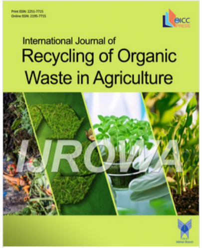

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Integrated application of wood ash and inorganic fertilizer sources on vegetative growth, fruit yield, and nutrient quality of *Solanum aethiopicum* L.

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Original Research

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Abstract:

Purpose: Wood ash is an important alternative source of inorganic potassium especially for farmers in areas with acidic soils.
Method: The experiment was carried out in two phases. In the first phase, treatments consisted of the application of inorganic fertilizer sources (0 kgha^{-1}, 130.44 kgha^{-1} of urea, and 300 kgha^{-1} of NPK of 20:10:10) and wood ash (0 tha^{-1}, 5 tha^{-1}, and 10 tha^{-1}) to garden egg seedlings. In the second phase of the experiment, garden eggfruits were analyzed for nutrient contents.
Results: Significant ($p \leq 0.05$) fruit yield followed this order: 10 tha^{-1} of wood ash $>$ control $>$ 5 tha^{-1} of wood ash. Inorganic fertilizer sources effect on fruit yield followed this sequence: 300 kgha^{-1} of NPK 20:10:10 $>$ 130.44 kgha^{-1} of urea $>$ control. The interaction of 10 tha^{-1} of wood ash and 300 kgha^{-1} of NPK 20:10:10 produced the highest fruit yield (57 ± 0.50 tha^{-1}). A combined application of 300 kgha^{-1} of NPK and 5 tha^{-1} of wood ash showed a greater improvement in vitamin C while an integrated application of 130.44 kgha^{-1} of urea and 10 tha^{-1} of wood ash increased vitamin A contents of garden egg.
Conclusion: Integration of 10 tha^{-1} of wood ash and 300 kgha^{-1} of NPK 20:10:10 positively improved the growth and yield of the garden egg. The addition of a lower rate of wood ash to NPK fertilizer and a higher rate of wood ash to urea significantly improved the nutrient contents of garden eggs.

Keywords: Acidic soil; Fruit vegetable; Potassium; Soil amendment; Organic lime

1. Introduction

The garden egg (*Solanum aethiopicum* L.) is a crop of the Solanaceae family. Garden eggs are one of the lost crops in Africa (Council, 2006). The leaves and fruits of garden eggs are used as vegetables in local delicacies and can be eaten raw in Nigeria. The fruits are known to have medicinal properties such as anti-inflammatory, anti-asthmatic, anti-glaucoma, hypoglycemic, and fat-burning properties in humans (Ayodele, 2018). These healing properties of the garden eggs can be attributed to the high presence of fibre, ascorbic acid, anthocyanin, glycoalkaloids, and alpha-chaconine (Sanchez-Mata et al., 2010). Nutritional studies on garden eggs showed that the fruits are rich in fibre, protein, and minerals (Yamoah, 2016).
Like all crops of the Solanaceae family, garden egg requires high potassium content to achieve flowering and fruit yield. According to Ditschar and Ivanova (2005), the nutrient requirement to produce one tonne per hectare of fruit yield in the garden egg is 2.63 tha^{-1} of nitrogen, 0.63 tha^{-1} of phosphorus, and 4.08 tha^{-1} of potassium. Garden egg is predominantly cultivated in southeast Nigeria, a rainforest

zone which has very poor fertile soil because of high rainfall resulting in the leaching of soil nutrients (Nkwopara et al., 2020).

Nitrogen and potassium are limiting in the soils of rainforest zone because nitrogen and potassium are highly soluble and can also be easily lost through leaching, percolation, and displacement in soil solution (Thomas et al., 2016; Mendes et al., 2016). Potassium is a soluble ion and can move downwards in the soil profile during rainfall or excessive irrigation beyond the reach of the crop root system. Limiting nitrogen in soil causes stunted growth and low potassium causes poor flower initiation, abortion, and poor fruit development in crops (Dursun et al., 1999).

In order to replenish soils of leached elements, farmers apply organic and inorganic fertilizers to improve soil fertility status and improve soil pH. Wood ash, a product of the incineration of wood constitutes waste and can cause environmental pollution if not utilized as lime or manure (Emma-Okafor et al., 2022). Wood ash has a high pH and contains potassium, calcium, magnesium, phosphorus, and little nitrogen (Mbah et al., 2010). Wood ash has been reported to improve crop growth and yield in okra (Okoli et al., 2015; Ojeniyi, 2007), cowpea (Ojeniyi et al., 2017), soybean (Nottidge and Nottidhe, 2012), and garden egg (Moyin-Jesu, 2013).

The use of wood ash individually as manure for crop production is limited by low nitrogen content (Emma-Okafor et al., 2022; Olugbemi, 2019). In order to breach the gap of very low nitrogen content of wood ash, integrated application of wood ash and organic or inorganic fertilizers to improve crop growth and yield should be encouraged. Positive findings on the integrated application of wood ash and inorganic fertilizers for improved growth and yield in crops like pepper (Olugbemi, 2019), okra (Iderawumi, 2018), tomato (Ewulo et al., 2009), and maize (Awodun et al., 2007) have been reported.

Different researchers have reported improved growth and yield in garden eggs using integrated application of poultry manure and NPK fertilizer. Paul et al. (2017) reported that application of 5 tha^{-1} of poultry manure and 125 $kgha^{-1}$ of NPK fertilizer gave the best garden egg fruit yield in Nigeria. Integrated application of poultry manure and NPK fertilizer to sandy soil in Ghana gave higher garden egg fruit yield than the sole application of either poultry manure or NPK fertilizer (Khalid et al., 2014). A combination of compost and mineral fertilizers significantly improved fruit yield and quality in tomatoes (Khan et al., 2017). Application of 10 tha^{-1} of poultry manure and 4 tha^{-1} of wood ash improved yield in cucumber (Emma-Okafor et al., 2022).

The application of fertilizers has been found to improve nutrient contents of crops. Seung and Adel (2000) reported that fertilizers influence the nutrient contents of green vegetables. Compost has been reported to improve phytochemical contents in produce (Amujoyegbe et al., 2007; Toor et al., 2006). Higher vitamin C, iron, magnesium, and phosphorus have been reported in organically produced crops than in conventionally produced crops (Worthington, 2001). However, there is a paucity of information on the integrated application of wood ash rates and inorganic fertilizer sources on garden egg growth, yield, and nutrient quality, and therefore, the experiment was carried out to determine the performance of the sole and combined application of wood ash rates and inorganic fertilizer sources on the growth, yield and nutrient quality of garden egg.

2. Material and methods

Experimental site

The study was carried out in the Teaching and Research Farm of the Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka, Nigeria. The research farm lies at the latitude of 06 °15 N and longitude 07 °08 E, with an average annual rainfall of 1810.3 mm and relative humidity of 72.3%. The average minimum and maximum temperatures of the field were 28.74 °C and 28.96 °C with average relative humidity of 63.48% during the experiment.

Soil and wood ash laboratory analytical methods

Pre-planting soil samples were taken at the depth of 0 – 20 cm. The samples were processed following standard laboratory procedures and analyzed for the following parameters: soil pH (H_2O) using 1; 1 Soil/water ratio with pH meter, exchangeable bases (Ca^{2+}, Mg^{2+}. K^+ and Na^+) were determined using 1 N NH_4 AOC extractant and concentration of K^+ and Na^+ in the extract was read from a flame photometer, while Ca^{2+} and Mg^{2+} concentration were determined by Versenate titration method. Available P was assessed by the $Bray^{-1}$ method, as described by Okalebo et al. (1993). Organic carbon was determined using the dichromate wet oxidation (Walkley-Black) method as described by Rowell (1996). The Micro Kjeldhal method as described by Okalebo et al. (1993) was deployed for the determination of the soil total nitrogen.

Experiment one: Effect of wood ash rates and inorganic fertilizer sources on the growth and yield of garden egg

Treatments and experimental design

The treatments consisted of inorganic fertilizer sources (0 $kgha^{-1}$, 130.44 $kgha^{-1}$ urea, and 300 $kgha^{-1}$ NPK 20:10:10) and wood ash rates (0, 5 tha^{-1} ash and 10 tha^{-1} ash) applied in combination to garden egg seedlings. This experiment was carried out in the field and the experimental design was a 3×3 factorial experimental design in a completely randomized block design with three replications. Each rate in the inorganic fertilizer supplied 60 $kgha^{-1}$ of nitrogen respectively.

