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Full Length Research

Evaluating the influence of pre-harvest hybrid treatments (compost manure and potassium nitrate fertilizer) on the mechanical properties of eggplant (cv. Bello) fruits

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ABSTRACT: There is an urgent need for fruits enhancers due to rise in food insecurity globally. Eggplant (*Solanum aethiopicum* L.) fruit is one of the most widely consumed fruit in the world, and Nigeria in particular. The aim of this study was to evaluate the potential of using compost manure and potassium nitrate (KNO_3) fertilizer as fruit enhancers in eggplant production. The research was carried out on Bello eggplant using seven different treatments. Apart from the control unit, compost manure was applied at the rate of 2500 and 5000 kg/ka; the KNO_3 fertilizer was applied at the rate of 150 and 300 kg/ha; combined treatment of compost manure and KNO_3 was applied at the rate of 2500 kg (compost) + 150 kg (KNO_3) and 5000 kg (compost) + 300 kg (KNO3) per hectare. Fruits from all the treatments were harvested at peak maturity stage, and the mechanical properties determined, in accordance to international procedures. Results obtained from the mechanical test revealed that fruits produced with combined treatment had better failure force, failure energy and compressibility, compared to the control fruits, or the fruits produced with single treatment. Regarding the single treatment, the results revealed that fruits produced with compost manure had better compression properties than the fruits produced with KNO_3. A failure force of 829.00 and 855.33 N were recorded in the fruits produced with compost manure at the two concentration levels respectively. Similarly, failure force of 798.33 and 831.67 N were recorded in the fruits produced with KNO_3 at the two concentration levels respectively. This study results affirmed that combined treatment was better than single treatment, and the combined treatment can be used as fruits enhancer. Results obtained from this study can also be used to design and develop eggplant fruit harvesting, handling and packaging machines.

Keywords: Compressibility, eggplant fruit, food insecurity, fruit enhancer, potassium nitrate.

INTRODUCTION

Eggplant (*Solanum aethiopicum* L.) fruit is one of the most widely consumed fruit in the world, and Nigeria in particular. Its global production has greatly increased within the last one decade. Information obtained from the official portal of the Food Agriculture Organization (FAO) showed that global eggplant produced had increased from 44.1 million tons in 2010 to 55.2 million tons in 2019 (FAOSTAT, 2019). There are over 20 cultivars of eggplant, with each having unique features such as fruit size and shape, leaf colour, size and shape, corolla diameter and fruit body mass, maturity period, etc. (Osei et al., 2010; Nwanze and Uguru, 2020). According to Msogoya et al. (2014) eggplant fruits contain essential nutrients such as vitamins (B_1, B_2, B_6, C, etc.), minerals (calcium, iron, etc.) and carbohydrates. Similarly, Sanchez-Mata et al. (2010) reported that eggplant fruits contain large amount of essential compounds, such as phenols, anthocyanin, glycoalkaloids, α-chaconine, etc. which are medicinal compounds that helped to cure many infections. One of the main factors that are usually considered during crop harvesting, handling, processing and storage operations is the mechanical properties of the crop. This property helped in the design and development of agricultural machines, that optimized their production.

The mechanical properties of agricultural products determined the force and energy they absorbed during agricultural harvesting, processing and storage operations. According to Varela et al. (2007), the mechanical properties of agricultural products are dependent on the anatomical and biochemical specifications of their cellular structure. Furthermore, Li et al. (2011) state that agricultural products had heterogeneous structural makeup and anisotropic in nature, hence, compression forces are distributed inhomogeneous within their body system. One of the major factors that determine the engineering properties of agricultural products is the farming method, under which the crop is produced. Farming method involves the addition of either organic or inorganic amendment to the soil to improve the soil fertility. Previous research results had revealed that organic soil amendment and pre-harvest treatment of crops not only remediate the contaminated soil, but enhance crops productivity and their engineering properties (Ouédraogo et al. 2001; Eboibi et al., 2018; Obah et al., 2020). According to Akpokodje and Uguru (2019) and Ijabo et al. (2019), the mechanical properties of crops are highly influenced by the plant cultivar, farming method, climatic conditions, maturation and pre-harvest treatment.

