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RESEARCH

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Effects of different soil amendments and age of transplant on the post-harvest quality and shelf life of sweet pepper (*Capsicum annuum*) fruits

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Abstract

Background: Two separate experiments were conducted in the minor season from September to November, 2019 and major season from March to May, 2020 to determining the type of soil amendment and transplanting age that can best improve the post-harvest quality and shelf life of sweet pepper fruits at Benso oil palm plantation of Adum Banso Estate in the Mpohor District of the Western Region of Ghana. The experiments were conducted as a 4 × 2 factorial, arranged in a Randomized Complete Block Design. Four fertilizer treatments including no fertilizer (control), 10 tons/ha of poultry manure, 300 kg/ha of NPK 15-15-15 and 5 t/ha of poultry manure + 150 kg/ha of NPK 15-15-15 and two ages of transplants including 6-week-old seedlings and 7-week-old seedlings were applied during the cultivation periods and were later evaluated of their effects on the post-harvest quality and shelf life of harvested fruits after a two-weeks storage period. Data collected on weight loss, shrinkage, decayed fruits and shelf life of harvested fruits were subjected to analysis of variance using the Genstat Statistical package. The least significant difference criterion was used to separate treatment means at 5% probability.

Results: Post-harvest qualities of sweet pepper fruits were not significantly influenced by age of transplant throughout the study. Fertilizer application generally increased percentage fruit weight loss, fruit shrinkage, fruit decay and reduced shelf life of sweet pepper fruits in the major season. Sole application of poultry manure mostly enhanced post-harvest quality of sweet pepper fruits in the minor rainy season, but fruit shelf life was improved if no fertilizer was applied. Application of a combination of poultry manure and NPK 15-15-15 to 6-week-old transplants gave relatively low fruit weight loss and shrinkage values. Generally, fruit quality and shelf life were enhanced in 6-week-old transplants treated with no fertilizer.

Conclusions: The use of poultry manure alone should be encouraged to probably increase yield while improving the quality and shelf life of harvested sweet pepper fruits. Transplanting of 6-week-old seedlings is also encouraged for quality harvested fruits and extended shelf life.

Keywords: Age of transplant, Benso, Fertilizer, Post-harvest, Sweet pepper, Shelf life

Background

Sweet pepper (*Capsicum annuum* L.) is an important vegetable crop ranked after tomato and onion in the world (Alhrout 2017; Belel et al. 2011). It belongs to the Solanaceae family. It can be cultivated all-year-round (Kabura et al. 2008). The crop is believed to have

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originated from Tropical South America, specifically Brazil. It is widely cultivated in Central and South America, Peru, Bolivia, Costa Rica, Mexico, almost all the European countries, Hong Kong and India (Jamir et al. 2017).

Sweet pepper is an important vegetable/condiment and an active ingredient for cooking (Tarara 2000). It can be cooked or eaten as a raw salad. According to Khan et al. (2010), the leaves are also eaten as salad in soups or eaten with rice. Tarara (2000) reported that the sweet pepper fruit is rich in vitamins, especially vitamins A, C and E as well as thiamine, vitamin B6, beta-carotene and folic acid. Sweet pepper also contains a large amount of phytochemicals including chlorogenic acid, zeaxanthin and coumaric acid with exceptional antioxidant activity. Green peppers including sweet pepper have been shown to be protective against cataracts due to the vitamin C and beta-carotene content. They have also been shown to prevent blood clotting and reduce the risk of heart attacks and strokes probably due to their capsaicin and flavonoids content in addition to the vitamin C (Tarara 2000). Studies by Komla (2013) showed that sweet pepper can be recommended for individuals with elevated levels of cholesterol. Khan et al. (2010) reported that it could be used to treat black vomit, gout and paralysis (Khan et al. 2010).

Sweet pepper is cultivated in Ghana for both local consumption and export. Although small scale and commercial farmers grow it commercially to support the export drive (Norman 1992), sweet pepper production in Ghana needs to be expanded due to the high export demand. The success of green pepper production begins with proper soil amendments and improving soil fertility (Itelima et al. 2018). The use of fertilizers in vegetable production has therefore assumed a great significance in recent years probably due to the need to enhance sustainable increase in production (Khan et al. 2010). A wide range of fertilizers such as NPK 15:15:15, NPK 20:20:0, sulfate of ammonia, urea and poultry manure are used to improve soil fertility in some major vegetable growing areas in Ghana (Nyamah 2011). It has been shown that sweet pepper responds positively to nitrogen and phosphorus fertilizers (Aliyu 2002).

