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Wood Ash Liquid Fertilizer as Sustainable Soil Nutritional Supplement Modulates Changes on Growth and Fruits Nutritional Compositions of *Capsicum frutescens* L.

Sürdürülebilir Toprak Besin Takviyesi Olarak Odun Külü Sıvı Gübrenin *Capsicum frutescens* L.'nin Büyümesi ve Meyve Besin Kompozisyonundaki Etkileri

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ABSTRACT

The use of plant-derived fertilizers is a promising approach towards sustainable crop production. This study exploited supplementary effects of 100, 75, 50, and 25% wood ash liquid fertilizer (WALF) on the growth and fruit nutritional contents of *Capsicum frutescens*. Ordinary water served as control. Agronomical, physiological, and fruit nutritional parameters of the pepper were determined. Higher plant height (25.17 cm) was observed in pepper seedlings sprayed with 25% WALF while several leaves (71.20), leaf area (100.62 cm^2), specific leaf area (67.14 m^2kg^{-1}), and leaf area index (0.31 m^2m^{-2}) were higher (p<.05) in pepper treated with 50% WALF compared with other treatments. Higher net assimilation rate (0.0078 $gm^{-2}day^{-1}$) and leaf area ratio (0.07 m^2kg^{-1}) were observed in pepper sprayed with 100 % the treatment as well as the relative growth rate (0.05 $mg^{-1}day^{-1}$) of *C. frutescens* spayed with 75 % WALF. 50% WALF produced the highest number of fruits (38). Also, vitamin A (64.01 mg/100g), vitamin B3 (1.73 mg/100g), vitamin B5 (1.30 mg/100g), vitamin B6 (0.27 mg/100g) were observed in the fruits of pepper spayed with 50% WALF. Furthermore, sodium (11.17mg/100g), potassium (363.92 mg/100g), calcium (108.14 mg/100g), and magnesium (58.11 mg/100g) as well as moisture (68.32%), fat (2.77%), ash (3.55%), crude fiber (2.49%), crude protein (4.43%) and carbohydrate (9.20%) higher in the fruits of *C. frutescens* treated with 50% WALF. In conclusion, 50% WALF better enhanced the growth, yield, and nutritional quality of *C. frutescens* fruits.

Keywords: Antioxidants, Flavonoids, Growth components, Soil conditioners, Net assimilation rate, Relative growth rate

ÖZ

Bitki kökenli gübrelerin kullanımı, sürdürülebilir ürün üretimi için umut verici bir yaklaşımdır. Bu çalışma, *Capsicum frutescens* bitkisinin büyümesi ve meyve besin içeriği üzerinde %100, %75, %50 ve %25 oranlarındaki odun külü sıvı gübresi (OKSG) ilavesinin etkilerini araştırmıştır. Kontrol grubu olarak normal su kullanılmıştır. Biber bitkisinin agronomik, fizyolojik ve meyve besin parametreleri belirlenmiştir. En yüksek bitki boyu (25,17 cm), %25 OKSG püskürtülen biber fidelerinde gözlenirken, yaprak sayısı (71,20), yaprak alanı (100,62 cm^2), özgül yaprak alanı (67,14 m^2kg^{-1}) ve yaprak alan indeksi (0,31 m^2m^{-2}), diğer uygulamalarla karşılaştırıldığında %50 OKSG ile muamele edilen biberde daha yüksek bulunmuştur (p<,05). En yüksek net asimilasyon hızı (0,0078 g m^{-2} $gün^{-1}$) ve yaprak alan oranı (0,07 m^2kg^{-1}), %100 OKSG ile püskürtülen biberlerde gözlenirken, %75 OKSG ile püskürtülen *C. frutescens*'in bağıl büyüme hızı (0,05 mg^{-1} $gün^{-1}$) daha yüksek olmuştur. %50 OKSG, en fazla meyve sayısını (38) üretmiştir. Ayrıca, %50 OKSG ile püskürtülen biber meyvelerinde A vitamini (64,01 mg/100 g), B3 vitamini (1,73 mg/100 g), B5 vitamini (1,30 mg/100 g) ve B6 vitamini (0,27 mg/100 g) değerleri gözlenmiştir. Bunun yanı sıra, sodyum (11,17 mg/100 g), potasyum (363,92 mg/100 g), kalsiyum (108,14 mg/100 g) ve magnezyum (58,11 mg/100 g) değerleri ile birlikte nem (%68,32), yağ (%2,77), kül (%3,55), ham lif (%2,49), ham protein (%4,43) ve karbonhidrat (%9,20) oranları da %50 OKSG ile muamele edilen *C. frutescens* meyvelerinde daha yüksek bulunmuştur. Sonuç olarak, %50 OKSG, *C. frutescens* meyvelerinin büyümesini, verimini ve besin kalitesini daha iyi artırmıştır.