Several authors (Li et al., 2001; Haq and Rab, 2012; Uguru and Obah, 2020) works had shown that pre-harvest treatment of crops, greatly increased their tissues resistance to mechanical stress. Truong and Wang (2015) observed that the qualities of tomato fruits produced with vermicompost were superior compared to the fruits harvested from the control unit. Additionally, Nwanze and Uguru (2020) reported that the engineering properties of Djamba eggplant fruits produced with potassium nitrate (KNO_3) were better, when compared with the fruits produced without any pre-harvest treatment. Although several works had been done on pre-harvest treatment of fruits, there is still paucity of information on the combination of compost manure and potassium nitrate, as fruits enhancer in eggplant fruits production. Hence, the objective of this research was to evaluate the effect of combined treatment and treatment concentration of compost manure and potassium nitrate fertilizer as fruit enhancers on the mechanical properties of eggplant (cv. Bello) fruits.

MATERIALS AND METHODS

The Bello eggplant seeds were obtained from the seed bank of the Department of Agricultural and Bio-environmental Engineering, Delta State Polytechnic, Ozoro, Nigeria. The seeds were nursed inside the screen house of the Department of Agricultural and Bio-environmental Engineering, Delta State Polytechnic, Ozoro, for 28 days.

Compost manure preparation

The compost manure was prepared from poultry waste, cattle dung, waste and cassava peelings and oil palm fruit bunch waste, mixed at the ratio of 2:5:2:1 (weight to weight). The passively aerated static pile composting method was adopted, and the composting took a period of four months.

Pre-harvest treatments

The seven treatments were used for this study as summarized in Table 1. All the treatments were randomized in three replicates. Each of the plots measured 2 m x 2 m, with a spacing of 1 m x 1 m, between the plots.

The compost manure was thoroughly applied on the soil two weeks before the transplanting of the eggplant seedlings. This is to enable the compost manure to release its nutrients into the soil before the transplanting will be carried out. Unlike inorganic fertilizers, compost manure usually released their nutrients into the soil environment at a very slow pace. Then KNO_3 was applied through ring application, one week after the transplantation of the eggplant seedlings.

Eggplant fruits harvesting

The fruits were harvested at 40 days after flowering. This is the stage when the fruit is mostly consumed fresh, as the seeds inside the fruit are still soft and succulent. The fruits were manually scrutinized, in order to discard all deformed fruits from the lot.

Mechanical properties test

This test was carried out by using a Universal Testing Machine (Testometric model), equipped with a microprocessor. The test was done in accordance to American Society of Agricultural and Biological Engineers (ASABE, 2008) recommended procedures. To determine the compression parameter of the fruit, the fruit was placed between the two compression platens of the machine, pre-set at a speed of 20 mm/min, and compressed until rupture occurred (Umurhurhu and Uguru, 2019). As the compression progresses, force-deformation curve was plotted by the machine, in response of the fruit's resistance to compression loading and displayed on the screen (Figure 1).

At the end of each test, failure force, failure energy and deformation (compressibility) of the fruit were calculated automatically, by the machine micro-processor and read from the screen attached to the machine. According to Steffe (1996), failure point which is also expressed as yield

Table 1. Treatment options.

Treatment code	Remarks
T_1 (Control)	No pre-harvest amendment
T_2	Compost manure applied at the rate of 2500 kg/ha
T_3	Compost manure applied at the rate of 5000 kg/ha
T_4	KNO_3 fertilizer applied at the rate of 150 kg/ha
T_5	KNO_3 fertilizer applied at the rate of 300 kg/ha
T_6	Compost manure applied at the rate of 2500 kg/ha + KNO_3 fertilizer applied at the rate of 150 kg/ha
T_7	Compost manure applied at the rate of 5000 kg/ha + KNO_3 fertilizer applied at the rate of 300 kg/ha