It has also been reported that the supply of most vegetable fruits is lower than their demand due to huge post-harvest losses. In many countries such as Ghana, post-harvest loss of fresh fruits is estimated to be about 20 to 50% (Nyamah 2011). Post-harvest losses may be attributed to the inability of the fruits to possess certain post-harvest qualities such as reduced weight loss, fruit cracks, decay that could affect the shelf life of the fruits. According to Radajewska and Dejwor-Borowiak (2000), the shelf life of stored fruits is an important feature producers and distributors use to determine the commercial value of fresh fruits. Cultural practices like nutrient application are known to influence the shelf life and other qualities of fruits before and after harvest (Arah et al. 2015). Sowing date is also an important aspect of production systems of different crops. Optimum sowing or planting time fosters proper growth and development of plants, resulting in maximum yield of crop and economic use of land (Islam et al. 2010). Studies showed that cultural factors, such as age of transplant, pruning and fertility, influenced pepper yield. It has also been reported that both growth and yield of chilli pepper for instance are markedly influenced by different ages of transplants and transplanting date (Osei 2013). It has, however, been reported that, the effect of transplanting age is dependent on the type of vegetable grown, the kind of environment the transplants will be grown and the expected economic returns (Akinrotimi and Aniekwe 2018). Also, there is lack of literature on the effect of transplanting age on the post-harvest quality and shelf life of harvest fruits. This study, therefore, aimed at determining the type of soil amendment and transplanting age which can best improve the post-harvest quality and shelf life of sweet pepper fruits.

Methods

The study areas

The experiments for the study were conducted during the 2019 minor season, from September to November and the 2020 major season, from March to May at Benso oil palm plantation, Adum Banso Estate in the Mpohor District of the Western Region of Ghana.

The Mpohor District is located at the south-eastern end of the region. It is bounded on the west by Ahanta West District, east by Wassa East District, north-west by Tarkwa-Nsuaem Municipality and Shama District. The District covers a total land area of 524.533 square kilometres.

The experimental site (Adum Banso) is geographically located at 5° 3′ 0″ North and 1° 54′ 0″ West (Ghana Statistical Service [GSS] 2014). The Mpohor District falls within the tropical climate zone. The annual rainfall ranges from 1300 to 2000 mm with a mean of 1500 mm. The major rainy season occurs between March and July, and the minor rainy season extends from November to January (GSS 2014).

The District lies within the low-lying areas of the country with most parts below 150 m above sea level. The landscape is generally undulating with an average height of about 70 m. The highest elevation ranges between 150 and 200 m above sea level. The drainage pattern of the Mpohor District is largely dendritic. There are a number of rivers and streams in the District, some of which are Subri, Butre and Hwini (GSS 2014).

Four main categories of rock and soil types underlie the District; Lower Birimian, Dixcove granite, Cape Coast granite and Tarkwaian. More than half of the soil consist of Cape Coast granitic soils. Existing underground rocks in certain communities hinder the drilling of water facilities. The District, therefore, has large deposits of gold, traces of iron and kaolin, hence the upsurge of mining activities, which have resulted in the pollution of water resources in the District. The vegetation is a tropical rainforest (GSS 2014).

Experimental design and treatments

The field experiments for the two seasons consisted of two levels of age of transplants and four levels of fertilizer formulations evaluated in a Randomized Complete Block Design (RCBD) with three replicates, resulting in 24 treatment plots.

Factor A (age of transplants) comprised:

- 6-week-old transplants after pricking out
- 7-week-old transplants after pricking out

Factor B (fertilizer type) included:

- Control/ No fertilizer application (F_0)
- Poultry manure at 10 tons/ha (F_1),
- NPK 15:15:15 at 300 kg/ha (F_2)
- 5t/ha poultry manure + 150 kg/ha NPK 15:15:15 (F_3)

Initial characteristics of soils in treatment plots and poultry manure used for the study are presented in Table 1.

