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ORIGINAL RESEARCH

Variations in the performance, fruit shelf life, and mineral compositions of two varieties of pepper (*Capsicum chinense)* grown under different soil amendments and seasons

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Abstract

Purpose: A study was carried out during the 2021 dry season and 2022 rainy season to evaluate the differences in the performance, fruit longevity, mineral, and vitamin C compositions of two varieties of pepper (*Capsicum chinense*) cultivated using different organic amendments and inorganic fertilizer as a check. Poultry manure (PM), *Tithonia diversifolia* (TD), cattle manure (CM), inorganic fertilizer (NPK 15:15:15), and the control (CTRL) were used as treatments.

Method: Organic amendments were applied at a rate of 20 t ha^{-1}, while NPK was applied at a rate of 180 kg ha^{-1}. The experiment was a 2 x 2 x 5 factorial with three replications laid out in a Randomised Complete Block Design. Vegetative, yield, and quality parameters were collected.

Results: Results show that Caribbean red produced higher values for vegetative parameters, yield, and longer shelf life in season 1. In a similar vein, mineral compositions (Cu, Ca, and Mg) of the Caribbean red variety were found to be higher than that of the Efia variety. Results also indicated that the use of poultry manure was found to improve the vegetative parameters, increased the number of days to fruit shrinkage, and increased the Ca, Cu, Mg, and vitamin C content.

Conclusion: This study, therefore, concludes that the use of the Caribbean red variety cultivated during the dry season (season 1) under the application of poultry manure will give the best vegetative performance, longer shelf life, and improved fruit minerals and vitamin C contents.

Keywords: Pepper, Varieties, Soil improvements, Periods, Harvest, Quality

Introduction

Peppers, which include both hot and sweet varieties, are an important food crop that originated in the Americas and belong to the Solanaceae family (Bouchard 2017). Peppers (*Capsicum spp*.) are highly valued for having antioxidants, which may provide health advantages and protection against various diseases (Arimboor et al. 2014). The genus Capsicum contains roughly 31 types, of which the major five cultivated types are *C.annuum* (spicy and sweet pepper), *C. baccatum* (Aji), *C. chinense* (hot pepper, also known as Habanero pepper), C. *frutescens* (finger pepper), and C. *pubescens* Ruiz and Pav. (rocoto) (Bosland 1996). *C. annuum*, *C. chinense*, and *C. frutescens* are the most widely grown

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in both tropical and temperate climates (Grubben and Denton 2004). *C. chinense* is one of the five domesticated species that thrives well in most parts of Nigeria and is used as a spice for coloring and flavoring a variety of dishes while providing essential vitamins and minerals (Dipeolu and Akinbode 2008).

Worthington (2001) determined that organic crops had significantly higher levels of vitamin C, phosphorus, magnesium, and iron, lower levels of heavy metals, fewer nitrates, and significantly less protein, but of better quality, when compared to conventional crops. Fruits of Capsicum species or peppers have high amounts of vitamin C (ascorbic acid) (Teodoro et al. 2013) The vitamin C and minerals in capsicum fruits are abundant (Park et al. 2006). These nutritional components are crucial for keeping a healthy body (Koyuncu et al. 2020).

Most farmland in the tropics has poor soil because it has been farmed continuously for so long without a fallow phase to allow for the restoration of lost fertility. Utilizing both organic and inorganic fertilizers is the best way to overcome the threat of food insecurity that may result from poor soil. Many studies (Adeyeye et al. 2019), showed the superiority of organic manure over inorganic fertilizers in soil management and sustainable vegetable production. While organic fertilizer is known as natural fertilizer, inorganic fertilizer is known as chemical or synthetic fertilizer, and these are the two most common fertilizers commonly applied to the soil.

Bhandari et al (2002) reported that organic matter content in organic manure increases the values of nitrogen, phosphorus, potassium, and main cations in the soil and thus allows plants to use the nutrients for a long time due to the slow rate of decomposition and reduces the loss of those that are not utilized by the plants. This has also been demonstrated by several researchers that, the use of organic inputs such as crop residues, manures, and compost has great potential for improving soil productivity and crop yield through the improvement of the physical, chemical and microbiological properties of the soil as well as nutrient supply (Zhang et al. 2016; Li et al. 2016; Akintola et al. 2021).

Cow dung is a natural, organic fertilizer produced by bovine animals, containing no trace of synthetic chemicals. It is rich in nutrients that are beneficial for plant growth, including increased soil pH, carbon, nitrogen, phosphorus, calcium, potassium, and sodium (Binoy et al. 2004). Study by Ekwealor et al. (2020) found that cow dung can be used to enhance the growth, productivity and yield of tomato in low nutrient soil at the rate of 20 kg/ha. Poultry manure is a cost-effective and environmentally friendly way to keep soil fertility high. It is easily accessible and provides essential nutrients to help soil retain its fertility. Poultry manure are the most widely-used sources of organic nutrients, and have been proven to be an effective source of nutrients for tomato cultivation (Adediran et al. 2003). The use of poultry manure for soil fertility and crop improvement has been extensively documented (Adekiya 2019). This is due to the fact that poultry manure helps in enhancing soil properties, such as increasing the organic matter content and cation exchange capacity (CEC) of the soil. The Mexican sunflower (*Tithonia diversifolia*) belongs to the family Asteraceae and grows luxuriantly in humid and sub-humid tropics, particularly in southwest Nigeria, where it is found along roads and fallow lands (Sonke 1997). A study conducted by Jama et al. (2000) found that *Tithonia* has a high concentration of nitrogen (N), phosphorus (P), and potassium (K).

Due to the increase in the price of inorganic fertilizer and its scarcity, farmers are discouraged in its purchase and use. Therefore, there is a need to use other means of supplying nutrients required by plants that are cheaply available to enhance pepper production. Numerous studies have examined how pepper growth and yield respond to both organic and inorganic fertilizers (Moneruzzaman et al. 2017). Presently, little research has been conducted on how the fruit shelf life, minerals, and vitamin C compositions in pepper are influenced by the combination of seasons and different soil amendments.

Therefore, the study was conducted to determine the performance, fruit longevity, minerals, and vitamin C compositions of two varieties of *C. chinense* using organic and inorganic amendments at different seasons.

Materials and methods

Description of the experimental sites

The experiments were conducted during the 2021 dry season and 2022 rainy season at the Teaching and Research Farm of Landmark University, Omu-Aran, Kwara State with geographical coordinates of latitude 8° 8' 0" North and longitude 5° 6' 0" East in the transitional rainforest located at an elevation of about 555.85 m above sea level. It has an annual rainfall ranging between 800 mm and 1, 200 mm and an annual average temperature of 24.9 °C with a distinct wet and dry season from April to October and November to April respectively.

