.55c
40 NPK + 0 PM (T ₂)	9.03a	9.40a	35.12b	36.00b	45.67b	47.50b	14.33b	15.70a
32 NPK + 8 PM (T ₃)	9.10a	9.55a	34.40b	34.90b	43.33b	45.90b	14.00b	14.85b
24 NPK + 16 PM (T ₄)	8.73a	9.29a	35.03b	35.52b	43.33b	46.85b	14.20b	14.80b

3.3. Effects of Sole and Combined Application of Organic and Inorganic Sources of N Fertilizers on the Vegetative Parameters of Sweet Pepper in 2017 and 2018 Cropping Seasons

There was no significant difference ($p > 0.05$) in the plants' height between treatments at one week after transplanting both in 2017 and 2018 years of the experiments (Table 4).

There was a significant difference ($p < 0.05$) between the treatments on the vegetative parameters (plant height at 50% flowering, number of leaves at 50% flowering, and number of branches at 50% flowering) in both years of the experiments. 20 NPK + 20 PM (T₈) gave a statistically higher values for all the parameters when compared with the application of 40 NPK + 0 PM (T₂), 32 NPK + 8 PM (T₃) and 24 NPK + 16 PM (T₄). Values obtained from the application of 20 NPK + 20 PM (T₈) were statistically similar with those obtained when 0 NPK + 40 PM (T₅), 8 NPK + 32 PM (T₆), and 16 NPK + 24 PM (T₇) were applied. The least value for all the vegetative parameters was from the control.

(Table 4) contd....

Treatments (kg ha ⁻¹)	Plant Height at one week After Transplanting		Plant Height at 50% Flowering		Number of Leaves at 50% Flowering		Number of Branches at 50% Flowering	
0 NPK + 40 PM (T ₅)	9.53a	8.98a	37.63a	38.00a	51.00a	52.00a	15.25a	15.90a
8 NPK + 32 PM (T ₆)	9.27a	9.00a	38.90a	40.10a	53.67a	54.15a	15.67a	15.90a
16 NPK + 24 PM (T ₇)	9.13a	9.10a	38.33a	39.80a	53.00a	54.70a	15.50a	16.55a
20 NPK + 20 PM (T ₈)	9.40a	9.65a	39.40a	40.00a	55.33a	55.85a	16.00a	16.35a
SD	0.25	0.25	4.58	4.66	6.93	6.23	1.29	1.28

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to the Duncan's multiple range test

Table 5. Effects of sole and combined application of organic and inorganic sources of N fertilizers on flowering, fruiting, and yield parameters of sweet pepper in 2017 and 2018 cropping seasons.

Treatments (kg N ha ⁻¹)	Days to 50% flowering		Days to 50% fruiting		Days between flowering and fruiting		Yield/plant (kg)	
	2017	2018	2017	2018	2017	2018	2017	2018
0 NPK + 0 PM (T ₁)	90.67a	92.00a	98.00a	99.75a	7.33a	7.75a	3.85c	4.25c
40 NPK + 0 PM (T ₂)	86.33b	87.50b	91.33b	92.45bc	5.00c	4.95c	8.57a	8.85a
32 NPK + 8 PM (T ₃)	86.00b	87.30b	91.33b	91.84c	5.33c	4.54bc	7.75b	7.80b
24 NPK + 16 PM (T ₄)	87.67b	88.00b	93.67b	95.10b	6.00b	7.10b	7.00b	7.25b
0 NPK + 40 PM (T ₅)	85.63b	86.85b	92.33b	93.95b	6.70b	7.10b	7.80b	8.00b
8 NPK + 32 PM (T ₆)	88.00b	89.10b	94.66b	95.88b	6.66b	6.78b	8.40a	8.55a
16 NPK + 24 PM (T ₇)	85.63b	87.24b	91.67b	93.00b	6.04b	5.76b	8.55a	8.60a
20 NPK + 20 PM (T ₈)	87.67b	88.81b	94.00b	95.56b	6.33b	6.75b	8.75a	8.95a
SD	1.70	1.67	2.26	2.52	0.77	1.13	1.62	1.54

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to the Duncan's multiple range test.