Cultural practices

Garden eggs seedlings were raised in a nursery located at the Teaching and Research Farm of the Department of Crop Science and Horticulture in seedling trays filled with standard nursery mixture (Topsoil + poultry manure + river sand in a ratio of 3:2:1) and were transplanted when the young seedlings had five leaves and were 20 cm tall by gently lifting up the seedlings with the standard nursery mixture and placing them in their respective holes of raised beds. The seedlings were planted at a spacing of 50 cm between rows and 50 cm within rows. The crop production was carried out under rain-fed conditions. Treatments were applied using ring methods one week after transplanting. The nursery and the field were kept weed-free by hand pulling and hoeing respectively throughout the period of the experiment. Fruits were harvested from three months after transplanting while still green in color.

Data collection and analysis

The following growth and yield data were recorded; plant height (measured with measuring tape from ground level to tip apex), number of leaves (physically counting the number of fully open leaves), girth (using vernier caliper (Mitutoyo, 530-101, Japan) at 10 cm above the ground level), number of branches (physically counting the number of branches), number of fruits (counting the number of fruits per plant) and fruit yield (weighing the fruit weight using Electronic Kitchen Scale SF-400, China). Growth parameters were measured at 2, 4, 6, and 8 weeks after transplanting (WAT) while yield parameters were measured from 9 WAT. Data collected were subjected to analysis of variance for completely randomized block design using GENSTAT 2009 version statistical software package and means were separated using least significant difference (LSD) at a 5% level of probability.

Experiment two: Effect of wood ash rates and inorganic fertilizer sources on the nutrient contents of garden egg

Experimental design

Experimental design for laboratory analysis of garden egg was complete randomized design and each nutrient element was analyzed thrice for each treatment combination.
Garden egg from each treatment was analyzed in the laboratory of National Root Crops Research Institute, Umudike to determine the following nutrient contents:

Moisture content

The moisture content of the sample was determined using the Association of Official Analytical Chemist (AOAC, 2010) method. The crucibles used were properly washed and dried at 100 °C for one hour in the oven. The dry empty crucibles from the oven were cooled in a desiccator, weighed, and documented as W1. Three grams (3 g) of the samples were weighed into the crucibles (W2) and dried at a temperature of 100 °C for 4 hours. They were removed from the oven afterward, kept in a desiccator to cool, and weighed (W3). The drying process continued until the weight was not constant and was stopped when a constant weight was achieved. The calculation for the percentage of moisture contained in the sample was done as follows:

$$\text{Moisture content}(\%) = \frac{\text{W2–W3} \times 100}{\text{W2–W1}}$$

where:
W1 = Initial weight of the empty crucible
W2 = weight of crucible + weight of sample before drying
W3 = weight of dish + weight of the sample after drying

Crude fibre

The crude fibre determination was carried out using AOAC (2010) method. Two grams of samples were defatted using petroleum ether and boiled under reflux for 30 minutes with 200 mL of 0.125 g of H_2SO_4 per 100 mL of solution. Filtration of the solution was done with linen followed by washing with boiled water until no acidic washings were obtained. The residue was transferred into a beaker and boiled with 200 mL of solution containing 1.25 g of carbonate-free NaOH per 100 mL for 30 minutes. The residue obtained was drained, introduced into a silica ash crucible, and dried at 100 °C in an oven for 2 hours. The dried residue was cooled and weighed and the drying was repeated until the weight was constant. Drying was stopped when a constant weight was achieved. Ashing (600 °C for 5 hours) of the sample in a muffle furnace then followed. The sample was finally cooled in a desiccator and the weight was recorded. The weight loss was taken as the crude fibre.

$$\text{Crude fibre}(\%) = \frac{\text{weight of the oven dried sample (g)-weight of the sample after incineration} \times 100}{\text{The initial weight of the sample (g)}}$$

Crude protein

The crude protein content of the sample was evaluated using AOAC (2010), which involved the Kjeldahl method. An aliquot (2 g) of the sample was measured and introduced into the Kjeldahl digestion flask and 1 tablet of the Kjeldahl catalyst was added. Twenty five milliliters (25 mL) of concentrated H_2SO_4 was added with a small number of boiling chips. The flask with its content was heated in the fume cupboard until a clear solution was obtained. The solution was cooled to room temperature and filtered into a volumetric flask of 250 mL and made up to a 100 mL mark using distilled water. Cleaning of the distillation unit was done and the apparatus was set up. A conical flask of 100 mL capacity was used as a receiving flask. The addition of 5 mL of 2% boric acid then followed, the flask was placed under the condenser and 2 drops of methyl red indicator were added. A digest of 5 mL was pipetted into the setup through a small funnel and was washed down with distilled water followed by the addition of 5 mL of 60% NaOH (sodium hydroxide) solution. Heating of the digestion flask was done until 100 mL of ammonium sulphate (distillate) was collected in the receiving flask. Titration was done using 0.1 N HCL against the solution from the receiving flask to an endpoint indicated by a pink color. The same procedure was carried out for the blank.

$$\%\text{Nitrogen of sample } (\%\text{N}) = \frac{\text{Vs} - \text{Vb} \times \text{Nacid} \times 0.0401}{\text{W}} \times \frac{100}{1}$$

where:
Vs = volume (mL) of acid required to titrate the sample
Vb = volume (mL) of acid required to titrate the blank
Nacid = Normality of acid (0.1 N)
W = Weight of sample in gram
% Crude protein = % N × 6.25 (conversion factor)

Total Carbohydrate

Total carbohydrate content was calculated by subtracting the moisture, protein, fat, ash, and alcohol content of the garden egg from the total weight of the garden egg (AOAC,

2010).
Percentage carbohydrate (%) = 100 – (% moisture + % fat + % protein + % ash).

Vitamin A

Vitamin A was determined according to the method of Aremu and Nweeze (2017). One gram (1 g) of the sample was measured out and soaked in 20 mL of n-hexane in a test tube for 10 minutes. Then 3 mL of the top portion of the n-hexane extract was introduced into an already dried test tube in two replicates and evaporation was carried out until dryness was achieved. Following this, acetic anhydridechloroform reagent (0.2 mL) was added followed by the addition of 2 mL 50% trichloroacetic acid in chloroform. After 15 and 30 seconds intervals, the absorbance was measured at a wavelength of 620 nm.

Vitamin C

Vitamin C concentration was determined according to Ikewuchi and Ikewuchi (2011). An aliquot of 0.5 g of the sample was weighed, soaked in a test tube with 0.4% oxalic acid (10 mL) for 10 minutes, and centrifuged for 5 minutes. Filtration of the solution was done afterward, 1 mL of the filtrate was introduced into a test tube that was clean and dry, and 9 mL of 2, 6-dichlorophenol indophenol was added. Absorbance was read at 520 nm wavelength after 15 and 30 seconds intervals, respectively.

Data collection

Laboratory analysis of nutrient elements was done in three runs and data generated were subjected to analysis of variance using GENSTAT, 2009 and means were separated using least significant difference (LSD) at a 5% level of probability.

3. Results and discussion

Soil and wood ash chemical properties

The soil used for planting was slightly acidic, low in organic matter, and had very poor nitrogen content. Wood ash is alkaline in nature and contains high potassium, calcium, and sodium with low nitrogen content (Table 1).

Table 1. Chemical properties of soil and wood ash.

Elements	Soil	Wood ash
Nitrogen (%)	0.01	1.10
Organic carbon (%)	0.11	6.86
Organic matter (%)	1.51	11.83
Sodium (cmol/kg)	0.03	88.00
Magnesium (cmol/kg)	0.60	21.87
Calcium (cmol/kg)	0.80	68.00
Potassium (cmol/kg)	0.07	440.64
Available phosphorus (ppm)	9.28	38.20
pH in water	5.80	8.20