The experimental sites had been cultivated and left fallow for more than five years, with itch grass (*Rottboellia cochinchinensis* (Lour) Claton), goosegrass (*Eleusine indica* (L.) Gaertn), sour millet (*Echinochloa colona* (L.) Link), milkweed (*Euphorbia heterophylla* L) and goat weed (*Ageratum conyzoides* L.) being the dominant weeds.

Soil sampling and analysis

Soil samples were collected randomly from the experimental area before land preparation using a soil auger at 0 – 15 cm depth and bulked together to form a composite sample. The composite soil sample was taken to the University Crop and Soil Science Laboratory for routine analysis. Similarly, poultry manure, cattle manure, and fresh *T. diversifolia* leaves were collected from the Teaching and Research Farm of Landmark University, Omu-Aran and taken to the laboratory for analysis of their nutritional composition.

Land preparation

The experimental site was cleared of all existing vegetation, and the soil was thoroughly pulverized with a disc plough and a disc harrow. Thereafter, the field layout was carried out to mark out the appropriate number of treatments per plot. The total land area for each season experiment was 126.50 m^2 , divided into 10 treatments per plot and replicated three times. A raised bed was made representing a plot. Each plot measured 2 m × 2 m, with a 0.5 m borderline in between each replicate and 0.5 m apart to differentiate the treatment plots.

Application of amendments

Cured organic manures (cattle dung and poultry manure) and fresh *T. diversifolia* were incorporated into the soil immediately after land preparation at a depth of about 5 cm using a hand held hoe. Each of the amendments were applied at the rate of 20 t ha^{-1}, two weeks before transplanting for mineralization to take place. According to (Abegunrin et al. 2016), the development of tomato plants was significantly influenced by the application of cattle manure at a rate of 20 t ha^{-1}. The results of the study conducted by Onyegbule et al. (2018) showed that the highest growth and output of tomato crops might be achieved with 20 t ha^{-1} of poultry manure. Similarly, 180 kg NPK ha^{-1} of inorganic fertilizer (N-P-K: 15-15-15) was applied to the assigned plots two weeks after transplanting using the side placement method.

Experimental design

The experiment was a 2 x 2 x 5 factorial arranged in a Randomized Complete Block Design with three replications. Two varieties of *C. chinense* (Efia and Caribbean red), two seasons (dry season and rainy season), and five different types of soil amendments (poultry manure, cattle manure, Tithonian leaves, NPK, and the control) were used for the study. The dry season study started in November 2021 while that of the rainy season started in March 2022.

Seed sowing, transplanting and irrigation during the dry season

The seeds were sown in a shaded and enclosed nursery for 6 weeks, using a germination tray and sterile soil as the growing medium. During the two seasons, four healthy seedlings were transplanted per bed at 30 x 60 cm intra and inter-row spacing and were watered until they stabilized.

During the dry season (November 2021 – February 2022) field establishment, water was applied to the plots immediately after the incorporation of various organic amendments and after seedlings transplanting. This is to ensure proper crop establishment, mineralization of applied organic amendments, and provision of water requirements for crop growth and development. Irrigation water was applied to field capacity averaging about 10 L/1 m^2 plot through surface irrigation at intervals of four days. The water run-offs were prevented by slightly raising the edges of the beds. The quantity of irrigation water applied for an effective rooting zone depth of 0.31 m and wetting diameter of 41.67 m km^{-1} was based on the water requirements of capsicum (Ertek et al. 2007).

Varieties used and their characteristics

Efia F1 hybrid and Caribbean red seeds were used for this experiment. The seeds were bought from AFRI-AGRI products, a reputable agro-allied store in Lagos, Nigeria.

Data collection

Data were collected on plant height, number of leaves, number of primary and secondary branches, number of fruits, Fruit weight/plot (Fruit yield), fruit pericarp thickness, moisture content, shelf life, mineral (Ca, Cu, Zn, and Mg), and vitamin C composition of the fruits.

Procedure for the determination of shelf life and mineral compositions of pepper fruit

The shelf life of sampled fruits was determined when more than 50% of the fruits symptomatically displayed shrinkage or sunken lesions (Rao et al. 2011). The compositions of copper (Cu), zinc (Zn), Ca (Calcium), and Mg (Magnesium) were determined using the Atomic Absorption Spectrophotometer (AAS Model SP9) as described by AOAC (2006).

Procedure for the determination of ascorbic acid in pepper fruit

The determination of ascorbic acid in the fruit of *C. chinense* was carried out using the Spectrophotometric method according to Klein and Perry (1982). The juice sample was extracted for 45 minutes at room temperature (29°C) with 10 mL of 1% metaphosphoric acid and the extract was then strained through Whatman No. 4 filter paper. One milliliter of the extract was mixed with nine milliliters of 2, 6-dichlorophenolindophenol, and the absorbance at 515 nm was measured within 30 minutes against a blank solution. The ascorbic acid content was calculated using a genuine L-ascorbic acid calibration curve. The tests were performed in triplicate, and the findings were represented as ppm of ascorbic acid per 100 mL of the sample as the mean value and standard deviation.

Procedure for the determination of fruit moisture content

To evaluate the moisture content (MC) of the fruits, fresh pepper fruits were weighed, longitudinally incised, then put in a Brabender moisture tester Model MT-E drying chamber (Brabender® GmbH & Co., Duisburg, Germany). After the pods had been exposed to 105°C for 24 hours, the MC was calculated as described by AOAC (2006). The moisture content of fresh pepper fruit was calculated using the following formula:

Moisture content = $\frac{A-B}{A}$ x 100

Where A is the initial weight of fruits (g), and B is the final weight of fruits at every weight (g).

Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using GENSTAT Discovery Software, Edition 4 (2014). Differences between significant means were separated using Duncan multiple range test at a 0.05 level of probability. The relationship between yield and seasonal differences was determined using the Pearson's correlation coefficient at 0.01 level of significance.

Results and discussion

Initial soil properties

The initial physical and chemical properties of the experimental soil for the two seasons are shown in Table 1. The soil was a sandy loam texture, with a pH of 5.3 and 5.2 for both the dry and rainy seasons respectively, and it was at the threshold for organic content. The available phosphorus and nitrogen were relatively low while the exchangeable K, Ca, and Mg were low to moderate but not adequate.