Anahtar Kelimeler: Antioksidanlar, Flavonoidler, Büyüme bileşenleri, Toprak düzenleyiciler, Net asimilasyon oranı, Göreceli büyüme oranı

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Introduction

All member states of the United Nations in 2016 agreed on seventeen sustainable development goals in order to ensure that humans rights are met globally, today and in the future. Goal number two aims to "end hunger, achieve food security, improved nutrition and promote sustainable agriculture". There are a number of agricultural challenges that need to achieve this goal. One of them is the issue of soil degradation (Barth & Duarte, 2008) which often limits food production due to poor soil health status. When cultivated, soils depleted of nutrients require fertilizer application to sustain crops such as Capsicum with sufficient nutrients (Barth & Duarte, 2008) so that its production will be able to meet the pepper demand of large populations of countries including Nigeria.

The genus *Capsicum* L. belongs to the family *Solanaceae*. Members of the family *Solanaceae* are mostly herbs while some others are climbers (Singh, 2004). *Capsicum frutescens* is a species of plant genus Capsicum which is native to Southern North America and Northern South America (Latham & Elizabeth, 2009). This species is the most common and extensively cultivated of the five domesticated species of *Capsicum* L (Latham & Elizabeth, 2009). It is an important economic annual tropical food crop rich in bioactive nutrients, sensory attributes and dietary antioxidants (Navarro et al., 2006) as potent health-enhancing factors (Bramley, 2000; Ademoyegun et al., 2011). It is also used in sauces, soups, stews and as a flavouring agent (Reyes-Escogido et al., 2011; Chigoziri & Ekefan, 2013; Amruthraj et al., 2014).

Despite the diverse importance of the pepper, there is low production of the vegetable due to poor land practice, insufficient fertilizers, or high cost of the few inorganic fertilizers and their possible deleterious effects on the land and crops. Over the years, the intensive utilization of land has resulted to depletion of soil mineral nutrients (Oti & Ojo, 2012).

The supply of organic manure is not enough, especially in urban areas to substitute the use of chemical fertilizers that have been increasing the acidity level of tropical soils and as a quick means of restoring the soil fertility. However, sustainable utilization of organic waste such as wood ash may help to improve low nutrient level and ensure sustainable usage of the waste.

Wood ash is the residue left from the complete combustion of wood and wood products. The liming effect of wood ash enhances soil pH, improving nutrient availability, particularly in acidic soils (Sharifi et al., 2013). This creates favorable conditions for the growth of *Capsicum frutescens*, increasing biomass and plant height (Cruz-Paredes et al., 2017). In many farming households, especially in local areas, wood or charcoal is the main sources of fuel used for cooking which often generates ash. It has a high pH, base cations and phosphorus, necessary for proper development of plants (Mousavi, 2011). Due to its chemical compositions, it has been shown that ash can be used to raise pH in soils (Chigoziri & Ekefan, 2013). Its contents in many of the plant nutrients often enhance plant growth suggesting that wood ash could also be useful fertilizer. In nitrogen-fixing crops, ash often supplies nutrients to meet the crop requirement due to the availability of essential nutrients such as potassium, phosphorus, and micronutrients (Sharifi et al., 2013; Chigoziri & Ekefan, 2013).

In most over utilized agricultural land, it is necessary to fertilize the soil to prevent nutrient mining. The use of inorganic fertilizer to supply these nutrients may not always be of economic benefit to the farmers. Furthermore, inappropriate use of mineral but also organic fertilizers can cause negative environmental effects such as soil acidification and eutrophication for plants. It is therefore of great importance to use these fertilizers, even organic fertilizers, in an appropriate manner so as to ensure sustainable and affordable utilization of wood ash.