The main effect of wood ash rates on the garden egg growth and yield parameters

Wood ash rates did not significantly ($p \leq 0.05$) affect plant height at 2, 4, and 8 weeks after transplanting (WAT). A tall garden eggplant (102.10 ± 12.96 cm) was produced by the control while the application of 10 tha^{-1} of wood ash produced a dwarf garden egg (85.90 ± 12.37 cm) at 6 WAT (Table 2). This disagrees with the findings of Obidiebube et al. (2022) who reported increased height in carrots with higher rates of wood ash. This observation of the poor performance of the wood ash on the growth parameters affirms the result of Purwanto et al. (2020) who found that wood ash treatment on pepper significantly affected plant dry weight, root volume, number of fruits per plant and fruit weight per plant but had no significant effect on plant height.
Stem girth was not significantly affected by wood ash rates at 2 and 4 WAT (Table 2). The biggest stem girth was produced by the control (5.33 ± 0.30 mm) while the smallest stem girth was produced by 10 tha^{-1} of wood ash (4.79 ± 0.55 mm) at 6 WAT. Application of 10 tha^{-1} of wood ash produced the smallest stem girth (4.76 ± 0.78 mm) while control produced the biggest stem girth (5.91 ± 1.10 mm) at 8 WAT. Emma-Okafor et al. (2022) reported a big girth in cucumber stems as the wood ash rates increased from 0 – 4 tha^{-1}.
The number of leaves was highest in the garden egg produced with 5 tha^{-1} of wood ash (9.31 ± 7.86) while the control (7.33 ± 1.80) produced the lowest number of leaves at 2 WAT (Table 3). A higher number of leaves could be a result of the higher nutrient contents of wood ash. Okoli et al. (2015) and Ojeniyi et al. (2017) reported a higher number of leaves in okra and cowpea using 2 tha^{-1} of palm bunch ash and wood ash, respectively. Number of leaves was not significantly affected by wood ash rates at 4 and 6 WAT. Control produced the highest number of leaves (182.20 ± 45.84) while application of 10 tha^{-1} of wood ash produced the lowest number of leaves (118.70 ± 50.87) at 8 WAT. A higher number of leaves in carrots cultivated without wood ash in comparison with carrots cultivated with different rates of wood ash at 60 and 75 days after sowing was reported by Obidiebube et al. (2022).
The number of branches was highest in the garden egg produced with 5 tha^{-1} of wood ash (2.87 ± 3.21) while the control produced the lowest number of branches (1.84 ± 0.98) at 2 WAT (Table 3). Application of 10 tha^{-1} of wood ash produced the lowest number of branches while control produced the highest number of branches at 4, 6, and 8 WAT. Wood ash supplied N, P, and K, hence higher performance of garden egg cultivated in amended soil than control at 2 WAT. Emma-Okafor et al. (2022) reported a higher number of branches in cucumbers grown with 2 tha^{-1} of wood ash.
The number of fruits was highest in the control (105.00 ± 72.37) while garden eggs produced with 5 tha^{-1} of wood ash had the lowest number of fruits (43.50 ± 43.07) (Table 4). The lowest fruit yield of garden egg was observed in garden egg that received 5 tha^{-1} of wood ash (17.80 ± 8.56 tha^{-1}) while 10 tha^{-1} of wood ash (33.00 ± 19.44 tha^{-1}) produced the highest fruit yield in garden egg (Table 4). The improvement in fruit weight reiterates the importance

Table 2. Main effect of wood ash rates on plant height (cm), and stem girth (mm).

Treatments (tha^{-1})	Plant height (cm) WAT				Stem girth (mm) WAT			
	2	4	6	8	2	4	6	8
0	19.36 ± 4.71	52.90 ± 8.83	102.10 ± 12.96	126.50 ± 12. 52	1.87 ± 0.57	3.29 ± 0.63	5.33 ± 0.30	5.91 ± 1.10
5	21.46 ± 6.97	49.80 ± 13.09	91.30 ± 15. 63	120.10 ± 30.70	1.94 ± 0.43	3.39 ± 0.49	5.27 ± 0.70	5.00 ± 1.02
10	21.33 ± 5.81	48.50 ± 9.73	85.90 ± 12.37	104.70 ± 17.41	1.58 ± 0.23	3.32 ± 0.45	4.79 ± 0.55	4.76 ± 0.78
LSD (0.05)	3.06	7.62	9.72	18.92	0.31	0.37	0.43	0.77
Significant level	NS	NS	**	NS	NS	NS	*	**

WAT= weeks after transplanting, NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

of potassium in flowering and fruit development in fruit vegetable crops (Okoli et al., 2015). Wood ash has been found to improve pod yield in okra (Ojeniyi, 2007), root yield in carrot (Obidiebube et al., 2022), and cowpea pod yield (Ojeniyi et al., 2017).

Table 4. Main effect of wood ash rates on number of fruit and fruit yield (tha^{-1}).

Treatments (tha^{-1})	No of fruits	Fruit yield (tha^{-1})
0	105.00 ± 72.37	31.10 ± 21.57
5	43.50 ± 43.07	17.80 ± 8.56
10	64.90 ± 41.47	33.00 ± 19.44
LSD$^{(0.05)}$	44.62	12.18
Significant level	*	*

NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

The main effect of inorganic fertilizer sources on garden egg growth and yield parameters

Application of 300 kgha^{-1} of NPK fertilizer produced significantly ($p \leq 0.05$) tallest garden egg at 2 (23.64 ± 5.87 cm), 4 (55.60 ± 10.97 cm), 6 (105.80 ± 10.05 cm), and 8 (132.20 ± 26.30 cm) weeks after transplanting (WAT) while control produced a dwarf garden egg at 2 (16.26 ± 9.01 cm), 4 (42.70 ± 15.30 cm), 6 (83.50 ± 15.30 cm), and 8 (110.00 ± 17.92 cm) WAT (Table 5). The significant effect of inorganic fertilizer sources on growth and yield parameters could be attributed to the supply of nutrient elements such as nitrogen, phosphorus, and potassium by the fertilizers. This result agrees with the findings of Okoli et al. (2015) on the improvement of okra height by NPK 15:15:15 fertilizer with respect to control.

Stem girth was not significantly affected by inorganic fertilizer sources at 2, 4, and 8 WAT (Table 5). The biggest mean stem girth was produced by a garden egg cultivated with NPK fertilizer while the smallest girth was produced by control at 6 WAT. Poor soil fertility in the control plot caused stunted growth in pepper (Olugbemi, 2019).

The number of leaves was highest in garden egg produced with 300 kgha^{-1} of NPK (10.76 ± 4.83) and lowest in control (6.38 ± 1.59) at 2 WAT (Table 6). Number of leaves was not significantly affected by inorganic fertilizers at 4 WAT. Number of leaves was highest in garden eggs produced with 300 kgha^{-1} of NPK (111.80 ± 18.39) and lowest in control (73.40 ± 7.69) at 6 WAT. Application of 300 kgha^{-1} of NPK produced the highest number of leaves (178.00 ± 33.01) while the application of 130.44 kgha^{-1} of Urea produced the lowest number of leaves (124.50 ± 62.52) at 8 WAT. Urea contains N which increases the vegetative growth of African eggplant in relation to zero application of urea (Olunloyo et al., 2019).

The number of branches was highest in garden eggs produced with 300 kgha^{-1} of NPK (3.91 ± 2.52), followed by the application of 130.44 kgha^{-1} of urea (1.91 ± 1.04) and lowest in control (0.96 ± 1.04) at 2 WAT (Table 6). Number of branches was not significantly affected by inorganic fertilizers at 4, 6, and 8 WAT. These findings con-firm the results of Adeyeye et al. (2018) who reported that NPK fertilizer increased the number of nodes in tomatoes in comparison to urea.

The number of fruits was not significantly affected by inorganic fertilizer sources (Table 7). However, on the mean basis, the number of fruits was highest in garden eggs cultivated with 300 kgha^{-1} of NPK fertilizer (81.70 ± 45.93) and the lowest number of fruits in the control plot (53.10 ± 73.54). The highest fruit yield was produced by the application of 300 kgha^{-1} of NPK (41.00 ± 18.38 tha^{-1}) while the control (13.10 ± 5.82 tha^{-1}) produced the lowest fruit yield (Table 7). Inorganic fertilizer sources showed a significant effect on yield parameters in relation to the control

Table 3. Main effect of wood ash rates on number of leaves and number of branches.

Treatments (tha^{-1})	Number of leaves WAT				No of branches WAT			
	2	4	6	8	2	4	6	8
0	7.33 ± 1.80	40.30 ± 7.86	90.60 ± 14.54	182.20 ± 45.84	1.84 ± 0.98	15.11 ± 3.56	14.89 ± 3.73	21.11 ± 5.94
5	9.31 ± 7.86	41.90 ± 8.39	88.60 ± 35.28	128.20 ± 63.11	2.87 ± 3.21	11.53 ± 3.90	11.53 ± 3.90	15.13 ± 5.60
10	7.82 ± 4.70	41.50 ± 4.70	84.80 ± 15.37	118.70 ± 50.87	2.07 ± 1.21	11.20 ± 2.12	11.20 ± 2.12	12.38 ± 3.46
LSD (0.05)	1.18	6.08	6.82	36.07	0.83	2.98	3.11	4.30
Significant level	**	NS	NS	**	*	*	*	**

WAT= weeks after transplanting, NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

Table 5. Main effect of inorganic fertilizer sources on plant height (cm) and stem girth (mm).