Cultivation and management practices

Land preparation, field layout and planting

The nursery site and experimental field were cleared with a cutlass and manually tilled with a hoe. The field was demarcated, lined and pegged a week before transplanting. The experimental field was divided into four blocks. Each block was further prepared into plots, each measuring 1.5 m × 1.5 m with 1 m between plots and 1 m between blocks, giving a total land area of 126 m^2. Seeds of the sweet pepper variety (California wonder variety) were obtained from K. Badu agro input shop in Kumasi in the Ashanti Region of Ghana.

Seedlings were raised on well prepared nursery beds, 20 cm high from ground level. Seeds for the first experiment were sown on 2 and 9 September, 2019, and those of the second experiment were sown on 2 and 9 March, 2020 in order to obtain 7- and 6-week-old transplants after pricking out for each experiment. Beds were watered soon after sowing. A shed of palm fronds was erected over the beds, 1 m high from the ground to provide shade to protect the seedlings from harsh weather conditions. Watering was carried out every other day depending on the climatic conditions. Seedlings were pricked out 15 days after each sowing to allow seedlings enough space for development. Watering, hand picking of weeds, stirring of the soil to enhance aeration were carried out regularly. The nursery site was sprayed with Attack botanical insecticide at a rate of 10mls in 15L of water using a knapsack sprayer to protect seedlings from pests such as thrips, aphids, caterpillars and leaf miners. Transplanting was done as per the treatment imposed.

Table 1 Selected initial physical and chemical properties of soil and poultry manure. *Source*: Council for Scientific and Industrial Research-Soil Research Institute (CSIR-SRI), Kwadaso-Kumasi

Parameter	Treatment plot				Poultry manure
	Control	Organic	Inorganic	Organic + Inorganic	
Sand (%)	86.00	88.00	86.00	84.00	
Silt (%)	10.00	8.00	10.00	10.00	
Clay (%)	4.00	4.00	4.00	6.00	
pH (1:2.5 H_2O)	4.56	4.22	4.35	4.12	7.20
Organic C (%)	1.59	1.65	1.52	1.59	36.50
Total N (%)	0.16	0.20	0.17	0.18	1.70
OM (%)	2.74	2.85	2.62	2.74	
Ca^{2+}/100 g	1.70	1.92	1.28	1.92	1.44
Mg^{2+}/100 g	0.64	0.32	0.75	0.85	0.78
K^{+}/100 g	0.14	0.31	0.40	0.32	0.63
Na^{+}/100 g	0.02	0.20	0.61	0.23	
P (ppm)	78.46	88.31	98.37	78.46	1.80

Transplanting and replanting

Uniform and healthy 6- and 7-week-old pricked-out seedlings were transplanted on 20 October, 2019 and 20 April, 2020 for experiments 1 and 2, respectively, at a spacing of 50 cm × 50 cm. Transplanting was done late in the evening to reduce excessive loss of water from the transplants. Each plot had 10 plants. Refilling of vacancies was done two weeks after transplanting.

Weed management

Weed control was done manually by hoeing as and when necessary.

Pests and disease

Pests such as aphids, thrips, grasshoppers were chemically controlled with a knapsack sprayer every two weeks after transplanting with Attack botanical insecticide at a rate of 15mls in 15L of water.

Application of fertilizer

Fertilizer was applied to crops as per the treatment imposed. Thus, control plots received no fertilizer, plots with F1 received 10 tons/ha of poultry manure, plots with F2 received 300 kg/ha of NPK 15-15-15 and plots with F3 received 5 tons/ha of poultry manure and 150 kg/ha of NPK 15-15-15 throughout the study. Fertilizers were side-banded and split-applied at one and two weeks after transplanting.

Irrigation

Watering was occasionally done with a watering can as and when necessary depending on the prevailing climatic and soil moisture conditions.

Harvesting

Ten (10) fruits from six (6) plants were randomly sampled from each of the 24 plots. Harvesting of green fruits from the two experiments began 7–8 weeks after transplanting and continued at 3 days intervals till the plants wilted out and died.

Fruit storage

Sampled fruits were stored separately under ambient temperature on plastic trays in a well ventilated room, away from direct sunlight for two weeks during which data on post-harvest parameters were collected.

Data collection

Percentage fruit weight loss after harvest

After harvest, weight loss was determined by finding the difference between the initial weight and the final weight of fruits during a storage period of two weeks and the result was expressed as a percentage.