This study was conducted to evaluate effects of wood ash liquid fertilizer on the morphological and physiological parameters as well as nutritional compositions of *Capsicum frutescens*.

Methods

Material

Study Area: The study was conducted in the teaching and research botanical garden of Department of Botany, Lagos State University, Ojo Campus.

Sources of Seeds: Seeds of *C. frutescens* were extracted from *C. frutescens* fruits bought at Igando market in Lagos State, Nigeria and identified at Forestry Research Institute, Ibadan.

Soil Collection and Planting Preparation: Soil was collected at between 0-5cm at 500m apart from different locations of the botanical garden according to the procedure of National Soil Characterization Database of the United States Department of Agriculture described in Vijay et al. (2019) and Ojewumi et al. (2022). The soil was sieved and poured into twenty-five perforated planting buckets.

Nursery Preparation: Seedlings of *C. frutescens* were raised in the garden for 21 days. The seedlings (one per bucket) were thereafter transplanted into the buckets when they were 18-20cm high and watered for another 7days to ensure hardening of the seedlings to the environment (Ojewumi et al., 2022).

Method

Experimental Design: The planting buckets with one seedling per bucket were arranged in a completely randomized design with five replicates.

Source of Experimental Materials: Wood ash of (*Gambeya albida*) was collected from bakeries in Igando, Lagos State.

Preparation and Application of Wood Ash Liquid Fertilizer (WALF): Wood ash liquid fertilizer was prepared according to Ojewumi and Kadiri (2021) with little modifications. Wood ash collected was thoroughly sieved to remove pebbles, then 1000 g of the sieved wood ash was weighed and diluted using 2L of water. The mixture was filtered using muslin cloth and allowed to settle. The residue was discarded while the filtrate obtained was used to constitute different percentages of wood ash liquid fertilizer. 250 mL of WALF was diluted in 1000 mL of water and regarded as 25% WALF. Similar procedure was adopted for 50, 75 and 100% WALF while ordinary water served as control. Fifty (50 mL) of each treatment was exogenously applied to the seedlings daily for 3 months.

Determination of Physical and Chemical Properties of Soil: Soil samples collected and air-dried. The dried soil samples were passed through a 2-mm sieve and used for the analysis of physical and chemical analysis. Soil pH, Organic carbon, total nitrogen and available phosphorus were determined. Soil texture was determined according to the method of Hardie *et al.,* (2014) while exchangeable minerals (copper, magnesium, phosphorus, potassium, sodium, sulphur and zinc) were estimated following the procedure of Huang et al. (2022).

Physicochemical Properties of WALF: Physicochemical properties such as pH, available phosphorus and exchangeable cations were also determined (Oladele et al., 2019).

Data collection

Determination of Vegetative Parameters of *C. frutescens*: The vegetative parameters such plant height was determined using a ruler calibrated in centimeter (cm) while the numbers of leaf were measured using physical counting at one week interval (Kadiri, 1999).

Determination of Total Leaf Area, Specific Leaf Area and Leaf Area Index: The total leaf area was determined using leaf area meter (Ojewumi et al., 2023). Using the leaf area and weight of leaf values specific leaf area, leaf area index, relative growth rate, net assimilation rate, and leaf area ratio were computed (Alireza et al., 2012);

Specific leaf area = Leaf area / Corresponding weight of leaf

Leaf area index = Leaf area / Area of litter fall

$$\text{Relative growth rate} = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

$$\text{Net assimilation rate} = \frac{W_2 - W_1}{A_2 - A_1} \times \frac{Log_e A_2 - Log_e A_1}{t_2 - t_1}$$

$$\text{Leaf area ratio} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e A_2 - Log_e A_1}{W_2 - W_1}$$

Where A_1= Area of leaf at t_1, A_2= Area of leaf at t_2, W_1= first measured weight (g), W_2= second measured weight (g), T_1= initial time (weeks) and T_2= final or second time (weeks)

Determination of yield (Number of fruit per plant) of *C. frutescens* fruits:
Pepper yield was determined by hand harvesting according to the method of Sezen et al. (2011) with little modifications

Determination of nutritional contents of *C. frutescens* fruits: Procedure of AOAC (2000) with medications was used to determine proximate contents of *C. frutescens* fruits.