Treatments (tha^{-1})	Plant height (cm) WAT				Stem girth (mm) WAT			
	2	4	6	8	2	4	6	8
0	16.26 ± 2.37	42.70 ± 9.01	83.50 ± 15.30	110.00 ± 17.92	1.71 ± 0.45	3.19 ± 0.52	4.82 ± 0.57	4.89 ± 1.20
130.44 kgha^{-1} of Urea	22.24 ± 5.73	52.90 ± 7.10	90.00 ± 9.40	109.10 ± 16.87	1.80 ± 0.46	3.46 ± 0.58	4.99 ± 0.39	5.02 ± 1.17
300 kgha^{-1} of NPK	23.64 ± 5.87	55.60 ± 10.97	105.80 ± 10.05	132.20 ± 26.30	1.88 ± 0.46	3.34 ± 0.50	5.58 ± 0.50	5.76 ± 0.62
LSD (0.05)	3.06	7.62	9.72	18.92	0.31	0.37	0.43	0.77
Significant level	**	**	**	*	NS	NS	*	NS

WAT= weeks after transplanting, NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

in African garden eggs (Olunloyo et al., 2019). Urea and NPK fertilizers supplied nitrogen elements necessary for the growth and yield of the garden egg in very poor soil. This confirms the work of Masome (2013) who stated that nitrogen from urea is effective in the growth and reproductive factors of tomato. Both inorganic fertilizers supplied 60 kgha^{-1} of nitrogen, however, NPK fertilizer also supplied phosphorus and potassium elements additionally and thus had better vegetative and yield parameters in garden eggs than those produced with urea. Nitrogen is responsible for plant vegetative growth and development, phosphorus is involved in root growth while potassium increases photosynthesis capacity, strengthens cell tissue, activates the absorption of nitrates, and stimulates flowering and fruit development in tomatoes and eggplants (Dursun et al., 1999).

Interaction effect of wood ash and inorganic fertilizer sources on the growth and yield of garden egg

Interaction of 5 tha^{-1} of wood ash and 300 kgha^{-1} of NPK produced significantly ($p \leq 0.05$) tallest garden egg while (30.23 ± 2.39 cm) control produced dwarf garden egg (16.10 ± 1.85 cm) at 2 weeks after transplanting (WAT) (Table 8). Application of a mixture of 5 tha^{-1} of wood ash and 300 kgha^{-1} of NPK produced the tallest garden egg (66.20 ± 1.55 cm) while a dwarf garden egg was produced using 10 tha^{-1} of wood ash (40.90 ± 13.26 cm) at 4 WAT. There was no significant effect of the interaction of wood ash rates and NPK fertilizer sources on the garden egg at 6 and 8 WAT. The superior performance of the integrated application of wood ash and NPK fertilizer in relation to the integrated application of wood ash and urea could be attributed to the availability of higher contents of phosphorus and potassium. Iderawumi (2018) reported tall okra plants cultivated using sawdust ash and ammonium nitrate.

Stem girth was broadest (2.40 ± 2.77 mm) in the garden egg produced with the interaction of 5 tha^{-1} of wood ash and 300 kgha^{-1} of NPK and narrowest (1.37 ± 1.50 mm) in the garden egg produced with 10 tha^{-1} of wood ash at 2 WAT (Table 8). Stem girth was not significantly affected by the interaction of wood ash and inorganic fertilizer at 4, 6, and 8 WAT.

The number of leaves was highest in the garden egg produced with the interaction of 5 tha^{-1} of wood ash and 300 kgha^{-1} of NPK at 2 and 4 WAT while the application of 5 tha^{-1} of wood ash produced the lowest number of leaves at 2 and 4 WAT (Table 9). The highest number of leaves was observed in garden egg produced with the interaction of 5 tha^{-1} of wood ash and 300 kgha^{-1} of NPK at 6 (135.50 ± 1.41) and 8 (205.30 ± 36.72) WAT while the application of 5 tha^{-1} of wood ash and 130.44 kgha^{-1} of urea and 10 tha^{-1} of wood ash and 130.44 kgha^{-1} of urea produced the lowest number of leaves at 6 (64.40 ± 4.51) and 8 (82.80 ± 15.47) WAT, respectively. Ayeni (2008) reported that the combination of 10 tha^{-1} of cocoa pod ash and 100 kg of NPK 20:10:10 fertilizer gave the highest number of leaves in two trials.

The number of branches was significantly highest in garden egg produced with a combination of 5 tha^{-1} of wood ash and 300 kgha^{-1} of NPK (7.07 ± 0.31) and lowest in garden egg produced with 5 tha^{-1} of wood ash (0.33 ± 0.58) at 2 WAT. However, there was no significant difference in the effect of the interaction of wood ash and inorganic fertilizer on the number of branches at 4, 6, and 8 WAT (Table 9). Growth parameters of garden eggs were improved using a combination of poultry manure and NPK fertilizer (Khalid et al., 2014).

The number of fruits was significantly highest (127.20 ± 0.63) in garden eggs produced with 130.44 kgha^{-1} of Urea while garden eggs produced with 5 tha^{-1} of wood ash produced the lowest (9.00 ± 0.67) number of fruits (Table 10). Fruit yield was not significantly affected by the interaction

Table 6. Main effect of inorganic fertilizer sources on number of leaves and number of branches.

Treatments (tha^{-1})	Number of leaves WAT				No of branches WAT			
	2	4	6	8	2	4	6	8
0	6.38 ± 1.59	40.40 ± 4.50	73.40 ± 7.69	127.20 ± 65.23	0.96 ± 0.92	11.16 ± 4.26	11.16 ± 4.26	15.11 ± 7.16
130.44 kgha^{-1} of Urea	7.33 ± 1.82	39.50 ± 7.73	78.90 ± 18.50	124.50 ± 62.52	1.91 ± 1.04	12.64 ± 4.15	12.42 ± 4.15	15.49 ± 3.22
300 kgha^{-1} of NPK	10.76 ± 4.83	43.80 ± 7.99	111.80 ± 18.39	178.00 ± 33.01	3.91 ± 2.52	14.04 ± 1.71	14.04 ± 1.71	18.02 ± 7.49
LSD (0.05)	1.18	6.08	6.82	36.07	0.83	2.98	3.11	4.30
Significant level	**	NS	**	**	*	NS	NS	NS

WAT= weeks after transplanting, NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

Table 7. Main effect of inorganic fertilizer sources on number of fruit and fruit yield (tha-1).

Treatments (kgha-1)	No of fruits	Fruit yield (tha-1)
0	53.10 ± 73.54	13.10 ± 5.82
130.44 kgha-1 of Urea	80.40 ± 52.83	27.80 ± 16.03
300 kgha-1 of NPK	81.70 ± 45.93	41.00 ± 18.38
LSD (0.05)	44.62	12.18
Significant level	NS	*

NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

of wood ash and inorganic fertilizer (Table 10). However, on the mean basis, the application of 10 tha-1 of wood ash and 300 kgha-1 of NPK (57.00 ± 0.50 tha-1) produced the highest yield, followed by urea (39.90 ± 0.25 tha-1) while 5 tha-1 of wood ash produced the lowest yield (39.90 ± 0.25 tha-1). Integrated application of organic and inorganic fertilizers improved soil physical and chemical properties by supplying organic matter and soluble nutrient elements (Emma-Okafor et al., 2022). Similar results were corroborated by Ewulo et al. (2009) who reported an increase in number of fruits and fruit weight in tomatoes when cultivated with sawdust ash and urea in relation to a single application of urea and sawdust. Higher yields were reported in pepper (Olugbemi, 2019) and tomato (Ayeni, 2008); (Ewulo et al., 2009) grown with ash and inorganic fertilizers.