Percentage fruit shrinkage after harvest

This was determined by inspecting the stored fruits daily for number of shriveled fruits, and this was expressed as a percentage.

Percentage fruit decay

Fruits were inspected daily and fruits with fungal mycelia on fruit surfaces were counted as decayed fruits. The number obtained was expressed as a percentage.

Shelf life of fruits

The shelf life of fruits was calculated by counting the days required to attain the last stage of rotting, but up to the stage when fruits remained acceptable for consumption.

Statistical analysis

Data were subjected to analysis of variance using the Genstat Statistical package. The Least Significant Difference (LSD) criterion was used to separate treatment means at 5% probability.

Results

Results of 2019 minor season

Percentage weight loss

The response of percentage weight loss of harvested fruits was not significant ($P > 0.05$) with treatment application (Additional file 1: Table 2: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the minor season of 2019). However, there was significant ($P < 0.05$) fertilizer by age of transplants interaction for percentage weight loss. The interaction between control and 7-week-old transplants recorded the highest percentage weight loss of fruits (10.33%), while 6-week-old transplants treated with poultry manure combined with NPK 15-15-15 gave the least percentage weight loss of fruits (5.67%).

Percentage fruit shrinkage

Age of transplants had no significant ($P > 0.05$) effect on percentage fruit shrinkage, but application of fertilizer significantly ($P < 0.05$) affected percentage fruit shrinkage (Additional file 1: Table 2: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the minor season of 2019). The control and NPK 15-15-15 did not vary from each other in percentage fruit shrinkage, and these treatments recorded the highest percentage fruit shrinkage (4.50%). Sole application of poultry manure did not differ from its combination with the mineral fertilizer. The lowest percentage fruit shrinkage () was associated with the combination of the organic and mineral fertilizer. There was significant ($P < 0.05$)

treatment interaction for percentage fruit shrinkage. The highest treatment interaction (5.67%) was noticed in plots with 6-week-old transplants without fertilizer, while 6-week-old transplants treated with poultry manure and its combination with the mineral fertilizer gave the lowest treatment interaction (2.00%).

Percentage fruit decay

There was no significant ($P > 0.05$) difference between the two different ages of transplants in terms of percentage fruit decay (Additional file 1: Table 2: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the minor season of 2019). However, application of fertilizer significantly ($P < 0.05$) affected percentage fruit decay with the highest value (5.33%) being found in fruits obtained from plants treated with NPK 15-15-15, even though this treatment was not significantly ($P > 0.05$) different from its combination with poultry manure. The control and poultry manure did not differ from each other in percentage fruit decay, and these treatments recorded the lowest percentage fruit decay (1.50%). There was significant ($P < 0.05$) treatment interaction for percentage fruit decay. The highest treatment interaction (8.00%) was noticed in fruits obtained from 7-week-old transplants treated with NPK 15-15-15, while the least treatment interaction of 1.33% was observed in fruits produced from 6-week-old transplants, which received no fertilizer and the 6-week-transplants treated with poultry manure alone.

Fruit shelf life

There was no significant ($P > 0.05$) variation between the two different ages of transplants in terms of fruit shelf life (Additional file 1: Table 2: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the minor season of 2019). Significant ($P < 0.05$) differences were observed among all the fertilizer treatments. The longest shelf life of 15.17 days was obtained from fruits produced from plants which received no fertilizer, whereas plants treated with NPK 15-15-15 produced fruits with the shortest shelf life of 9.17 days. There was significant ($P < 0.05$) treatment interaction for fruit shelf life. Fruits from 6-week-old transplants in plots without fertilizer had the longest shelf life of 15.33 days, while fruits from 7-week-old transplants in plots treated with NPK 15-15-15 had the shortest shelf life of 9.00 days.

Results of 2020 major season

Percentage weight loss

The response of percentage weight loss of harvested fruits in the major season of 2020 was not significant ($P > 0.05$) with treatment application. Fertilizer application by age of transplants interaction was not significant (Additional file 1: Table 3: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the major season of 2020). The control as well as 6-week-old transplants resulted in the lowest weight losses (5.90% and 7.27%, respectively), while the highest values were obtained from the NPK 15-15-15 fertilizer and 7-week-old transplants (8.27% and 8.00%, respectively).