Table 1 Physical and chemical properties of the initial soil used for the experiment during the dry and rainy seasons

Parameter	Dry	Rainy	Parameter	Dry	Rainy
Sand (%)	76	78	Organic matter (%)	2.04	2.07
Silt (%)	12.5	12	K (mg/kg)	0.13	0.13
Clay (%)	11.5	10	Ca (mg/kg)	2.00	1.95
Textural class	Sandy loam	Sandy loam	Mg (mg/kg)	0.32	0.33
pH (H_2O) 1:1	5.30	5.20	Available P (mg/kg)	9.15	9.12
Total nitrogen (%)	0.107	0.102	Zn (mg/kg)	0.41	0.35

Meteorological data of the experimental site during the first and second season of the study

The meteorological data for the periods of the experiment is shown in Table 2. The average rainfall and relative humidity were greater during the rainy season than the dry season, while the average temperature was higher in the dry season than the rainy season.

Table 2 Meteorological data of the study area

Parameters	Dry season Nov.2021 – Feb. 2022					Rainy season Mar. 2022 – June 2022				
	Nov	Dec	Jan	Feb	Average	Mar	April	May	June	Average
Rainfall (mm)	19.6	0	0	12.19	7.95	157.7	96.3	214.9	228.6	174.38
Relative humidity (%)	76.4	47.1	34.3	63.7	55.38	78.8	85.2	87.5	90.2	85.43
Mean Temp (°C)	28.3	29.2	29.1	27.7	28.58	24.8	25.9	23.6	22.2	24.13

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

Chemical composition of the organic amendments used for the study

The results of the laboratory analyses of the organic amendments used for the study are shown in Table 3. The results showed that all the amendments contained varying values of macro and micronutrients required for improved soil fertility and plant growth. Poultry manure had higher values for nitrogen, phosphorus, potassium, Calcium, Magnesium, and zinc but lower value for C:N.

Table 3 Chemical composition of the organic amendments used for the study

Parameters	Cattle manure	Poultry manure	*Tithonia diversifolia*
Organic carbon (%)	25.70a	22.40b	14.65c
Nitrogen (%)	1.84b	2.70a	1.70b
Phosphorus (%)	0.82b	1.29a	0.80b
Potassium (%)	1.98b	3.62a	2.98b
Calcium (%)	0.99b	3.33a	3.30a
Magnesium (%)	0.54a	0.60a	0.13b
Zinc (%)	0.10b	0.20a	0.03c
C:N	14.78a	8.29b	8.62b

Values followed by the same letters within the same row are not significantly different at p = 0.05 according to Duncan's multiple range test.

Effects of seasons, organic amendments, and NPK fertilizer on plant height and number of leaves of the two varieties of *C. chinense*

Caribbean red had a significant increase in plant height when compared to the Efia variety (Table 4). The effect of the seasons shows that season 2 significantly increased the plant height. Plant height increased significantly with the application of poultry manure though the value was statistically similar to the values obtained when *T. diversifolia*, cattle manure, and NPK were applied. The control showed a significant reduction in plant height except at 6 WAT, where the values were similar to other treatments. The ANOVA response revealed that the effects of varieties and seasons were significant at all sampling periods except on a variety at 10 WAT. Interaction between varieties and seasons was only significant at 8 and 10 WAT. Caribbean red produced more leaves, though not significant at 8 and 10 WAT. The effect of seasons also revealed that season 2 significantly increased the number of leaves. The application of amendment showed that poultry manure greatly enhanced the number of plant leaves, followed by NPK, cattle manure, and *T. diversifolia*. Poultry manure increased the number of leaves significantly, followed by NPK, cattle manure, and *T. diversifolia* with the control having the fewest leaves. The ANOVA response revealed that the effects of all the treatments were significant at all sampling periods except on variety where the ANOVA response was only significant at 6 WAT. The interaction was only significant between varieties and seasons at 6 WAT. This study found that the vegetative performance of *C. chinense* varieties was a reliable predictor of plant phenology and total output. Vegetative parameters of *C. chinense* varieties differ due to their physiological processes which may be controlled by the synergistic and/or interaction between the environment and their genetic make-up. Increased vegetative performance in season 2 as compared to season 1 could be ascribed to adequate and favorable environmental conditions in season 2, which was suitable for vegetative growth. A similar result was by Idowu-Agida et al. (2010) where they found that seasonal variability affects the performance of Cayenne pepper.

This variety's differential performance might be linked to genetic diversity, adaptability, morphological traits, and physiological conditions throughout crop growth stages. Similar results were found by Bergefurd et al. (2011) where the authors found that variations in responses by diverse varieties may be linked to alterations in the genetic components of the variety and varying environmental situations.

The application of various organic and inorganic fertilizers enhanced vegetative growth of *C. chinense*. In both seasons, values obtained for plant height in the control plot were lower compared to other treatments. In contrast to the Efia variety, the Caribbean red variety produced more primary and secondary branches.

Table 4 Effects of seasons, organic amendments, and NPK fertilizer on plant height and number of leaves of the two varieties of *C. chinense*

	Plant height			Number of leaves		
Treatment	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT
Varieties						
Efia	20.74b	30.79b	38.32a	30.90b	51.50a	71.61a
Caribbean red	22.90a	33.99a	40.77a	34.72a	53.32a	71.85a
Seasons						
S_1 (Dry)	16.58b	29.20b	37.39b	29.61b	45.74b	65.68b
S_2 (Rainy)	24.98a	34.79a	41.23a	35.37a	56.20a	74.69a
Amendments						
Poultry manure	24.65a	36.80a	42.61a	37.93a	60.39a	83.33a
Tithonia diversifolia	22.17ab	31.74b	38.67b	33.33b	51.30b	71.02b
Cattle manure	21.94ab	33.92ab	40.85ab	33.87ab	53.19b	71.41b
NPK	21.89ab	33.39b	41.80ab	33.93ab	53.70b	72.54b
Control	20.27b	28.79c	35.83c	28.19c	45.00c	60.13c
Anova Response						
Variety	0.021	0.007	0.121	0.020	0.506	0.994
Season	0.000	0.000	0.006	0.000	0.000	0.001
Amendment	0.025	0.000	0.001	0.000	0.000	0.000
Interaction						
V*S	0.056	0.001	0.007	0.003	0.604	0.946
S*A	0.983	0.997	0.675	0.502	0.360	0.017
V*A	0.346	0.566	0.072	0.659	0.177	0.572
V*A*S	1.000	0.978	0.969	0.994	0.998	0.998

Means in a column followed by the same letter(s) are not significantly ($P \leq 0.05$) different according to DMRT. WAT = Weeks after transplanting, V = variety, S = season, A = amendment

Effects of seasons, organic amendments, and NPK fertilizer on the number of Primary and secondary branches of the two varieties of *C. chinense*