The main effect of wood ash rates on the nutrient contents of *garden egg*

The moisture content of the *garden egg* was not significantly ($p \leq 0.05$) affected by wood ash rates (Fig. 1). However, on the mean basis, the control had the lowest moisture content (76.60 ± 2.02%) while the application of 10 tha-1 of wood ash had the highest moisture (77.65 ± 1.60%). The moisture content of tomatoes increased with increasing application of 150 - 400 kgha-1 of K_2O and peaked at 400 kgha-1 of K_2O (Sofonias et al., 2018). Wood ash is rich in potassium and potassium element plays an important role in water use efficiency in plants and maintains turgidity and amount of water in plant cells as well as the amount of water in plant organs like fruits (El-Latif et al., 2011).
Control had the highest mean crude fibre (2.86 ± 0.13%) while the garden egg produced with 5 tha-1 of wood ash had the lowest crude fibre (2.59 ± 0.28%) (Fig. 2). Direct opposite relationship between the amount of moisture content and crude fibre in fruits and vegetables was reported by Adekiya et al. (2019).
The mean ash value was highest in the control (5.18 ± 0.11%) and lowest (4.17 ± 0.59%) in the garden egg produced with 10 tha-1 of wood ash (Fig. 3). Control had the highest crude fibre and lowest moisture. Sofonias et al. (2018) observed the highest dry matter in tomatoes with the least moisture content. Potassium increases the water content of plasma volume and reduces the dry matter content (Asaduzzaman and Asao, 2018).
Crude protein showed an increase from zero application of wood ash to 10 tha-1 of wood ash (Fig. 4). Control had the lowest mean crude protein (2.42 ± 0.08%) while garden egg produced with 10 tha-1 of wood ash had the highest mean crude protein (2.63 ± 0.10%). The increase in crude protein as the wood ash rate increased agrees with the work of Thornburg et al. (2020) and Okoli and Okocha (2022) who reported that higher crude protein content in wheat and cassava leaves respectively as potassium increased. Higher crude protein content could be attributed to the influence of potassium on the synthesis of nitrate (Long et al., 2006). Thornburg et al. (2020) reported that potassium nitrate absorption resulted in transformation to protein in wheat.
Carbohydrate was not significantly ($p \leq 0.05$) affected by wood ash rates (Fig. 5). However, on the mean basis, the control had the highest carbohydrate (12.15 ± 2.00%) while the garden egg produced with 10 tha-1 of wood ash had the lowest carbohydrate (12.05 ± 1.72%). The carbohydrate content in garden eggs decreased as the potassium rate increased. Okoli and Okocha (2022) reported a linear decrease

Table 8. Interaction effect of wood ash rates and inorganic fertilizer sources on plant height (cm) and stem girth (mm).

Treatment combination		Plant height (cm) WAT				Stem girth (mm) WAT			
(tha-1)	(kgha-1)	2	4	6	8	2	4	6	8
0	0	16.10 ± 1.85	49.30 ± 4.17	95.90 ± 18.80	126.40 ± 92.36	2.03 ± 4.56	3.40 ± 4.56	5.33 ± 0.67	5.70 ± 16.49
0	Urea	21.90 ± 7.36	57.40 ± 7.06	110.70 ± 7.66	127.50 ± 20.04	1.87 ± 4.66	3.27 ± 5.44	5.23 ± 0.81	6.13 ± 4.17
0	NPK	20.07 ± 2.17	52.10 ± 13.94	99.90 ± 9.18	125.50 ± 66.51	1.70 ± 0.40	3.20 ± 0.40	5.43 ± 0.36	5.90 ± 18.27
5	0	16.50 ± 2.62	57.40 ± 5.23	76.60 ± 4.97	101.80 ± 0.00	1.73 ± 4.24	3.13 ± 4.24	4.63 ± 0.15	4.47 ± 12.38
5	Urea	17.63 ± 2.68	45.20 ± 3.33	88.10 ± 6.73	110.00 ± 11.33	1.70 ± 2.20	3.53 ± 2.20	5.23 ± 0.40	4.70 ± 1.25
5	NPK	30.23 ± 2.39	66.20 ± 1.55	109.20 ± 9.39	148.60 ± 2.26	2.40 ± 2.77	3.50 ± 2.77	5.93 ± 0.27	5.83 ± 41.76
10	0	16.17 ± 3.47	40.90 ± 13.26	78.10 ± 14.53	101.80 ± 24.42	1.37 ± 1.50	3.03 ± 1.50	4.50 ± 0.15	4.50 ± 16.00
10	Urea	27.20 ± 1.08	56.20 ± 2.35	81.90 ± 7.13	89.80 ± 26.00	1.83 ± 1.50	3.57 ± 1.50	4.50 ± 0.06	4.23 ± 6.90
10	NPK	20.63 ± 5.41	48.50 ± 4.55	97.60 ± 5.31	122.60 ± 36.64	1.53 ± 1.21	3.33 ± 1.21	5.37 ± 0.12	5.53 ± 9.04
$LSD_{(0.05)}$		5.31	13.19	16.83	37.77	0.54	0.64	0.74	1.33
Significant level		**	*	NS	NS	*	NS	NS	NS

WAT= weeks after transplanting, NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

Table 9. Interaction effect of wood ash rates and inorganic fertilizer sources on number of leaves and number of branches.

Treatment combination		Number of leaves				Number of branches			
(tha^{-1})	($kgha^{-1}$)	2	4	6	8	2	4	6	8
0	0	7.930 ± 1.85	40.70 ± 1.85	76.40 ± 4.84	191.10 ± 69.00	1.60 ± 1.11	14.87 ± 10.43	14.87 ± 1.11	21.33 ± 10.36
0	Urea	7.93 ± 2.40	43.30 ± 2.40	100.50 ± 12.04	203.70 ± 33.21	2.47 ± 1.22	16.87 ± 16.11	16.20 ± 1.22	24.07 ± 22.55
0	NPK	6.13 ± 0.70	36.90 ± 0.70	94.90 ± 6.91	151.90 ± 18.56	1.47 ± 0.50	13.60 ± 0.23	13.60 ± 0.50	17.93 ± 26.86
5	0	5.40 ± 0.20	36.40 ± 0.20	66.00 ± 3.02	94.10 ± 34.99	0.33 ± 0.58	8.93 ± 1.69	8.93 ± 0.58	12.20 ± 0.89
5	Urea	5.67 ± 0.99	36.90 ± 0.99	64.40 ± 4.51	87.10 ± 12.95	1.20 ± 0.72	10.60 ± 1.39	10.60 ± 0.72	12.27 ± 1.81
5	NPK	16.87 ± 0.31	52.50 ± 0.31	135.50 ± 1.41	205.30 ± 36.72	7.07 ± 0.31	15.07 ± 4.73	15.07 ± 0.31	20.93 ± 0.93
10	0	5.80 ± 1.06	44.00 ± 1.06	77.80 ± 2.25	96.40 ± 42.81	0.93 ± 0.76	9.67 ± 0.20	9.67 ± 0.76	11.80 ± 2.66
10	Urea	8.40 ± 0.35	38.20 ± 0.35	71.70 ± 7.46	82.80 ± 15.47	2.07 ± 1.04	10.47 ± 1.21	10.47 ± 1.03	10.13 ± 2.11
10	NPK	9.27 ± 1.17	42.10 ± 1.17	105.00 ± 1.29	176.90 ± 22.88	3.20 ± 0.60	13.47 ± 1.44	13.47 ± 0.60	15.20 ± 1.31
$LSD_{(0.05)}$		1.18	6.08	6.82	62.47	1.44	5.16	5.38	7.43
Significant level		**	*	**	**	**	NS	NS	NS

WAT= weeks after transplanting, NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

in carbohydrate content as palm bunch ash rates increased. Sugiyama and Goto (1966) reported that high carbohydrate contents in plants are associated with low potassium content. The reports of Sugiyama and Goto (1966) and Okoli and Okocha (2022) contradict the work of Liebhardt (1968) who reported an increase in carbohydrate metabolism and translocation with the application of potassium fertilizer.

Vitamin C (Fig. 6) and Vitamin A (Fig. 7) mean value contents of garden eggs decreased with an increase in wood ash rates. This observation refutes the findings of Adekiya et al. (2019), Worthington (2001), and Heaton (2001) which stated that Vitamin A and C contents in fruits and vegetables were improved by the application of potassium. Low vitamin A and C contents of garden eggs could be attributed to the very minute quantity of nitrogen in wood ash because crops require between 30 to 60 $kgha^{-1}$ of nitrogen for maximum vitamin C production (Hassan et al., 2012).

The main effect of inorganic fertilizer sources on the nutrient contents of *garden egg*

The moisture content of garden eggs was not significantly ($p \leq 0.05$) affected by fertilizer sources (Fig. 8). However, on the mean basis, the garden egg produced with NPK had the highest moisture content (76.91 ± 1.12%) while urea had the lowest moisture content (76.38 ± 2.07%). NPK fertilizer contains N, P, and K elements while urea supplies only N. Potassium plays an important role in water use efficiency in plants and maintains turgidity and amount of water in plant cells as well as the amount of water in plant organs like fruits (El-Latif et al., 2011). The moisture content of tomatoes increased with increasing application of 150 - 400 $kgha^{-1}$ of K_2O and peaked at 400 $kgha^{-1}$ of K_2O (Sofonias et al., 2018).