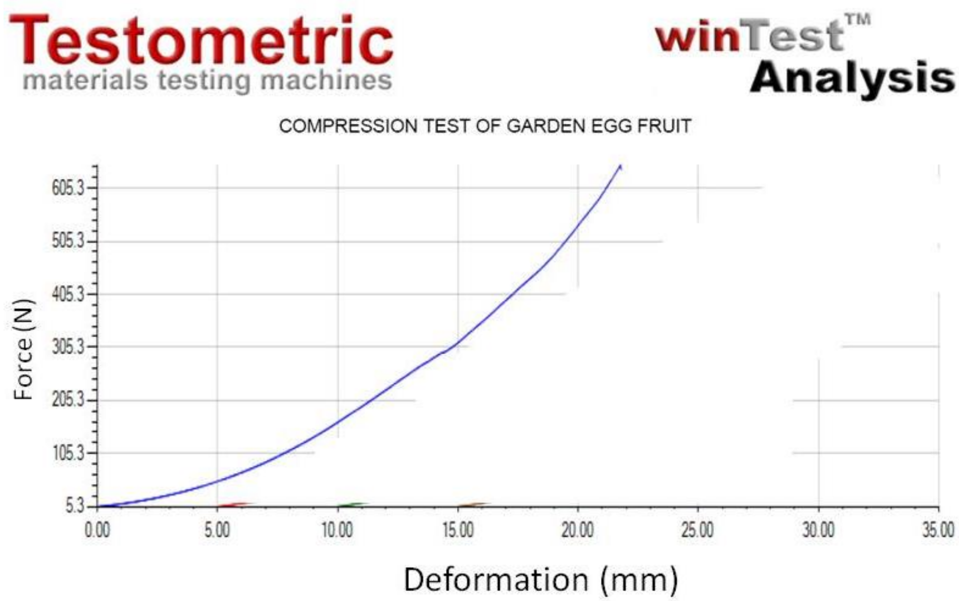

Figure 1. A force deformation curve.

point, is the point when an agricultural product experienced internal disruption in its cellular structure (microstructural failure).

Statistical analysis

The effect of pre-harvest treatments on the mechanical properties of Bello eggplant fruit was analyzed by using the one-way Analysis of Variance (ANOVA), with the aid of the SPSS (version 20.0) statistical software. The mean results were separated using the Duncan's test ($p<0.05$), while summary results were plotted by using the MS Excel software (2015 edition).

RESULTS AND DISCUSSION

Bello eggplant fruits failure parameters were considered in this research. This is because, this research is tailored as providing data for the design and development of automated system for the harvesting, handling and packaging of eggplants (cv Bello) fruits, without causing damages to the fruits. Any products that had experienced failure is highly susceptible to rapid deterioration, hence leading to food wastage which is one of the main causes of food insecurity (Idama and Uguru, 2021).

Failure force

Results of the one-way variance of analysis (ANOVA) of the effect of different treatments on the mechanical properties of eggplant fruit are presented in Table 2. The results depicted that pre-harvest treatments had significant effect ($p\leq0.05$) on the failure force of the Bello eggplant fruit. The average values of the failure force of the Bello eggplant fruit presented in Figure 2 revealed that the fruits failure force varied significantly ($p\leq0.05$) with the treatment concentrations. It was observed from the results that the control fruits (T_1) had the lowest failure force of 751.33 N, while T_7 fruits had the highest failure force of 860.67 N. As

Table 2. ANOVA results of the effect of treatment option on the mechanical properties of eggplant fruit.

Source	Groups	df	F	P-value
Failure force (N)	Between Groups	6	437.031	4.25E-15*
	Within Groups	14		
Failure energy (Nm)	Between Groups	6	74.500	8.13E-10*
	Within Groups	14		
Deformation (mm)	Between Groups	6	1122.104	5.94E-18*
	Within Groups	14		

* = not significant at p≤0.05.