Fruit shrinkage

Age of transplants had no significant ($P > 0.05$) effect on percentage fruit shrinkage, but application of fertilizer significantly ($P < 0.05$) affected it (Additional file 1: Table 3: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the major season of 2020). The control treatment varied significantly ($P < 0.05$) from all the nutrient-applied treatments in percentage fruit shrinkage. Poultry manure and NPK 15-15-15 differed significantly ($P < 0.05$), but were both similar to their combined application. The lowest percentage fruit shrinkage (2.047%) resulted from the control treatment, while the highest (5.675%) was from NPK 15-5-15. In terms of age of transplants, 7-week-old transplants resulted in a relatively high fruit shrinkage (4.33%). Treatment interaction for percentage fruit shrinkage was significant ($P < 0.05$). The highest treatment interaction of 5.78% was noticed in plots with 6-week-old transplants treated with NPK 15-15-15, while 7-week-old transplants treated with no fertilizer gave the lowest treatment interaction (1.88%).

Fruit decay

There was no significant ($P > 0.05$) difference between the two different ages of transplants in terms of percentage fruit decay (Additional file 1: Table 3: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the major season of 2020). However, application of fertilizer significantly ($P < 0.05$) affected percentage fruit decay with the highest value (6.333%) being found in fruits obtained from plants treated with NPK 15-15-15, even though this treatment was not significantly ($P > 0.05$) different from its combination with poultry manure. The control and poultry manure treatments did not differ from each other in percentage fruit decay. The poultry manure treatment recorded the lowest percentage fruit decay (3.267%). There was significant ($P < 0.05$) treatment interaction for percentage fruit decay. The highest treatment interaction (9.00%) was noticed in fruits obtained from 7-week-old transplants treated with NPK 15-15-15, while the least treatment interaction (3.00%) was observed in fruits produced from 6-week-old transplants treated with poultry manure.

Fruit shelf life

There was no significant ($P > 0.05$) variation between the two ages of transplants in terms of fruit shelf life (Additional file 1: Table 3: Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the major season of 2020). However, transplanting at 6 weeks prolonged fruit shelf life (10.42 days) better than the 7-week-old transplants (10.08 days). Sole application of poultry manure significantly ($P < 0.05$) reduced fruit shelf life, while the rest of the fertilizer treatments including the control did not vary significantly ($P > 0.05$). The longest fruit shelf life (11.17 day) was obtained from fruits produced from plants which received no fertilizer, followed by NPK 15-15-15 (10.50 days) and then combined application of poultry manure and NPK 15-15-15 (10.17). There was significant ($P < 0.05$) treatment interaction for fruit shelf life. Fruits from 6-week-old transplants in plots without fertilizer had the longest shelf life of 12.67 days, while fruits from 6-week-old transplants in plots treated with sole poultry manure had the shortest shelf life of 8.33 days.

Discussion

Treatment effects on post-harvest quality and fruit shelf life

Post-harvest quality was not significantly ($P > 0.05$) affected by age of transplants throughout the study. Results of post-harvest parameters in the minor season of 2019 showed no significant influence of fertilizer application on percentage weight loss. However, percentage fruit shrinkage, fruit decay and shelf life of fruits were significantly ($P < 0.05$) affected. Percentage fruit shrinkage was reduced by the application of 10 tons of PM and 5 tons of PM + 150 kg of NPK 15-15-15 compared to the control and NPK 15-15-15 alone treatments, whereas fruit decay was significantly ($P < 0.05$) increased due to the application of combined application of poultry manure and NPK 15-15-15 compared to the control and PM treatments. In the major season of 2020, fertilizer application significantly ($P < 0.05$) affected percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life. All fertilizer treatments significantly ($P < 0.05$) reduced shelf life of harvested fruits throughout the study. High percentage weight loss from the control treatment followed by sole organic fertilizer may be attributed to the low biomass accumulation. There were significant ($P < 0.05$) treatment interactions for post-harvest parameters throughout the study.