Control had significantly the highest mean crude fibre (2.81 ± 0.09%) while garden eggs produced with NPK fertilizer had the lowest (2.64 ± 0.34%) crude fibre (Fig. 9). Garden eggs produced with NPK fertilizer had the highest moisture content and lowest crude fibre.

The mean value of ash in garden eggs produced with urea was significantly highest (4.96 ± 0.31%) while garden eggs produced with NPK fertilizer had the lowest (4.23 ± 0.77%) ash content (Fig. 10). Abu et al. (2021) stated that ash contents in carrot, lettuce, and sweet pepper produced with fertilizers had higher ash contents than control. Gichuhi et al. (2014) reported that the ash content of sweet potatoes fertilized with nitrogen-rich broiler litter was higher than the control.

Crude protein was not significantly affected by fertilizer sources (Fig. 11). However, on the mean basis, the control garden egg had the highest crude protein (2.55 ± 0.12%)

Table 10. Interaction effect of wood ash rates and inorganic fertilizer sources on number of fruits and yield.

Treatment combination		Number of fruits	Fruit yield
(tha^{-1})	($kgha^{-1}$)		(tha^{-1})
0	0	127.20 ± 0.63	15.80 ± 0.45
0	Urea	140.40 ± 0.96	39.90 ± 0.25
0	NPK	47.40 ± 0.50	37.20 ± 0.25
5	0	9.00 ± 0.67	10.70 ± 0.57
5	Urea	25.50 ± 0.51	14.00 ± 0.61
5	NPK	101.40 ± 0.35	28.80 ± 0.12
10	0	23.10 ± 0.35	12.80 ± 0.40
10	Urea	75.40 ± 0.25	29.40 ± 0.20
10	NPK	96.30 ± 0.64	57.00 ± 0.50
$LSD_{(0.05)}$		77.29	21.09
Significant level		*	NS

NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

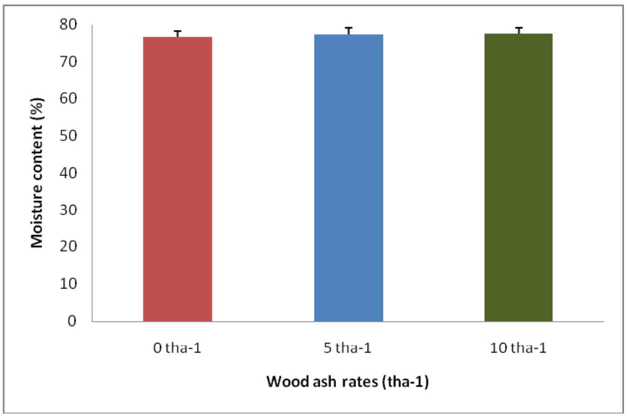

Figure 1. Main effect of wood ash rates on the moisture content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 1.71 comparing means of wood ash rates at harvest.
LSD = Least significant difference

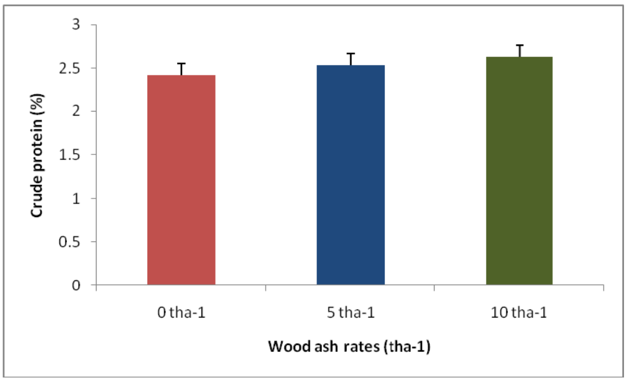

Figure 4. Main effect of wood ash rates on the crude protein content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.13 comparing means of wood ash rates at harvest.
LSD = Least significant difference

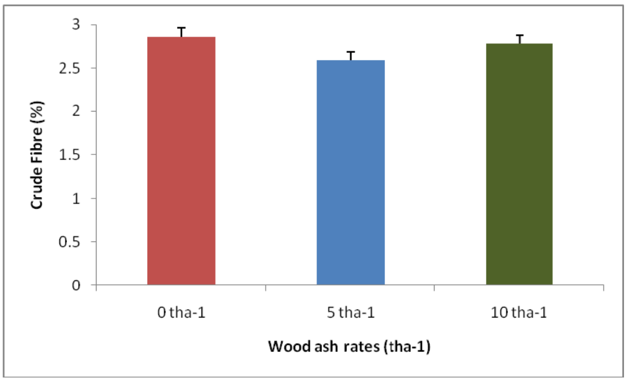

Figure 2. Main effect of wood ash rates on the crude fibre content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.10 comparing means of wood ash rates at harvest.
LSD = Least significant difference

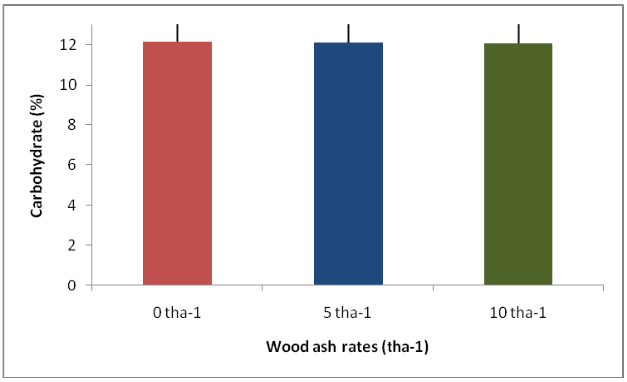

Figure 5. Main effect of wood ash rates on the carbohydrate content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.13 comparing means of wood ash rates at harvest.
LSD = Least significant difference

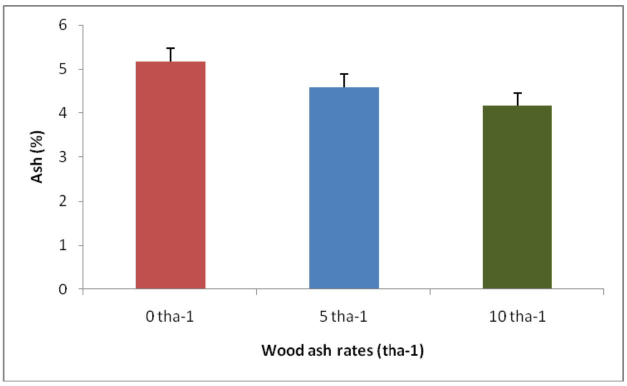

Figure 3. Main effect of wood ash rates on the ash content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.30 comparing means of wood ash rates at harvest
LSD = Least significant difference

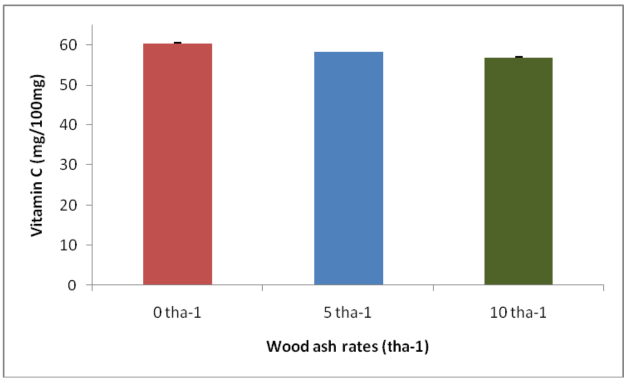

Figure 6. Main effect of wood ash rates on the vitamin C content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.08 comparing means of wood ash rates at harvest.
LSD = Least significant difference

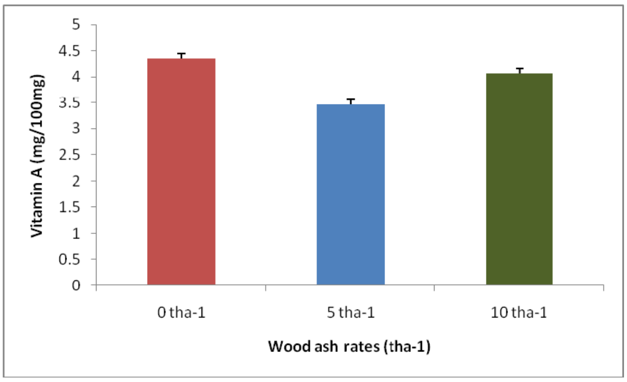

Figure 7. Main effect of wood ash rates on vitamin A content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.10 comparing means of wood ash rates at harvest.
LSD = Least significant difference