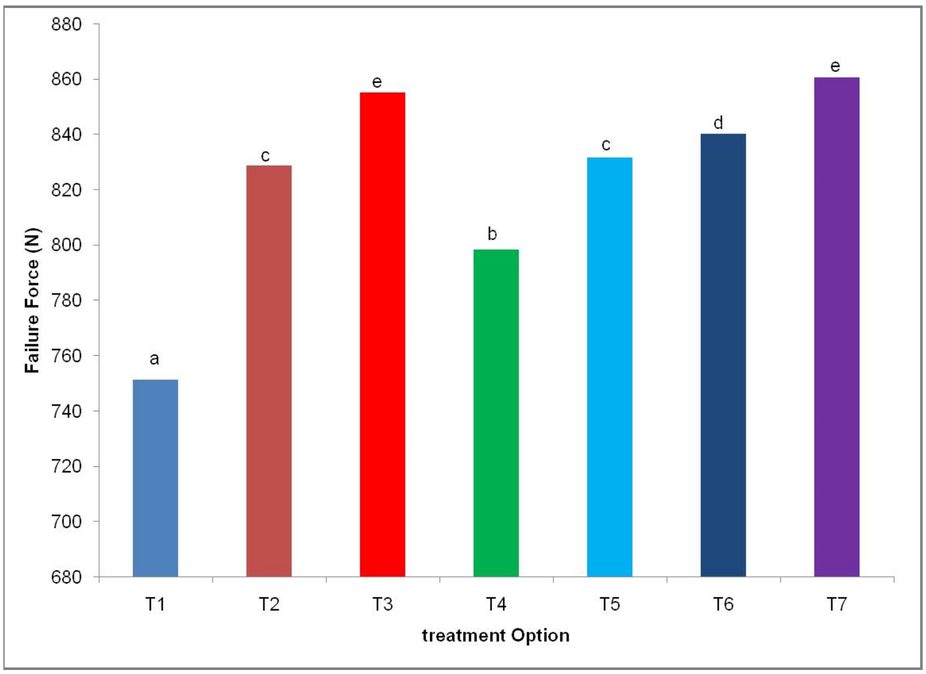

Figure 2. Effect of treatment option on the failure force of eggplant (cv Bello) fruits.

portrayed by the results, the eggplant fruits produced with compost manure (T_2 and T_3) generally had higher failure force, compared to the eggplant fruits produced with KNO_3 fertilizer (T_4 and T_5). Failure force of 829 and 855.33 N were recorded in the T_2 and T_3 fruits respectively; while failure force of 798.33 and 831.67 N were recorded in the T_4 and T_5 fruits respectively. Additionally, the study revealed that the failure force of the eggplant fruits produced with combined treatment (T_6 and T_7) was higher than those fruits produced with single treatment. This could be attributed to the higher concentration of essential nutrients presented in the combined treatment. Edafeadhe and Uguru (2018) reported that essential nutrients such as nitrogen, potassium, calcium etc., help to build up fruit cellular structures, hence increasing the ability to absorb more compression force.

Similar results were recorded by Nwanze and Uguru (2020) who reported that mechanical properties of Djamba eggplant fruit were significantly influenced by potassium nitrate (KNO_3) and organic manure pre-harvest treatment. A failure force of 617.76 N was recorded in the Djamba eggplant fruit cultivated with organic manure, while a failure force of 452.01 N was recorded in the Djamba eggplant fruit cultivated with KNO_3; all these forces were higher than the 305.8 N recorded in the fruits harvested from the control experimental plot. It can be seen from the results that fruits harvested from T_3 and T_7 did not exhibit any significant ($p \leq 0.05$) difference in their failure force, although the concentration of the essential nutrients in the T_7 treatment were higher than the concentration of the essential nutrients in the T_3 treatment. These results portrayed that after particular point, increasing the