A higher number of primary branches were produced in the Caribbean red variety though the value was not significant when compared with the Efia variety (Table 5). Seasons had no influence on the number of primary branches except at 6 WAT with season 2 having higher values for the number of primary branches. The effects of the application of amendments revealed that the number of primary branches at 4 WAT did not differ significantly. However, at 6, 8, and 10 WAT, the application of poultry manure significantly enhanced the number of primary branches that was comparable to the values observed when NPK was treated. When compared to other treatments, the control treatment provided the least significant value for the number of primary branches. The effect of season was significant on the number of branches at 6 WAT whereas the impact of the amendment on the number of branches was significant at 6, 8, and 10 WAT as indicated in the ANOVA response. None of the interactions was significant. The main and interaction effects of seasons, organic amendments, and NPK fertilizer on the number of secondary branches of the two varieties of *C. chinense* are shown in Table 4. At all weeks after transplanting, the effects of variety on the number of secondary branches were only significant at 6 WAT. Seasonal effects showed that the number of secondary branches on the plants increased significantly during season 2. The application of NPK significantly increased the number of secondary branches at 6 WAT, though the value was statistically similar to the value obtained with the application of poultry manure. At 8 and 10 WAT, treatments with poultry manure increased the number of secondary branches, followed by NPK, *T. diversifolia,* and cattle manure. Values obtained from the control plots showed a significant reduction in the number of secondary branches. The ANOVA response revealed that the effects of seasons and amendments were significant at all weeks after transplanting. Similarly, varieties were significant only at 6 WAT. Interaction between varieties and seasons was only significant at 6 WAT.

Effects of seasons, organic amendments, and NPK fertilizer on the yield of the two varieties of *C. chinense*

The analysis of variance revealed that there was no significant ($p<0.001$) interaction effect of the treatments on the number and weight of fruits (Table 6). A higher number and weight of fruits were observed with the Caribbean red though not significant when compared with the Efia variety. The effect of seasons (rainfall, humidity and temperature) on the number and weight of fruits was significant, with season 1 having a much larger number and weight of fruits. A higher number and fruit weight were observed with the application of poultry manure though not significant on fresh fruit weight. The least value for the two parameters was recorded in the control plots. The effect of seasons and amendments was significant on the number and weight of fruits as indicated in the ANOVA response. The interaction was not significant.

There were variations in the total fruit yield between the two varieties. The increased number of branches increased the ability of pods bearing buds, and leaf area, which greatly increases photosynthetic capacity and assimilates partitioning to the pods. These factors may be attributed to the higher fruit yield of the Caribbean red variety.

Vegetative growth has a beneficial influence on hot pepper yield and yield components, according to Godfrey-Sam-Aggrey and Bereke-Tsehai (2013) findings. Benson et al. (2013), discovered that secondary branches serve as the sites of fruit buds and the starting points for the creation of new fruit buds for bell pepper. The varietal difference in yield could also be that Caribbean red had higher nutrient utilization efficiency than the Efia variety (Abdelhamid et al. 2020). The inherent physiological and morphological features of fruits are some of the factors that determine fruit growth, development, and maturation. The yield increase in the Caribbean red variety might be as a result of optimum and adequate environmental factors. Chatterjee and Mahanta (2013) discovered that the development and production of broccoli are positively influenced by the presence of ideal temperature, humidity, and light intensity. The decline in yield caused by the seasons could be that the Efia variety is sensitive to varying temperatures and heat stress.

Table 5 Effects of seasons, organic amendments, and NPK fertilizer on the number of primary and secondary branches of the two varieties of *C. chinense*

	Number of primary branches			Number of secondary branches		
Treatment	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT
Varieties						
Efia	3.19a	3.49a	3.62a	1.58b	7.28a	10.80a
Caribbean red	3.30a	3.88a	3.97a	2.09a	7.600a	11.32a
Seasons						
S_1 (Dry)	2.41b	4.08a	4.04a	1.24b	5.41b	7.92b
S_2 (Rainy)	3.69a	3.73a	3.86a	2.26a	8.533a	12.76a
Amendments						
Poultry manure	3.83a	4.32a	4.32a	2.19ab	8.69a	13.11a
Tithonia diversifolia	3.33b	3.89ab	4.04ab	2.00b	7.556c	11.44bc
Cattle manure	2.94b	3.46ab	3.58b	1.48c	7.13c	10.63c
NPK	3.54ab	4.28a	4.30a	2.56a	8.30ab	12.63ab
Control	2.27c	2.60c	2.77c	1.37c	5.80d	7.91d
ANOVA Response						
Variety	0.880	0.917	0.763	0.008	0.66	0.49
Season	0.000	0.278	0.631	0.000	0.000	0.000
Amendment	0.005	0.004	0.003	0.000	0.000	0.000
Interaction						
V*S	0.859	0.815	0.958	0.000	0.189	0.048
S*A	0.533	0.991	0.971	0.790	0.584	0.559
V*A	0.486	0.819	0.618	0.730	0.816	0.532
V*A*S	1.000	1.000	1.000	0.989	1.000	0.999

Means in a column followed by the same letter (s) are not significantly ($P \leq 0.05$) different according to DMRT. WAT = Weeks after transplanting, V = variety, S = season, A = amendment

The results of this study are comparable to those of Erickson and Markhart (2001) where they observed that plant growth and development were influenced by cultivation and different seasons. The reduction in the yield of Efia variety could be attributed to the environmental stress during blooming and fruit set, which resulted in blossoms and flower abortion. High temperatures reduce fruit set and, as a result, yield in sweet pepper. The sweet pepper needs a temperature between 20 and 25°C to thrive and produce at its best. Temperature above 32°C or below 15°C negatively affected the growth and yield of sweet pepper (Saha et al. 1970). The study also revealed that during the season 1 trial, yield increased significantly as compared to the season 2 trial. This could be attributed to the onset of flowering of the two varieties, which coincided with favorable environmental conditions and subsequent transition to fruit for maximum yield (Abbas et al. 2013). Decreased yield in season 2 could also be attributed to flower abortion during the rainy season. The increasing order of pepper yield was control < NPK fertilizer < cattle manure < *Tithonia* < PM. The increase in the yield of pepper due to the application of the amendments relative to the control was due to the contribution made by these amendments to the fertility status of the soils, as the initial soil was low in soil nutrients. When manures are decomposed, they enhance the availability of macronutrients and micronutrients while also improving the physicochemical characteristics of the soil, which improves pepper growth and production. Pepper grown on poultry manure yielded more compared with other sources of organic amendment and NPK fertilizer. This can be attributed to its high nutritional value and minimal C: N ratio of the PM used in the study. The observed lower C: N ratio of PM resulted in earlier nutrient release and quicker mineralization for the pepper uptake, which increased the morphological development of the plant and higher output as compared to other amendments. The C: N ratio of organic materials, according to Wolf and Snyder (2005), has a major influence on the pace of decomposition and the mineralization of N because N governs the proliferation and turnover of the microorganisms that mineralize organic carbon. The value for C: N ratio of *Tithonia* in this study was statistically similar to C: N ratio of PM, but has an inferior nutrient content relative to PM which makes the differences in yield. NPK fertilizer though has higher nutrient content but has inferior yield relative to other organic amendments due to possible leaching of its nutrient, especially during heavy rainfall. The application of organic amendments, apart from increasing the nutrient content of the soil, also helps in enhancing the soil structure thereby preventing the leaching of nutrients from this amendment. This result is consistent with the findings of Adekiya et al. (2020) who reported that okra grown under organic soil amendment performed better.