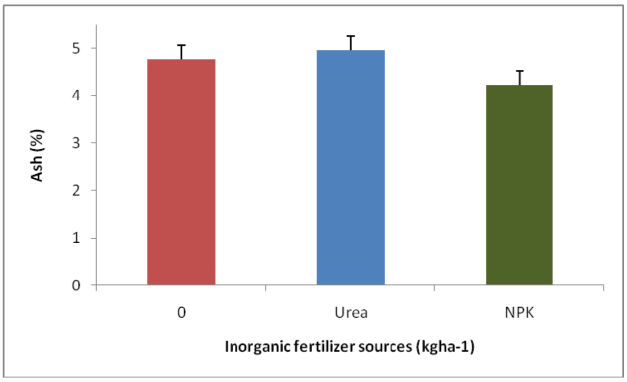

Figure 10. Main effect of inorganic fertilizer sources on the ash content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.30 comparing means of wood ash rates at harvest.
LSD = Least significant difference

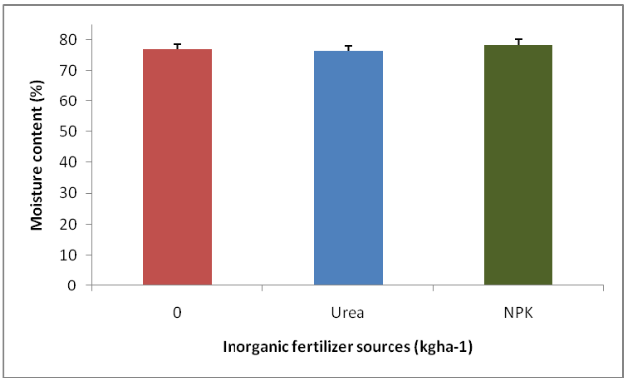

Figure 8. Main effect of inorganic fertilizer sources on the moisture content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 1.71 comparing means of wood ash rates at harvest.
LSD = Least significant difference

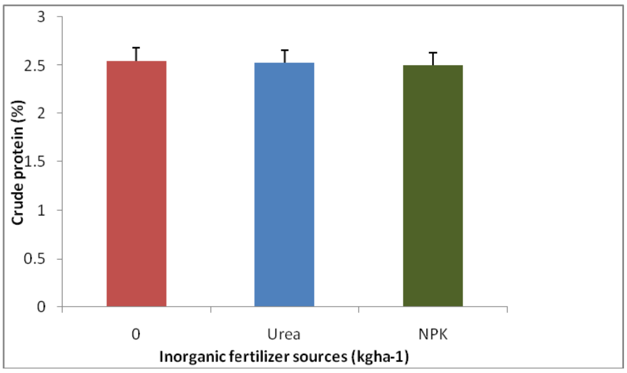

Figure 11. Main effect of inorganic fertilizer sources on the crude protein content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.13 comparing means of wood ash rates at harvest.
LSD = Least significant difference

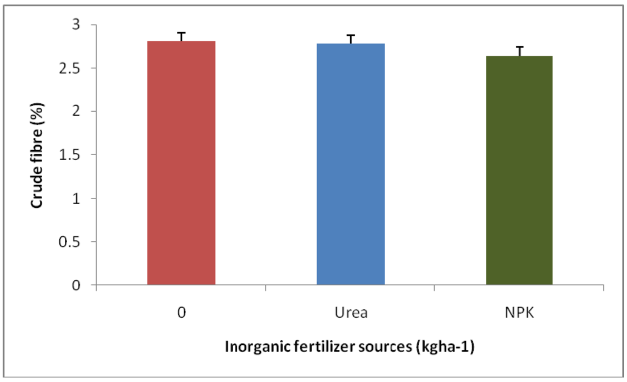

Figure 9. Main effect of inorganic fertilizer sources on the crude fiber content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.10 comparing means of wood ash rates at harvest.
LSD = Least significant difference

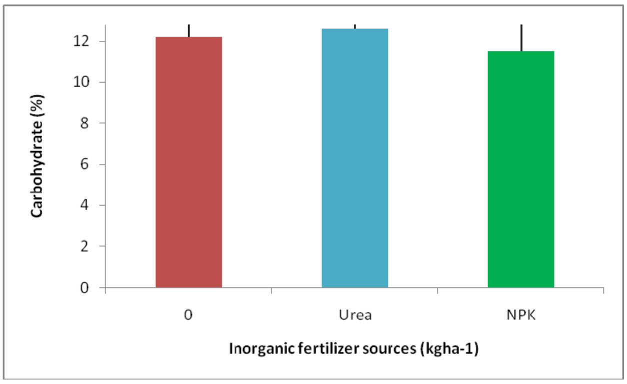

Figure 12. Main effect of inorganic fertilizer sources on the carbohydrate content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 1.81 comparing means of wood ash rates at harvest.
LSD = Least significant difference

while the garden egg produced with NPK fertilizer had the lowest crude protein (2.50 ± 0.16%). Higher crude protein in the control garden eggs is contrary to the findings of Simonne et al. (2007) and Qu et al. (2020) who reported that soluble protein content in tomatoes could be increased by increasing the level of nitrogen supply. In this experiment, both urea and NPK fertilizer supplied 60 $kgha^{-1}$ of nitrogen each and thus, had a higher nitrogen supply than the control. Soil amendment with different rates of urea improved crude protein content in tomatoes (Ogundare et al., 2015).
Carbohydrate was not significantly affected by fertilizer sources (Fig. 12). However, on the mean basis, the control garden egg had the highest carbohydrate (12.15 ± 0.42%) while the garden egg produced with NPK fertilizer had the lowest carbohydrate (11.50 ± 1.15%). Abu et al. (2021) reported the highest carbohydrate content in carrots produced without fertilizer in relation to carrots produced with a single nitrogen fertilizer and NPK fertilizer, Garden eggs produced with urea had significantly the highest mean vitamin C (59.60 ± 3.43 mg/100mg), followed by NPK fertilizer (58.55 ± 1.56 mg/100mg) while the control had the least (57.30 ± 3.54 mg/100mg) vitamin C (Fig. 13). The experimental soil was highly acidic and had very low nitrogen (Table 1). Application of nitrogen fertilizer to poor soils increased fruit quality in satsumas (Zhiguo et al., 2019) and persimmon fruit (Choi et al., 2012). Slow-release NPK fertilizer produced the highest vitamin C content in tomatoes in comparison with zero application of fertilizer (Motamedi et al., 2023). The higher vitamin C content of garden eggs produced with urea refutes the report of Colpan et al. (2013) which stated that the quality of fruit is dependent on levels of nitrogen and potassium available to the crop. The findings of Simonne et al. (2007) support the result of higher vitamin C in garden eggs produced with urea fertilizer.
Garden egg produced with urea produced significantly the highest mean vitamin A (4.10 ± 3.43 mg/100mg), followed by control (4.09 ± 0.49 mg/100mg) while NPK fertilizer had the least (3.68 ± 0.29 mg/100mg) vitamin A (Fig. 14). Odo et al. (2023) reported higher β-carotene and α-carotene in shombo and Nsukka yellow pepper produced with NPK fertilizer than in control.