Ghimire et al. (2013) reported that physiological weight loss of the fruits obtained from the application of NPK fertilizers was the highest (16.44%), but lowest 6.66%) in the application of goat manure 100%, followed by 50% goat manure + 50% urea (6.99%). Ramachandra (2005) also reported that maximum percent physiological loss in weight was recorded with 100% N through urea. Sole inorganic fertilizer application resulted in higher percentages of shrinkage and decay, while lowering fruit shelf life than the rest of the fertilizer treatments. According to Nyamah (2011), cell division and expansion determine final fruit size and carbohydrate dilution within cells. The source of carbon to the plant could affect sugar production through photosynthesis. Modification in carbon supply can result from environmental stresses or cultural practices such as fertilizer application. The degree of water loss in pepper fruits is subject to effect of genotype and pre- and post-harvest environments. Pre-harvest environment includes the soil within which the crop was cultivated. A study by Sobczak et al. (2020) to investigate the effect of phosphorus application in the form of polyphosphates on the yield and quality of sweet pepper fruits grown with LED (light-emitting diodes) assimilation lighting indicated no influence of polyphosphates on the concentration of such components in pepper fruits as dry matter, TSS (total soluble solids), ascorbic acid, TS, P, NO_3, K and Ca. Also, sensory analysis of pepper fruits did not show the influence of polyphosphates on attributes concerning odor, texture and flavor of pepper fruits. Significant changes of these components in the fruit resulted mainly from the cultivar.

A similar study by Rubio et al. (2010) showed that fruit quality parameters were affected by the different levels of Ca^{2+} and K^+. Fruit shape index increased with the highest Ca^{2+} concentration in the root medium. In addition, the lowest Ca^{2+} level decreased the TSS and increased the pH. Acidity increased gradually with increasing K^+ level through the studied range of 2.5 to 14 mmol L^{-1}, and a significant decrease in the maturity index with increased K^+ level in the root medium was observed. These effects of K + on fruit could enhance storage and also extend their shelf-life. According to Buczkowska et al. (2016), calcium supplementation modified the chemical composition of sweet pepper fruit. The application of calcium preparations led to reduced dry matter and total sugar content, and, with the exception of calcium nitrate, vitamin C and carotenoids. Ceglie et al. (2016) (as cited by Ceglie et al. 2016) also examined the qualitative attributes and postharvest performance of organic and conventionally grown strawberry fruit. Their findings revealed that organic strawberries have greater levels of vitamin C, malic acid, tartaric acid, fructose, and glucose than conventional strawberries. In fact, strawberries cultivated organically earned the best rating for sweetness and fragrance. Similar results were found by Conti et al. (2014) for various kinds in the same geographic region (South of Italy). However, further studies are necessary to establish a link between the use of fertilizers, rainwater, quality and recipes of peppers, and improvement in shelf life by complete analysis of pepper fruits and determination of their content of compounds to evaluate the effect of individual sets of cultural practices responsible for quality and improvement of shelf life.

Conclusions

The use of fertilizer generally compromised post-harvest qualities and shelf life of sweet pepper fruits in the major rainy season. Sole use of poultry manure mostly enhanced post-harvest quality of sweet pepper fruits in the minor rainy season, but fruit shelf life was improved if no fertilizer was applied. Post-harvest quality and shelf life of sweet pepper fruits were improved when pepper plants transplanted at 6 weeks after planting received no fertilizer.

Abbreviations

SRI: Soil Research Institute; CSIR: Council for Scientific and Industrial Research; CV: Coefficient of variation; F: Fertilizer; GSS: Ghana Statistical Service; LSD: Least significant difference; NS: Not significant; PM: Poultry manure; RCBD: Randomized complete block design; T: Transplant; WAT: Weeks after transplanting.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42269-021-00630-x.

Additional file 1. **Table 2**. Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the minor season of 2019. **Table 3**. Effect of fertilizer and age of transplants on percentage fruit weight loss, fruit shrinkage, fruit decay and fruit shelf life of sweet pepper in the major season of 2020.

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Authors' contributions

IA conceived the original idea, carried out the field experiments, collected data for the study and wrote the first draft of the manuscript. KGS and AAK read the first draft of the manuscript for necessary corrections. EA contributed the experimental design and performed analytical computations. All authors read and approved the final manuscript for submission.

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Availability of data and materials

The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

The studies involved in this article did not include animals or human participants as objects of research.

Consent for publication

Not applicable.

Competing interests

The Authors declare that they have no conflict of interest.

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