3.4. Effects of Sole and Combined Application of Organic and Inorganic Sources of N Fertilizers on Flowering and Yield Parameters of Sweet Pepper in 2017 and 2018 Experimental Years

Table 5 shows that there was a significant difference ($p > 0.05$) between the control and other treatment combinations on the number of days to 50% flowering and 50% fruiting in both years. Sole and combined application of treatments gave similar values except in 2018, where the application of 32 NPK + 8 PM (T₃) significantly reduced the number of days to fruiting.

The number of days between flowering and fruiting significantly increased with the control, while the application of 40 NPK + 0 PM (T₂) and 32 NPK + 8 PM (T₃) significantly reduced values of the parameters. Values for other treatment combinations were not significantly different.

There was a significant difference ($p < 0.05$) between the treatments on fruit yield/plant in both years of the experiments. In the 2017 and 2018 experimental years, the higher yield was obtained from the application of 20 NPK + 20 PM (T₈) values, and it was statistically similar when 40 NPK + 0 PM (T₂), 8 NPK + 32 PM (T₆) and 16 NPK + 24 PM (T₇) were applied. The control had the least value of 3.85 g/plant and 4.25 g/plant for 2017 and 2018, respectively.

3.5. The Effects of Sole and Combined Application of Organic and Inorganic Sources of N Fertilizers on the Heavy Metal, Nitrates, and Nitrites Concentrations (mg/kg) of Sweet Pepper Fruits

The results of the pooled data for the 2017 and 2018 cropping season are shown in Fig. (1). 0 NPK + 40 PM (T₅)

had the highest Cu concentration (0.023 mg/kg), while the control had the least concentration. The concentration of Ar, Cd, and Zn were low, ranging from 0.003 - 0.009, while Pb was not present in all the treatments. There was a significant difference ($p > 0.05$) in the nitrate and nitrite concentration of the fruits among the different fertilizer combination treatments. Nitrate values were only higher in 40 NPK + 0 PM (T₂) when compared with the control while all treatments except 40 NPK + 0 PM (T₂) had similar nitrates concentration in the sweet pepper fruit. Nitrite value was similar in all plots with sole NPK and in combination with the PM, but the values were significantly higher ($p > 0.05$) than the control treatment. The value of nitrite in all the fertilized treatments ranged from 1.25 mg/kg to 1.37 mg/kg. These values were higher ($p > 0.05$) than that of the control. Concentrations of Cu, Ar, Cd, Zn, Pb, and nitrates were all below the recommended limits, except the values for nitrite, which were far above the recommended limit as suggested by the Joint FAO/WHO Expert Committee on Food Additives (JEFCA, 2010).

3.6. Variation in Proximate Composition and Bio-Active Substance (vitamin C) of Sweet Pepper Fruits in Response to Sole and Combined Application of Organic and Inorganic Sources of N Fertilizer

Fig. (2) shows the results of the pooled data for the 2017 and 2018 experimental years. The values for crude protein ranges between 2.13% to 2.55% among the treatments, showing marginal differences between the fruits. It was observed that 40 NPK + 0 PM (T₂) and 0 NPK + 40 PM (T₅) had 7 and 8% ash content, respectively, while the control had 5.50% Ash. Crude fat for the fruits was the least in control (9.85%), while values for other treatments were statistically

similar. The crude fibre content of 0 NPK + 40 PM (T₅) was found to be higher (16.5%) among all other treatments, while the control had the least value (9.85%).

Moreover, vitamin C content of sweet pepper fruit increased with increasing rates of an organic source of N fertilizer, while it decreased with increasing rates of the inorganic source of N fertilizer. 0 NPK + 40 PM (T₅) had higher but statistically similar values with 8 NPK + 32 PM (T₆), 16 NPK + 24 PM (T₇) and 20 NPK + 20 PM (T₈).

4. DISCUSSION

The nitrogen content of the topsoils used for the experiments was low (0.109% N), and this may probably enhance the response of the plants to the application of both organic and inorganic sources of N fertilizer. Nitrogen fertilizer has always been considered a key element in crop production. Successful and economical yield from crop production could be achieved by proper and routinely nitrogen fertilization though, a high rate of N fertilizer could lead to the accumulation of excess nitrates above the safe limits in vegetables, leading to health risks in humans and animals [22]. Parmer and Sharma reported that there was an increase in the

total nitrogen of the soil with the application of fertilizers from chemical N sources, farmyard manure, and poultry manure [23]. Wiqar et al. also concluded an increase in the total N of the soil by the integrated use of fertilizers [24].