Ash: Ash in the samples was determined by adding 5g of the samples to a known weight crucible, weighed and dried at 932F and reweighed. Ash was determined using the formula:

Ash (%) = weight of ash / weight of sample × 100

Crude fat: Two grams of dried sample of pepper fruits was kept using paper thimble in a known weight fat extractor. Ninety (90 mL) of benzyne (C_6H_4) was added, refluxed and weighed. Crude fat was determined as shown below;

Crude fat (%) = (weight of flask - weight of empty flask) / weight of original sample × 100

Moisture: Moisture was calculated using the formula below;

Moisture (%) = (eight of sample before drying - weight of sample after drying) / eight of sample before drying × 100

Crude fibre: Three (3g) of the samples were boiled in 30 mLof 1.25% H_2SO_4 for 30 min, filtered, washed thoroughly in hot water and boiled using 200 mL of 1.25% NaOH for 20 minutes. Spotless beaker was dried at 100±5°℃ and the weights of the contents were calculated. Spout-less beakers and its content were dried at 9320F-11120F for 3 hours, and weighed. The crude fibre was calculated according to AOAC (2000) as shown below;

Crude fibre (%) = (weight of beaker containing crude fibre - weight of spoutless beaker and crude fibre) / weight of original sample × 100

Determination of vitamins in *C. frutescens* fruits:
Vitamin A (Retinol): Two (2g) of the sample was weighed into a flat bottom reflux flask, 10ml of distilled water was added followed by 25ml of alcoholic KOH solution and a reflux condenser attached. The mixture was heated using boiling water bath for one hour, shaken, cooled rapidly and about

30ml of water was added after which hydrolysate obtained was transferred into a separation funnel.

The solution was extracted thrice with 250ml quantities of chloroform. Two 2 g anhydrous Sodium sulphate was added to the extract and filtered into 100mL volumetric flask and made up to mark with chloroform. Standard solution of B-carotene Vitamin A ranged from 0-50 µg/mi and chloroform was used by dissolving 0.003 g of standard L-carotene in 100ml of chloroform. The above gradients of different standard solutions prepared were determined with reference to their absorbance from which average gradient was used to calculate Vitamin A (B-carotene in pg/ 100g)

Vitamin B3 (Niacin): Three (3g) of the sample was treated with 50 ml of H_2SO_4 and shaken for 20 minutes after which, 3 drops of the ammonia solution were added and filtered. Afterwards, 10 ml of the filtrate was added into a 50 ml volumetric flask and 5 ml of 0.02 H_2SO_4 470 nm according to AOAC (2000).

Vitamin B5 (Pantothenic acid): Three (3g) of sample was weighted and shaken with 200ml distilled water, diluted to mark to distilled water and filtered after which 5 ml of aliquot of the sample filtrate was pipetted into a 2 ml beaker, 5 ml of 12% potassium bromide (KBr), 10 ml of KMNO, were added and mixed thoroughly. The mixture was transferred to a stoppered flask put in a boiling water bath, cooled in ice for 5 min and 20% freshly prepared H_2SO_4, was added drop wise to decolonize the excess $KMNO_4$ solution, 10ml of 2,4 dimitrophenylmrazine (5 g/l) was added. The mixture was heated on a steam bath and cooled to room temperature. Yellow precipitate was obtained and dried for 30 at 100°C. The dry precipitate was dissolved in hot pyridine solution, mixed to form a homogenous suspension and filtered to mark with pyridine solution. All aliquot of the solution above was pipetted into a 200 ml flask and 50ml of distilled water was added, followed by 5 ml of 5M NaOH solution to develop the due colour. Absorbance of sample and standard pantothenic and solution of range 10 ug/ml - 50 pg/ml prepared from µg/ml stock pantothenic acid were read (570 nm).