Table 6 Effects of seasons, organic amendments, and NPK fertilizer on the yield of the two varieties of *C. chinense*

Treatments	Number of fruits/plot	Fruit fresh weight /plot (g)	Number of fruits/hectare	Fruit fresh weight /hectare (kg)
Varieties				
Efia	60.69a	391.38a	303,444a	1,956.9a
Caribbean red	74.22a	534.02a	371,111 a	2,670.1 a
Seasons				
S_1 (Dry)	101.13a	657.07a	505,667a	3,285.3a
S_2 (Rainy)	54.00b	401.18b	270,000 b	2,005.9b
Amendments				
Poultry manure	83.04a	632.11a	415,185a	3,160.55a
Tithonia diversifolia	67.00b	495.44ab	335,000b	2,678.40b
Cattle manure	65.22b	535.48ab	326,100b	2,477.20b
NPK	75.04ab	478.19ab	375,100ab	2,390.95bc
Control	48.26c	301.15c	241,300c	1,505.75d
ANOVA Response				
Variety	0.410	0.090	0.410	0.090
Season	0.001	0.000	0.001	0.000
Amendment	0.000	0.000	0.000	0.000
Interaction				
V*S	1.00	0.91	1.00	0.91
S*A	0.90	0.85	0.96	0.85
V*A	0.67	0.56	0.67	0.56
V*A*S	0.95	0.98	0.95	0.98

Means in a column followed by the same letter(s) are not significantly ($P \leq 0.05$) different according to DMRT. WAT = Weeks after transplanting, V = variety, S = season, A = amendment.

Correlation matrix of the effects of seasonal differences on the number and weight of *C. chinense*

Table 7 shows the measure of how the yield is related to variations in rainfall, relative humidity, and temperature as a result of differences in seasons. A positive correlation exists between NF and FW, NF and NFha, NF and FWha, NF and T°, FW and NFha, FW and FWha, FW and T°, NFha and FWha, NFha and T°, FWha and T°, and RF and RH. The values indicated that there was a positive relationship between the variables. All other relationships are negatively correlated which shows that as one variable increases the other decreases.

Table 7 Correlation matrix of the effects of seasons on number of fruits and fruit weight of capsicum

	NF	FW	NFha	FWha	RF	T°	RH
NF	1	0.701**	0.580**	0.724**	-0.605**	0.440**	-0.506**
FW		1	0.672**	0.570**	-0.566**	0.523**	-0.466**
NFha			1	0.698**	-0.610**	0.480**	-0.590**
FWha				1	-0.535**	0.501**	-0.572**
Rainfall					1	-0.485**	0.541**
Temp						1	-0.365**
Humidity							1

**. Correlation is significant at the 0.01 level. NF = Number of fruits, FW = Fruit weight, NFha = Number of fruits ha^{-1}, FWha = Fruit weight ha^{-1}, RF = Rainfall, T^{O} = Temperature, RH = Relative humidity

Pooled analysis of seasons 1 and 2 of the effects of organic amendments, and NPK fertilizer on the shelf life and vitamin C content of the two varieties of *C. chinense*

The pooled analysis for the two seasons on the shelf life of the two varieties of *C. chinense* varied significantly with different varieties, application of organic amendments, and NPK fertilizer (Fig. 1). The application of poultry manure and *T. diversifolia* significantly ($p<0.05$) produced longer shelf life for *C. chinense* with Caribbean red having more numbers of days. In both varieties, plots treated with NPK fertilizer and control had the least value for shelf life, though fruit harvested from the control plot had a longer shelf life than fruit harvested from NPK fertilizer plots (Fig. 1a). The vitamin C concentration of the two varieties of *C. chinense* varied significantly depending on variety, season, and treatment (Fig. 1b). The seasons had a significant effect on the vitamin C level of the two varieties, with season two having higher vitamin C content than season 1. The use of poultry manure and *T. diversifolia* generated the maximum vitamin C value for *C. chinense*, with the Efia variety having higher vitamin C. In all seasons, NPK fertilizer and control plots had the lowest vitamin C value, however, fruits collected from NPK fertilizer plots had somewhat higher vitamin C than those obtained from control plots. Post-harvest losses could arise from fruits that are devoid of post-harvest qualities which may inadvertently affect the fruit's shelf life. Radajewska and Dejwor-Borowiak (2000), found that one of the important factors that producers and distributors used in determining the commercial value of fresh fruits is the shelf life. Arah et al. (2015) concluded in their study that agronomic practices such as the application of amendments influenced the shelf life of fruits either before or after harvest. The result of this study on fruit shelf life, therefore, revealed that the application of NPK negatively affected the fruit shelf life of capsicum. This result is similar to that of Ghimire et al. (2013) where they reproted that application of NPK fertilizer increased the physiological weight loss of pepper fruits while there was a reduction in the physiological weight loss with the application of goat manure. Sole inorganic fertilizer application resulted in higher percentages of shrinkage and decay while lowering fruit shelf life than the rest of the fertilizer treatments (Ramachandra 2005). The potential of any plant to capture and photosynthesize the resources needed for growth and development is an important growth rate determinant. Cropping of pepper in season 2 improved vitamin C contents of pepper fruit relative to season 1 though the difference was not significant. This could be added to better soil moisture in season 2 relative to season 1. The better soil moisture would have made more nutrients available for pepper uptake. Organic amendments increased the vitamin C content of *C. chinense* fruits, which is explained by the fact that fruits obtained from organically treated plots had higher amounts of phenolic compounds and antioxidant capacity than inorganic samples. This is consistent with the findings of Aboyeji et al. (2017) on radish and Magkos et al. (2003) on lettuce, where they discovered that the organic production system increased the vitamin C content of both radish and lettuce.