Vegetative parameters increased with high rates of an organic source of N fertilizer with their corresponding inorganic source of N fertilizer when compared with the high rates of the inorganic source of N fertilizer with their corresponding organic source of N fertilizer. The increase in vegetative parameters as a result of the application of the former could be attributed to good physicochemical properties of the soil when poultry manure was applied. It could also be a result of adequate nutrient uptake, especially micronutrients that are essential for increased photosynthesis as a result of the application of poultry manure. Similar results were observed by Shiva et al. and Adhikari et al., where they recorded an increase in vegetative parameters of chilies with the application of organic sources of N [25, 26]. The overall increase in vegetative growth as a result of the application of sole and combined organic and inorganic sources of N fertilizer could also be due to the higher availability of nutrients in the integrated treatment, especially nitrogen [27].

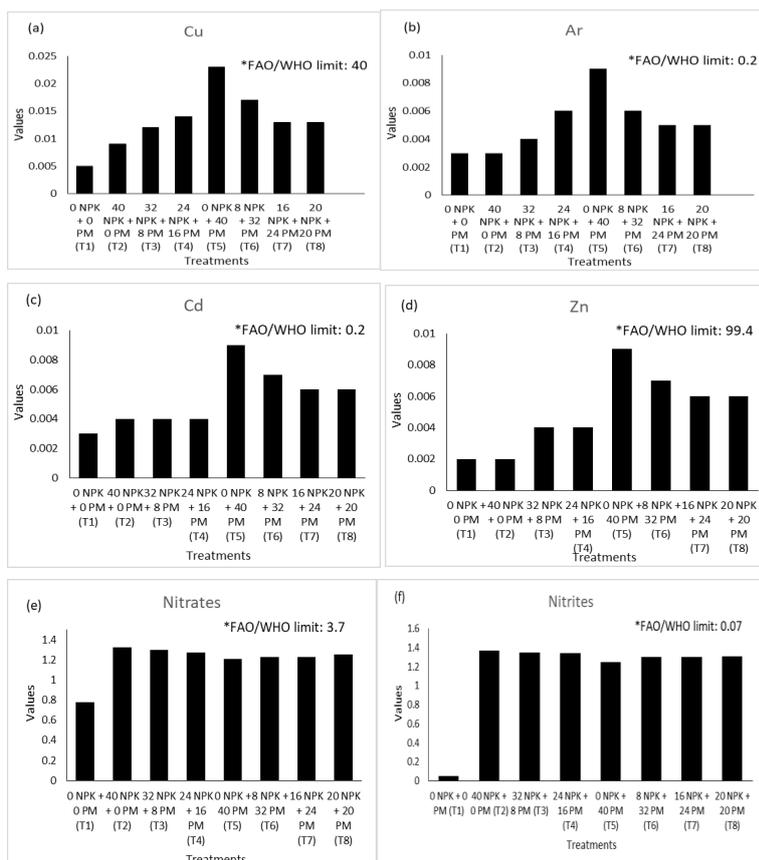


Fig. (1). Effects of sole and combined application of organic and inorganic sources of N fertilizers on (a) Copper (b) Arsenic (c) Cadmium (d) Zinc (e) nitrates (f) Nitrites concentrations (mg/kg) of sweet pepper fruits (pooled data of 2017 and 2018 cropping seasons) Source: *Joint FAO/WHO Expert Committee on Food Additives (JEFCA, 2010) recommended limit