The interaction effect of wood ash rates and inorganic fertilizer sources on nutrient contents of garden egg

The interaction effect of wood ash rates and inorganic fertilizer sources did not significantly ($p \leq 0.05$) affect moisture content (Table 11). However, on the mean basis, the highest moisture content was observed in garden eggs cultivated with 5 tha^{-1} of wood ash and NPK fertilizer (79.33 ± 0.00%) while the lowest moisture content was observed in garden eggs produced with urea (74.80 ± 0.06%). The moisture content of tomatoes increased with increasing application of 150 - 400 $kgha^{-1}$ of K_2O and peaked at 400 $kgha^{-1}$ of K_2O (Sofonias et al., 2018).
The crude fibre was significantly highest in garden eggs produced with 10 tha^{-1} of wood ash and NPK fertilizer (2.94 ± 0.00%) while garden eggs cultivated with 5 tha^{-1} of wood ash and NPK fertilizer had the lowest crude fibre (2.24 ± 0.00%). Garden egg fruits with higher contents of moisture had lower crude fibre and ash as observed in garden eggs produced with 5 tha^{-1} of wood ash and NPK fertilizer (Table 11). Okoli and Okocha (2022) reported that higher rates of palm bunch ash decreased moisture content in cassava leaves.
Ash was highest in control and lowest in garden eggs cultivated with 10 tha^{-1} of wood ash and NPK fertilizer (Table 11).
Crude protein was highest in garden eggs produced with 10 tha^{-1} of wood ash and NPK fertilizer (2.68 ± 0.00%) and lowest in garden eggs produced with 5 tha^{-1} of wood ash and NPK fertilizer (2.32 ± 0.00%) (Table 11). Ash is rich in potassium and plays an important role in protein synthesis (Long et al., 2006). Thornburg et al. (2020) reported that higher protein in wheat could be attributed to the influence of potassium in the absorption of nitrates and subsequent transformation to protein.
Carbohydrate was not significantly affected by the interaction of wood ash and inorganic fertilizers (Table 11). However, on the mean basis, garden eggs produced urea had the highest carbohydrate content (14.10 ± 0.01%) while

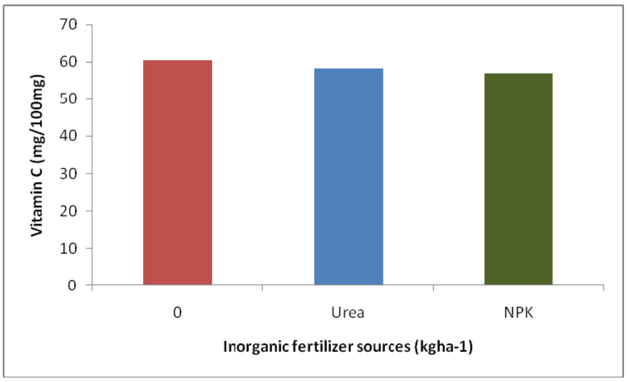

Figure 13. Main effect of inorganic fertilizer sources on vitamin C content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.08 comparing means of wood ash rates at harvest.
LSD = Least significant difference

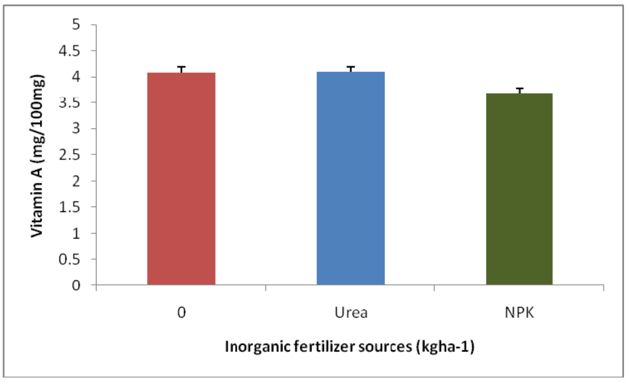

Figure 14. Main effect of inorganic fertilizer sources on vitamin A content of garden egg.
Vertical bars represent $LSD_{(0.05)}$ = 0.10 comparing means of wood ash rates at harvest.
LSD = Least significant difference

Table 11. Interaction effect of wood ash rates and inorganic fertilizer sources on nutrient contents of garden egg after harvest.

Wood ash (tha^{-1})	Inorganic fertilizer ($kgha^{-1}$)	Moisture content (%)	Crude fibre (%)	Ash (%)	Crude protein (%)	Carbohydrate (g)	Vitamin C (mg/100g)	Vitamin A (mg/100mg)
0	0	76.12 ± 0.04	2.91± 0.03	5.26 ± 0.03	2.40 ± 0.01	12.48 ± 0.07	60.43 ± 0.04	4.36 ± 0.01
0	Urea	74.80 ± 0.06	2.93 ± 0.04	5.07 ± 0.04	2.34 ± 0.01	14.10 ± 0.01	63.04 ± 0.03	4.64 ± 0.02
0	NPK	78.89 ± 1.73	2.74 ± 0.20	5.22 ± 0.14	2.51 ± 0.08	9.86 ± 1.29	57.68 ± 0.03	4.05 ± 0.01
5	0	76.24 ± 0.06	2.77 ± 0.04	5.12 ± 0.01	2.65 ± 0.01	12.49 ± 0.06	58.64 ± 0.04	3.34 ± 0.04
5	Urea	76.58 ± 1.44	2.77 ± 0.08	4.93 ± 0.52	2.66 ± 0.18	12.29 ± 2.00	55.47 ± 0.02	3.55 ± 0.03
5	NPK	79.33 ± 0.00	2.24 ± 0.00	3.76 ± 0.00	2.32 ± 0.00	11.55 ± 0.00	60.56 ± 0.00	3.49 ± 0.00
10	0	78.35 ± 0.06	2.74 ± 0.03	3.92 ± 0.02	2.62 ± 0.02	11.69 ± 0.08	52.85 ± 0.23	4.57 ± 0.23
10	Urea	77.77 ± 3.22	2.66 ± 0.04	4.88 ± 0.42	2.59 ± 0.21	11.39 ± 3.41	60.30 ± 0.03	4.10 ± 0.00
10	NPK	76.84 ± 0.00	2.94 ± 0.00	3.71 ± 0.00	2.68 ± 0.00	13.07 ± 0.00	57.41 ± 0.00	3.51 ± 0.00
$LSD_{(0.05)}$		2.97	0.17	0.52	0.22	3.31	0.13	0.18
Significant level.		NS	**	*	*	NS	**	**

NS = Non significant, * = Highly significant, ** = Significant, LSD = Least significant difference.

garden eggs produced with NPK fertilizer had the lowest carbohydrate (9.86 ± 1.29%). This agrees with the work of Sugiyama and Goto (1966) who reported that high carbohydrate contents in plants are associated with low potassium content and refutes the finding of Liebhardt (1968) who reported an increase in carbohydrate metabolism and translocation with the application of potassium fertilizer.

Interaction of 5 tha^{-1} of wood ash and NPK fertilizer produced the highest vitamin C in garden egg (60.56 ± 0.00 mg/100mg) while garden egg cultivated with 10 tha^{-1} of wood ash had the lowest Vitamin C (52.85 ± 0.23 mg/100mg) (Table 11). Higher vitamin C content was reported in okra fruit fertilized with maize cob ash (Adekiya et al., 2019). The higher vitamin C content of garden eggs could be attributed to balanced supply of N, P, and K for the production of vitamin C in garden eggs. This confirms the finding of Hassan et al. (2012) who reported that *Cosmos caudatus* required between 30 to 60 $kgha^{-1}$ of nitrogen for maximum vitamin C.

A mixture of 10 tha^{-1} of wood ash and urea increased the vitamin A content of garden egg to 4.64 ± 0.02 mg/100mg while integration of 5 tha^{-1} of wood ash and NPK fertilizer had 3.49 ± 0.00 mg/100mg of vitamin A (Table 11). Improvement in vitamin A content in fruits and vegetables was reported by Adekiya et al. (2019); Worthington (2001), and Heaton (2001).

4. Conclusion

The main effect of wood ash showed that 10 tha^{-1} of wood ash produced the highest fruit yield without commensurate improvement on the growth parameters. Inorganic fertilizer showed a superior effect of 300 $kgha^{-1}$ of NPK over 130.44 $kgha^{-1}$ of urea on the growth and yield parameters of the garden egg. Integrated application of 10 tha^{-1} of wood ash and NPK fertilizer gave the best performance on the growth and yield parameters of the garden egg. However, a combined application of 130.44 $kgha^{-1}$ of urea and 10 tha^{-1} of wood ash showed a greater improvement in vitamin A and C contents of garden egg. Therefore, the integrated application of 10 tha^{-1} of wood ash and 300 $kgha^{-1}$ of NPK fertilizer is recommended for improved garden egg growth and yield while an integrated application of 130.44 $kgha^{-1}$ of urea and 10 tha^{-1} of wood ash is recommended for improved nutrient content of garden egg. High yield and improved nutrient quality in garden eggs cultivated using the integrated application of wood ash rates and inorganic fertilizer sources will serve as food and nutrition security for poor income earners. Fertilizers used in the experiment are locally available to resource-poor farmers and thus, there are no known limitations in this experiment.

Author contribution

The authors confirm the study conception and design: Okoli Nneka Angela, Ibeawuchi Innocent Izuchukwu, data collection: M. Umegbolu and I. C. Nwafor; analysis and interpretation of results: L. C. Emma-Okafor, B.O. Nwosu, C. U. Onwuchekwa, draft manuscript preparation: Okoli Nneka Angela, Ibeawuchi Innocent Izuchukwu. The results were evaluated by all authors, and the final version of the manuscript was approved.

Conflict of interest statement

The authors declare that they are no conflict of interest associated with this study.

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