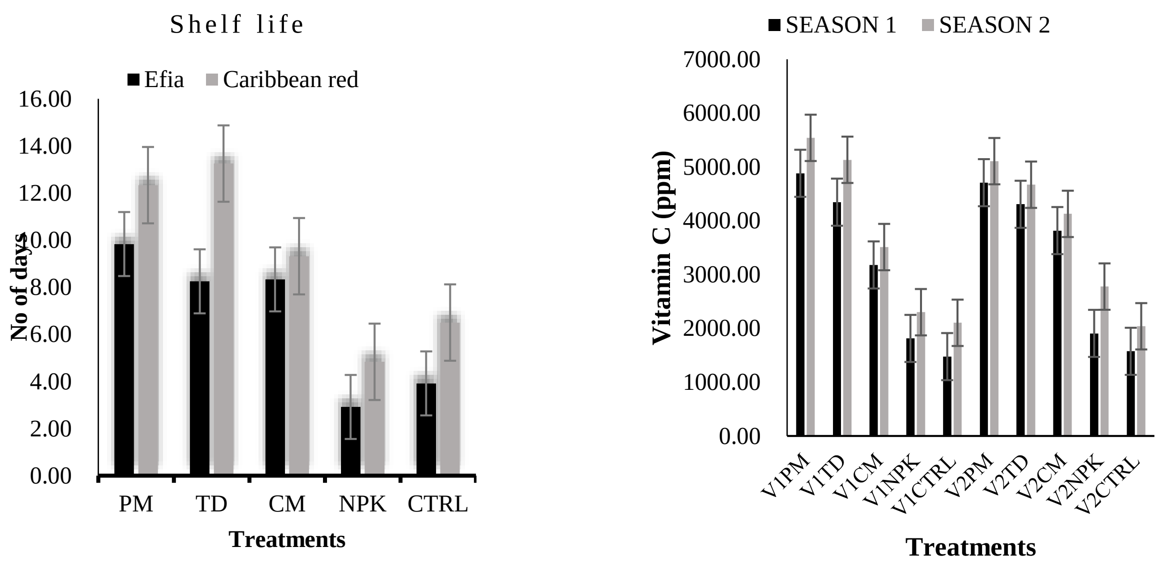

Fig. 1 Effects of organic amendments and NPK fertilizer on the (a) shelf life, and (b) Vitamin C content of the two varieties of *C. chinense* (Pooled analysis of seasons 1 and 2)

V1 = Efia, V2 = Caribbean red, PM = Poultry manure, CM = Cattle manure, TD = *T. diversifolia*, NPK = Inorganic fertilizer, CTRL = Control

Pooled analysis of seasons 1 and 2 of the effects of organic amendments, and NPK fertilizer on the mineral composition of the two varieties of *C. chinense*

The pooled analysis for the two seasons of the laboratory determination of mineral (Ca, Cu, Zn, and Mg) composition of *C. chinense* varied significantly with different varieties and application of organic amendments and NPK fertilizer (Fig. 2). The application of poultry manure produced higher values for Ca composition, which was similar to the values obtained with the application of *T. divesifolia* followed by the application of cattle manure for the two varieties. The least and most similar values for Ca were obtained with the application of NPK fertilizer and control (Fig. 2a). There was a significant difference ($p > 0.05$) in the Cu concentration of the fruits among the different amendments used for the study. Significantly, higher values for Cu were obtained in the application of poultry manure, *T. divesifolia* and cattle manure on the Caribbean red variety. Other amendments gave varying but similar values for the two varieties with the control having a significantly lower Cu value (Fig. 2b). Plots applied with poultry manures significantly increased the Zn content of Caribbean red, as compared with the Efia variety. The application of other amendments also increased the Zn value of Caribbean red though the differences in the Zn values were not significant (Fig. 2c). The value for Mg for the two varieties was higher and statistically similar to the application of poultry manure. There was no significant difference in the Mg values for the two varieties when *T. divesifolia* and cattle manure were applied.

The least value for Mg was obtained on the control plots for the two varieties (Fig. 2d). The concentration of minerals in plants is greatly influenced by climatic conditions. Climate changes have been observed to alter the chemical makeup of plants (Lefsrud et al. 2005).

The differences in mineral contents of the two varieties of pepper were attributed to variety and different genetic makeup.

Peterson et al. (1982) discovered a great difference in mineral concentration by genotype and found that the genotype effect was significantly greater than the influence of other environmental variables.

The enhanced nutrient availability in the soil because of manure mineralization, which led to better absorption by pepper plants, was attributed to soil amendments increasing pepper mineral contents as compared to the control. When compared to control and NPK fertilizer, pepper grown with organic amendments (poultry manure, *Tithonia*, and cattle manure) had a higher value for minerals (Ca, Cu, Zn, and Mg). This is due to the organic manures contain these nutrients as well as other micro and macro nutrients that are not easily leached. Aboyeji (2021) also reported that okra grown organically were greater quality than those grown conventionally.

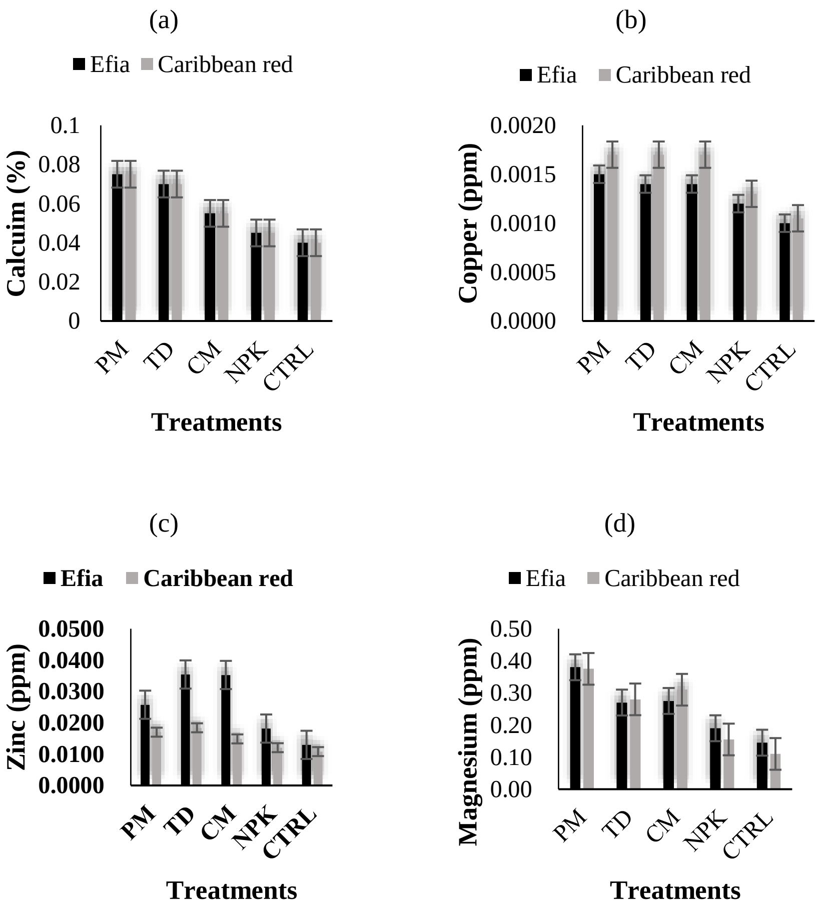

Fig. 2 Effects of organic amendments and NPK fertilizer on the (a) Calcium (b) Copper (c) Zinc and (d) Magnesium contents of the two varieties of *C. chinense* (Pooled analysis of seasons 1 and 2)