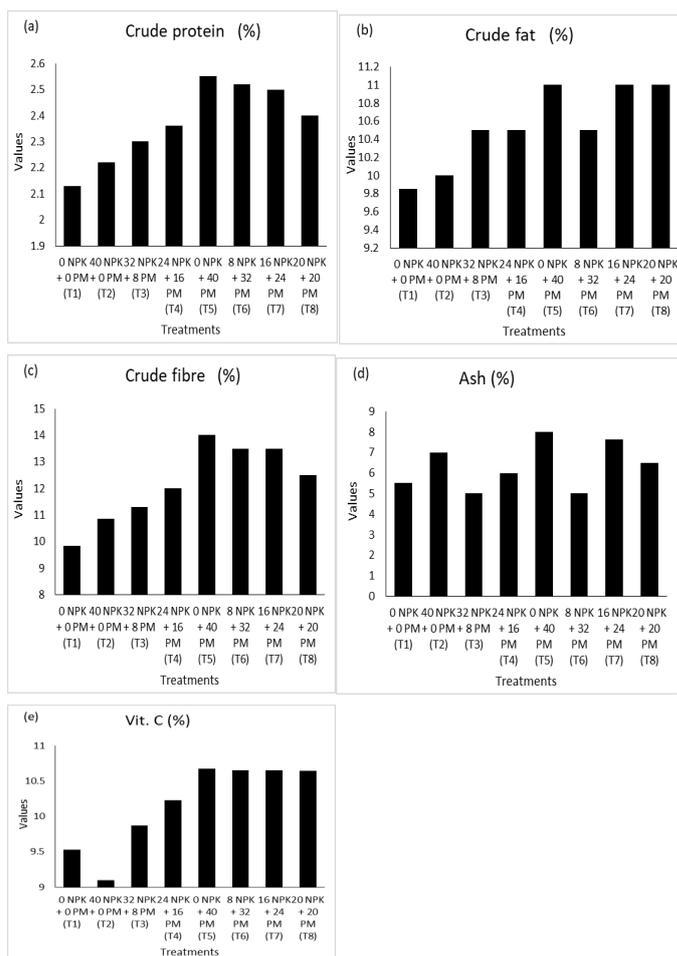


Fig. (2). Variation in (a) Crude protein (b) Crude fat (c) Crude fibre (d) Ash (e) Vitamin C composition of sweet pepper fruits in response to the sole and combined application of organic and inorganic sources of N fertilizer (pooled data of 2017 and 2018 cropping seasons).

Results showed that there was no significant difference in various rates of both organic and inorganic sources of N fertilizer on the flowering pattern. Satpal *et al.* and Law-Ogbomo *et al.* found that the integrated nutrient management enhanced vegetative growth and flowering pattern of tomatoes, thereby leading to early fruit setting [28, 29]. The significant difference in the flowering pattern of the control treatment, when compared with other treatments, could be attributed to improved vegetative growth and storing sufficient reserved food materials for the differentiation of buds into flower buds. It could also be a result of some plant promoting substances that are embedded both in the poultry manure and NPK fertilizer which facilitated plant metabolism. Leela *et al.* found that some plant growth promoters, such as phosphorus, auxins, and gibberellic acid, which induces flowering, are found in NPK fertilizer and organic amendments [30]. There was a reduction in both the vegetative and reproductive growth as a result of N deficiency in the control treatment; this resulted in more days required for flowering and fruit set.

It was observed from the results of this study that the combination of the two N fertilizer sources in equal amounts increased the yield of sweet pepper fruits. Poultry manure which is the source of organic N used in the study is a good

source of organic matter which also acts as a storehouse of all plant nutrients, including micronutrients, which is capable of gradually releasing its nutrients, thereby contributing towards balanced plant nutrition, resulting in maximum fruit yield. Similar results were obtained by Pariari *et al.* where they used integrated nutrient management on the chili pepper. The yield increased with the application of high rates of organic N fertilizer, and its corresponding inorganic N fertilizer, which could be a result of the production of more branches. Akondo *et al.* also discovered that crop yields could be doubled through balanced use of chemical fertilizers. Moreover, the authors said that the effect could also be more when combined with organic fertilizers that provide a slow release of other nutrients that are not supplied through chemical fertilizer sources [32]. The application of organic manure improves both physical and chemical characteristics; this could thereby increase nutrient and water use efficiency of the plant and subsequently the yield. In their experiment, Gomeiro *et al.* reported that besides enhancing soil quality, organic farming could also improve water use efficiency, leading to an increase in crop yield [33]. Aboyeji *et al.* revealed that there was a relative increase in the yield of tomato under combined application of PM and NPK fertilizer [34].