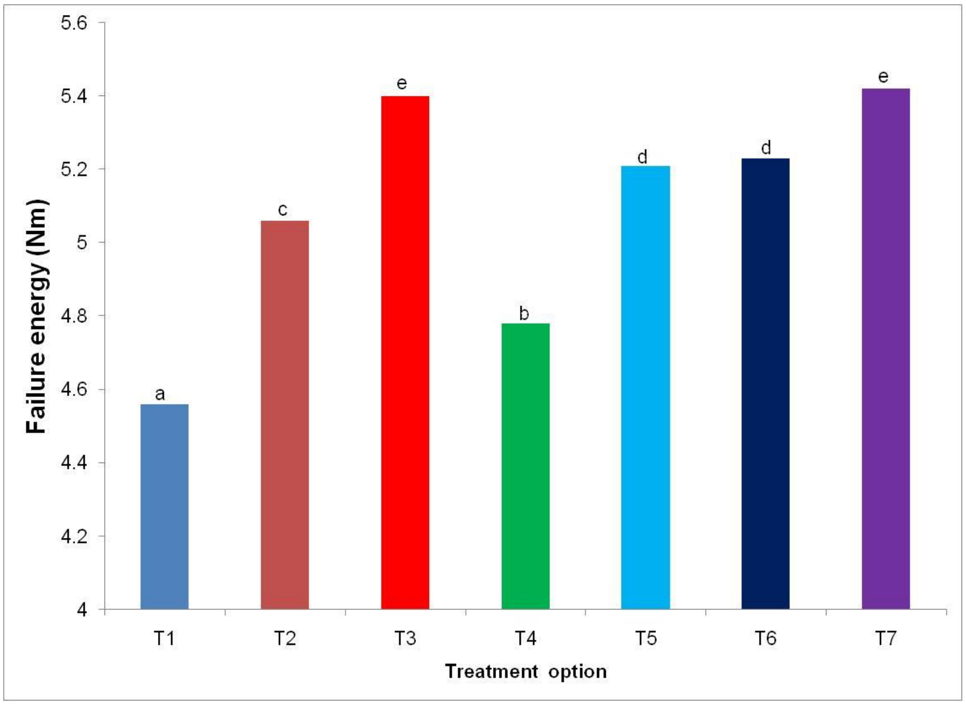

Figure 3. Effect of treatment option on the failure energy of eggplant (cv Bello) fruits.

concentration of the soil nutrients does not reflect on the development of the fruits body structure. This ascription is further buttressed by the previous research of Rettke et al. (2006) and Cuquel et al. (2011) which stated that high concentration of nitrogen and potassium lowered the ability of apricot fruits to withstand high compression and pressure forces.

Failure energy

The results of the ANOVA presented in Table 2 revealed that treatments had significant ($p \leq 0.05$) effect on the failure energy of the eggplant fruits. The mean failure energies of the fruits are plotted in Figure 3. As indicated in Figure 3, there was general increment in the fruits failure energies after to soil amendment, which was significantly ($p \leq 0.05$) dependent on the treatments. Generally, it was observed from the results that the fruits treated with compost manure (T_2 and T_3), developed higher failure energies of 5.06 and 5.4 Nm respectively, compared with the fruits treated with KNO_3 fertilizer (T_4 and T_5) that developed higher failure energies of 4.78 and 5.21 Nm respectively. The study revealed that although the failure energy of the combined treatment was higher than the single treatment, significant ($p \leq 0.05$) difference does not exist between the means of the fruits produced with T_3 and T_7. Likewise, it was observed that fruits produced with T_5 and T_6 does not exhibit significant ($p \leq 0.05$) difference in their failure energy. The higher failure energy exhibited by T_3, T_5 and T_7 produced fruits could be ascribed to the higher nitrogen and calcium concentrations in the treatment plan. Fallahi (1997) reported that nitrogen enhanced the development of fruit body structure, hence increasing their ability to absorb more compressive energy before failing. Similarly, Serrano et al. (2004) stated that calcium soil amendment helped to enhance fruits cellular structures, hence increasing their resistance to mechanical stress. Mechanical stress is one of the major causes of food wastage during fruits harvesting, handling and packaging operations (Shahedy, 2007; Ekruyota and Uguru, 2021).

Compressibility

The ANOVA results of the effect of pre-harvest treatments on the compressibility of the eggplant fruit are presented in Table 2. The ANOVA results depicted that treatments had significant ($p \leq 0.05$) effect on the compressibility of the eggplant fruit. Figure 4 presents the plot of the mean compressibility of the eggplant fruits. As shown in Figure 4, there was general increment in the fruit's compressibility, as the treatment concentration increases. It was observed from the results that the T_1 fruits had the lowest compressibility (18.55 mm), while the fruits produced with T_7 treatment had the highest compressibility (25.05 mm) before failure point. Generally, it can be seen that the fruits produced with compost manure (T_2 and T_3) developed higher compressibility (21.39 and 24.78 mm), when compared with the fruits produced with KNO_3 fertilizer (T_4 and T_5) that developed compressibility of