PM = Poultry manure, CM = Cattle manure, TD = *T. diversifolia* NPK = Inorganic fertilizer, CTRL = Control

Conclusion

The results of this study indicated that there are variations in all the parameters tested in response to varieties, seasons, and application of soil amendments. The Caribbean red variety had the best attributes for the vegetative parameters, yield, longer shelf life, and higher values for Cu, Ca and Mg. However, plants in season 1 had higher yields than those cultivated in season 2. Application of poultry manure was also found to improve the vegetative parameters, delayed fruit shrinkage (shelf life), and increased Ca, Cu, Mg, and vitamin C content of *C. chinense.* It can therefore be concluded that though there was a non-significant difference in the fruit vitamin C content between the two seasons, the Caribbean red variety cultivated during the dry season (season 1) under the application of poultry manure will give the best vegetative performance, longer shelf life, and improved fruit minerals contents.

Compliance with ethical standards

Conflict of interest; The authors declare that there are no conflicts of interest associated with this study.

References

Abbas AN, Sinaki J, Firouzabadi MB, Abbaspour H (2013) Effects of sowing date and biological fertilizer foliar on yield and yield components of cowpea. Intl J Agron Plant Prod 4:2822-2826

Abdelhamid MT, Horiuchi T, Oba S (2020) Composting of rice straw with oilseed rape cake and poultry manure and its effects on faba bean (*Vicia faba* L.) growth and soil properties. Bioresour Technol 93:183–189. https://doi.org/10.1016/J.BIORTECH.2003.10.012

Abegunrin TP, Awe GO, Ateniola KO (2016) Soil amendment for vegetable production: An example with cow dung manure and eggplant (*Solanum melongena*). Int J Curr Microbiol Appl Sci 5: 901–915. https://doi.org/10.20546/ijcmas.2016.508.102

Aboyeji CM, Adekiya AO, Dunsin O, Agbaje GO, Olugbemi O, Okoh HO, Olofintoye TAJ (2017) Growth, yield and vitamin C content of radish (*Raphanus sativus* L.) as affected by green biomass of Parkia biglobosa and *Tithonia diversifolia*. Agroforestry Systems 93:803–812. https://doi.org/10.1007/s10457-017-0174-6

Aboyeji CM (2021). Effects of application of organic formulated fertiliser and composted *Tithonia diversifolia* leaves on the growth, yield and quality of okra. Biol Agric Horticul 38: 17-28. https://doi.org/10.1080/01448765.2021.1960604

Adediran JA, Taiwo LB, Sobulo RA (2003) Comparative nutrient values of some solid organic wastes and their effect on tomato (*Lycopersicon esculentum*) yield. African Soils 33:99-113

Adekiya AO (2019) Green manures and poultry feather effects on soil characteristics, growth, yield, and mineral contents of tomato. Sci Hortic 257:108721. https://doi.org/10.1016/j.scienta.2019.108721

Adekiya AO, Ejue WS, Olayanju A, Dunsin O, Aboyeji CM, Aremu CO, Akinpelu O (2020) Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield quality of okra. Sci Rep 10: 16083. https://doi.org/10.1038/s41598-020-73291-x

Adeyeye AS, Olalekan KK, Lamidi WA, Aji PO, Othman HJ, Ishaku MA (2019) Comparative effect of organic and inorganic fertilizer sources on the growth and fruits yield of tomato (*Lycopersicum esculentum* mill.). Int J Agric Policy Res 6:122-126. https://doi.org/10.15739/IJAPR.18.014

Akintola OO, Abiola IO, Akinola OO, Babatunde KO, Ekaun AA, Olajiire-Ajayi BL (2021) Effects of organic and inorganic fertilizers on the growth of senecio biafrae (Worowo) olive & hiern. J Appl SCI Environ Manag 25(2):145-149

AOAC (2006) Official methods of analysis of the association of official analytical chemists. AOAC International. 18th. Editors, Horwitz W, Latimer GW, Gaithersburg (MD): AOAC International; 2005, 1–35

Arah IK, Amaglo H, Kumah EK, Ofori H (2015) Preharvest and postharvest factors affecting the Quality and shelf life of harvested tomatoes: A mini review. Int J Agronomy 2015:1–6. https://doi.org/10.1155/2015/478041

Arimboor R, Natarajan B, Menon KR, Chandrasekhar LP, Moorkoth V (2014) Red pepper (*Capsicum annuum*) carotenoids as a source of natural food colors: Analysis and stability—A review. J Food Sci Technol 52: 1258–1271. https://doi.org/10.1007/s13197-014-1260-7

Benson GAS, Obadofin AA, Adesina JM (2013) Evaluation of plant extracts for controlling insect pests of pepper (*caspicum spp.*) in Nigeria humid rain forest. N. Y Sci J 2014;7(1)

Bergefurd BR, Lewis W, Harker T, Miller L, Welch A, Weaks E (2011) Bell pepper cultivar performance trial grown in Southern Ohio (Midwest Vegetable Trial Report for 2011). The Ohio State University South Centers

Bhandari AL, Ladha JK, Pathak H, Padre AT, Dawe D, Gupta RK (2002) Yield and soil and nutrient changes in a long-term rice-cowpea cropping system in semi-arid tropics. Plant Soil 318:27-35

Binoy G, Charanjit K, Khurdiya DS, Hapoor HC (2004) Antioxidants in tomato as a function of genotype. Food Chem 84:45-5. https://doi.org/10.1016/S0308-8146(03)00165-1

Bosland PW (1996) Capsicums: Innovative uses of an ancient crop. In progress in new crops; ASHS Press: Arlington, VA, USA, 479–487

Bouchard RP (2017) Tomatoes, potatoes, and peppers. Retrieved July 20, 2021, from Medium website: https://medium.com/the-philipendium/tomatoespotatoes-and-peppers- bbcbd71f8479

Chatterjee R, Mahanta S (2013) Performance of off-season cauliflower (*Brassica oleracea* var. botrytis L.) under agro shade net as influenced by plantbergefurding dates and nutrient source. Int J Adv Agric Sci Technol 1: 56–62