In general, higher rates of organic N fertilizer source with its corresponding inorganic N fertilizer source improved vegetative, flowering pattern and yield parameters of sweet pepper when compared with high rates of inorganic N sources with their corresponding organic N fertilizer source. Improvement in the parameters could be attributed to the fact that organic amendments supplied the soil with essential macro and micronutrients needed for plant growth, development, and for obtaining a good yield, and it also assisted in adsorbing plant nutrients, thereby preventing leaching. Gobinath *et al.* found that the use of organic fertilizers provides soil with the essential nutrients and these nutrients are adsorbed against leaching [35].

Heavy metals, such as manganese, iron, zinc, copper, cadmium, lead, chromium, arsenic, and nickel, are of concern primarily because of their ability to harm soil organisms, plants, animals, and human beings [36]. The application of numerous biosolids (e.g., livestock manures, composts, and municipal sewage sludge) on the land inadvertently leads to the accumulation of heavy metals, such as As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Mo, Zn, Tl, Sb in the soil [37]. Among the different fertilizer combinations, heavy metals accumulation increased when organic fertilizer was added to all different fertilizer combinations. However, values of heavy metals accumulation obtained from all treatments were below the permissible limit when compared with the allowable body intake as recommended [38]. Eissa *et al.* reported that the addition of organic manures increased the concentrations of heavy metals [11].

High levels of nitrates and nitrites were recorded in treatments with high rates of the inorganic source of N fertilizer and their corresponding organic source of N fertilizer. It was observed from the study that nitrate values were below the recommended limit, while values for the nitrite content exceeded the recommended limit of 0.07 mg/kg body weight per day [38] except for the control treatment. Lower values for nitrates and nitrites in the fruits of sweet pepper when no treatment was applied is an indication that the soil is deficient of N.

The result of this study also revealed that the values for crude protein range between 2.13% to 2.55% among the treatments, showing marginal differences between the fruits. Crude fat for the fruits was the least in control (9.85%), while values for other treatments range between 10 and 11%. The Crude Fibre content of 0 NPK + 40 PM (T₅) was found to be higher among all treatments, while the control had the least. 40 NPK + 0 PM (T₂) and 0 NPK + 40 PM (T₅) had 7 - 8% Ash content while the control had 5.5%. The values obtained, therefore, showed that the proximate composition of sweet pepper was affected by varying the rates of organic and inorganic sources of N fertilizer when compared with the control.

Vitamin C levels in vegetables depend on several factors, including cultivar, plant nutrition, production practice, and maturity [39]. The study showed that increasing rates of organic N fertilizer increased the levels of vitamin C. Also, organic fertilizers using chicken manure gave higher values of TSS and vitamin C in fruits of sweet pepper [40]. The results

were also in agreement with a previous study in which it was observed that the compost application at different concentrations improved vitamin C of the fruit [41]. Therefore, our study confirmed previous results that the level of vitamin C in organically grown peppers was consistently higher than that in conventionally grown peppers.

CONCLUSION

The study indicated that high rates of an organic source of N fertilizer and its corresponding inorganic source of N fertilizer produced higher vegetative parameters and yield similar to the sole application of an inorganic source of N fertilizer. The effects of sole and combined application of organic and inorganic sources of N fertilizer was not evident on heavy metals and nitrate accumulation, as suggested by the Joint FAO/WHO Expert Committee on Food Additives, though the application of high rates of the inorganic source of N fertilizer and its corresponding organic source accumulated higher nitrites in the fruits of sweet pepper. There was variation in the proximate composition of sweet pepper with the application of the amendments, but the bio-active substance increased with increasing rates of an organic source of N fertilizer. This, therefore, suggests the superiority of the organic source of N fertilizer over the inorganic source of N fertilizer in this study. Hence for optimum growth, economically higher yield, and good quality of sweet pepper, application of 20 NPK + 20 PM (T₈) might be considered sufficient with safer human consumption of sweet pepper.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The raw data supporting the findings of the article is not available in the text, it can be requested from corresponding author [C.M.A] upon reasonable request.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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