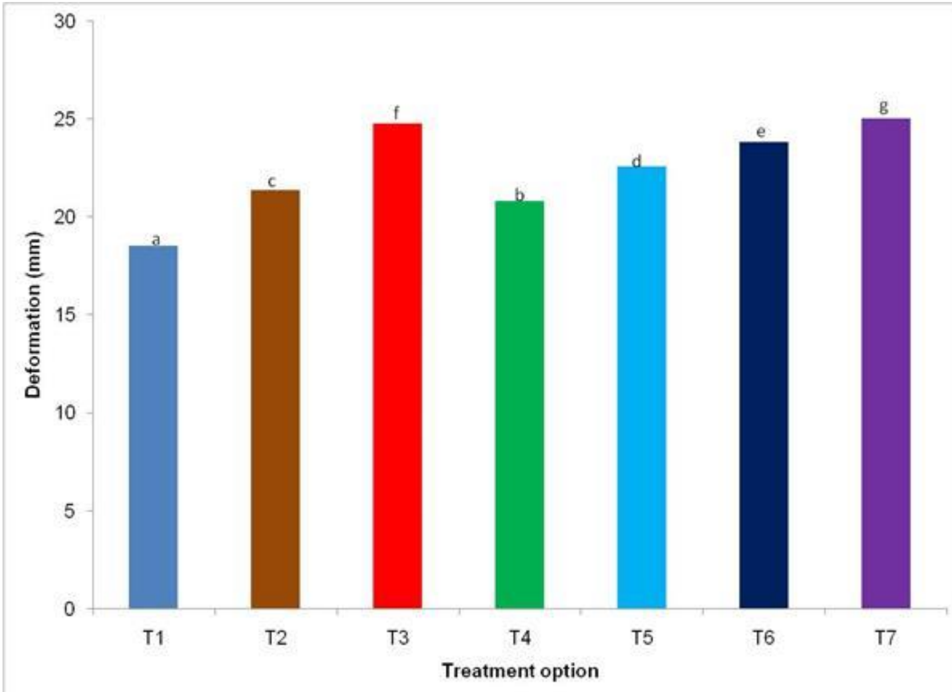

Figure 4. Effect of treatment option on the compressibility of eggplant (cv Bello) fruits.

20.82 and 22.57 mm, respectively. This portrayed that fruits produced with compost manure withstand more deformation, during compression loading compared to the control and the fruits produced with KNO_3 fertilizer. Similar results were obtained by Jahanbakhshi and Kheiralipour (2019) for tomato fruits, where the compressibility of tomato fruits produced with vermicompost was higher than the control tomato fruits. According to Edafeadhe and Uguru (2020), pre-harvest treatment of plants can altered their biological structures, hence improving the mechanical properties of the plants' tissues and their fruits' qualities.

This study results had revealed that the compressive force and energy exerted by Bello eggplant fruit during harvesting and storage operations were dependent on the type of soil amendment used for the production of the fruits. The study further revealed that combined treatment yield better results than single treatment; but at higher combined treatment concentration, there was no significant improvement in the amount of failure force and failure energy the Bello eggplant was able to absorb during the compressive loading. This suggested that farmers should use combined treatment at lower concentration to optimize crop yield and produce crops with better mechanical properties to minimize crop production cost.

Conclusion

This present research evaluated the mechanical properties of Bello eggplant fruits produced with compost manure, KNO_3 and the combination of compost manure and KNO_3. The eggplant fruits were harvested at peak maturity stage, and their mechanical properties determined according to ASABE (2008) procedure. Results obtained from the compression test revealed that the control fruits had the lowest failure force, failure energy and compressibility; compared to the fruits produced with compost manure, KNO_3 or combination of compost manure and KNO_3. Likewise, the results depicted that eggplant fruits produced with combined treatment developed higher failure force, failure energy and compressibility, when compared to the fruits produced with single treatment. In terms of single treatment, it was observed that fruits produced with compost manure had higher failure force, failure energy and compressibility than the fruits produced with KNO_3. It can be concluded that combined treatment at lower concentration help to enhance failure parameters of the eggplant fruits, hence reducing the incidence of food wastage through mechanical damage during harvesting, handling and storage operations.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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