Dipeolu AO, Akinbode SO (2008) Technical, economic, and allocative efficiencies of pepper production in south-west Nigeria: A stochastic frontier approach. J Econs R Dev 17: 24-33. https://doi.org/10.22004/ag.econ.147641

Ekwealor KU, Egboka TP, Anukwuorji CA., Obika IE (2020) Effect of different rates of organic manure (cow dung) on the growth of *Solanum Lycopersicum* L. Univers J Plant Sci 8(2): 34-37. https://doi.org/10.13189/ujps.2020.080203

Erickson AN, Markhart AH (2001) Flower production, fruit set, and physiology of bell pepper during elevated temperature and vapor pressure deficit. J Am Soc Hortic Sci 126: 697–702. https://doi.org/10.21273/JASHS.126.6.697

Ertek A, Sensory S, Gedik I, Kucukyumuk C (2007) Irrigation scheduling for green pepper grown in field conditions by using class-A pan evaporation values. Am.-Eurasian J Agric Environ Sci 2 :249–358

GenStat (2014) GenStat for Windows. Release 4.23. DE Discovery Edition, 2014. VSN International Limited, Hemel Hepsteins, UK

Ghimire S, Shakya SM, Srivastava A (2013) Effects of organic manures and their combination with urea on sweet pepper production in the mid-hills. J Agric Environ 14:23–30

Godfrey-Sam-Aggrey W, Bereke-Tsehai T (2013) Proceedings of the first Ethiopian horticultural workshop, 20-22 February 1985, Addis Abeba, Ethiopia. Retrieved July 19, 2022, from AGRIS: International Information System for the Agricultural Science and Technology

Grubben GJH, Denton OA (2004) Plant resources of tropical Africa 2. Vegetables. PROTA Foundation, Wageningen Idowu- Agida OO, Adetimirin VO, Nwanguma EI, Makinde AA (2010) Effects of seasonal variability on the performance of long cayenne pepper collected from southwestern Nigeria. Int J Appl Agric Res Volume 5 Number 2 (2010) pp. 117–127

Jama B, Palm CA, Buresh RJ, Niang A, Gachengo C, Nziguheba G, Amadalo B (2000). *Tithonia diversifolia* as a green manure for soil fertility improvement in western Kenya: A review. Agrofor Syst. 49 (2):201-221

Klein BP, Perry AK (1982) Ascorbic acid and vitamin a activity in selected vegetables from different geographical areas of the United Sates. J Food Sci 47: 941-945

Koyuncu F, Çetinbaş M, Erdal İ (2020) Nutritional constituents of wild-grown black mulberry (*Morus nigra* L.). J Appl Bot Food Qual 87: 93-96. https://doi.org/10.1111/j.1365-2621.1982.tb12750.x

Lefsrud MG, Kopsell DA, Kopsell DE, Curran-Celentano J (2005) Air temperature affects biomass and carotenoid pigment accumulation in kale and spinach grown in a controlled environment. Hort Sci 40:2026–2030. https://doi.org/10.21273/HORTSCI.40.7.2026

Li X, Guo J, Dong R, Ahring BK, Zhang W (2016) Properties of plant nutrient: Comparison of two nutrient recovery techniques using liquid fraction of digestate from anaerobic digester treating pig manure. Sci Total Environ 544:774–781. https://doi.org/10.1016/j.scitotenv.2015.11.172

Magkos F, Arvaniti F, Zampelas A (2003) Organic food: Nutritious food or food for thought? A review of the Evidence. Int J Food Sci 54(5):357-71. https://doi.org/10.1080/09637480120092071

Moneruzzaman Khandaker M, Rohani F, Dalorima T, Mat N (2017) Effects of different organic fertilizers on growth, yield and quality of *Capsicum Annuum* L. Var. Kulai (Red Chilli Kulai). Biosci Biotechnol Res Asia 14: 185–192. http://dx.doi.org/10.13005/bbra/2434

Onyegbule UN, Uwanaka CE, Nwosu PU (2018) Growth and fruit yield of garden egg (*Solanum gilo*) as affected by different organic fertilizer types and rates. CJ Agric Sci 12: 20– 30

Park H, Lee S, Jeong H, Cho S, Chun H, Back O, Kim D, Lillehoj HS (2006) The nutrient composition of the herbicide-tolerant green pepper is equivalent to that of the conventional green pepper. Nutr Res 26(10): 546-548. http://dx.doi.org/10.1016/j.nutres.2006.09.001

Peterson CJ, Johnson, VA, Mattern, PJ (1982) Evaluation of variation in mineral element concentrations in wheat flour and bran of different cultivars. Cereal Chem 60:450-455

Radajewska B, Dejwor-Borowiak I (2000) Refractometric and sensory evaluation of strawberry fruits and their shelf life during storage. In: IV Int Strawberry Symposium 567. pp 759–762

Ramachandra NAIK (2005) Influence of N-substitution levels through organic and inorganic sources on growth, yield and post harvest quality of capsicum under protected condition. Doctoral dissertation, University of Agricultural Sciences GKVK, Banglore

Rao R, Gol B, Shah K (2011) Effect of postharvest treatments and storage temperatures on the quality and shelf life of sweet pepper. Sci Hortic 132**:**18-26

Saha S, Hossain M, Rahman M, Kuo C, Abdullah S (1970) Effects of high temperature stress on the performance of twelve sweet pepper genotypes, Bangladesh J Agric Res 35: 525–534. https://doi.org/10.3329/bjar.v35i3.6459

Sonke D (1997) Tithonia weed - a potential green manure crop. ECHO Development Notes No. 57

Teodoro AFP, Alves RDB, Ribeiro LB, Reis K, Reifschneider FJB, Fonseca MEDN, da Silva JP, Agostini-Costa TDS (2013) Vitamin C content in Habanero pepper accessions (*Capsicum chinense*). Hortic Bras 31(1): 59-62. https://doi.org/10.1590/S0102-05362013000100009

Wolf B, Syder GH (2005) Sustainable soils - the place of organic matter in sstaining soils and their productivity. J Plant Nutr Soil Sci 1683):399-399. https://doi.org/10.1002/jpln.200590013

Worthingon V (2001) Nutritional quality of organic versus conventional fruits, vegetables, and grains. J Altern Complement Med 7(2): 161-173. https://doi.or/10.1089/107555301750164244

Zhang P, Chen X, Wei T, Yang Z, Jia Z, Yang B (2016) Effects of straw incorporation on the soil nutrient contents, enzyme activities, and crop yield in a semi-arid region of China. Soil Tillage Res 160: 65–72. https://doi.org/10.1016/j.still.2016.02.006