Vitamin B5 (µg) = (Absorbance of sample × average gradient factor × gradient factor) / weight of sample

Vitamin B6 (Pyridoxine): The vitamin B6 was determined by extracting 2 g of sample with 0.5 g of ammonium chloride, 45 ml of chloroform and 5 ml of absolute ethanol. The mixture was mixed for 30 minutes and 5 ml of distilled water added. The chloroform layer containing the pyridoxine was filtered and made up to mark with chloroform. 0-10 ppm of vitamin B6 standard solutions were prepared and treated in a similar way as sample, and their absorbance measured on spectrophotometer at 415 nm. The vitamin B6 was then calculated.

Vitamin B5 (µg) = (Absorbance of sample × gradient factor) / weight of sample

Vitamin C (Ascorbic acid): Two grams of the sample was weighed and 10 ml of oxalic acid (0.05 M), EDTA (0.02 M) solution was added and placed in the sample for 24 hours to provide the required reaction time. After 24 hours, the samples were filtered using 0.45 um filter paper. Then, 2.5 ml of each sample was transferred to a separate 25 ml volumetric brown flask, after which 2.5 ml of the oxalic acid (0.05 M)-EDTA (0.02 M) solution was added.

Vitamin E (Tocopherol): One (1 g) of the was weighed and filtered after which 10 ml of absolute alcohol and 20 ml of IM alcoholic H_2SO_4, were added. The condenser and flask were wrapped in Aluminum foil and refluxed for 45 minutes and cooled for another 15 minutes. Fifty (50 ml) of distilled water was added to the mixture and transferred to a 250 ml separating funnel covered with Aluminum foil. The unsaponifiable matters in the mixture were extracted with 5 x 30ml dimethyl ether. The combined extracts were washed free of acid and dry evaporated and the residues obtained were dissolved in 10ml absolute alcohol. Aliquot of solutions of the samples and standards (0.3-3.0 mg vitamin E) were transferred to a 20 ml volumetric flask and 5 ml alcohol was added, followed by 1 ml concentrated Nitric acid. The flasks were placed on a water bath at 90°C for 3 minutes from the time the alcohol begins to boil, volume with absolute alcohol and absorbance was taken at 470 nm against a blank containing absolute alcohol and 1 ml conc. Nitric acid (HNO) was treated in a similar manner (AOAC, 2000). Vitamin E (Tocopherol) using spectrophotometer (Achikanu *et al*.,2013).

Vitamin E (µg/100g) = (Absorbance of sample × gradient sample × diluted factor × weight of sample) / weight of sample

Vitamin K (Phylloquinone): Five (5 g) of sample was weighed into a 250 ml beaker and 30 ml of Butyl alcohol was added. The mixture was thoroughly shaken to obtain a homogenous solution and filtered through filter paper into a 100ml volumetric flask and made up to mark with butyl alcohol. 10 ml aliquot of the filtrate was pipetted into a 30 ml centrifuge tube and 3 drops of 2, 4- dinitrophenyl hydrazine was added to develop the blue colour which will subsequently change to bluish green upon addition of 3ml of alcoholic ammonia. Standard solutions of vitamin K from 0-20 µg/ml were prepared and treated as samples to obtain a gradient factor. The Absorbances of standards and sample were read at a wavelength of 480mm

Vitamin K (µg) = (Absorbance of sample × average gradient factor × gradient factor) / weight of sample

Determination of phytochemicals in *Capsicum frutescens* fruits:
Phytochemical contents of the samples were determined following the procedure of Harborne, (1973) in Ojewumi and Oyebanji (2020) with little modifications.

Alkaloids: Finely ground 2 g of simple was weighed into a 100 ml beaker and 30 ml of 80% absolute alcohol was added. The mixture was transferred to a 250 ml flask and more alcohol was added to make up to 100 ml after which 1g magnesium oxide added. The mixture was digested in a boiling water bath for 2hrs and filtered. The residue was returned to the flask and re-digested for 30 min with 50 ml alcohol was evaporated and 3 drops of 10% HCl was added. The whole solution was later transferred into a 250 ml volumetric flask after which 5ml of zinc acetate solution and 5ml of potassium ferrocyanide solution were added separately and mixed to give a homogenous solution. The flask was allowed to stand for a10 minutes and 10ml of the filtrate was transferred into a separatory funnel. The alkaloids were extracted by shaking with chloroform. The residue obtained ''as dissolved in 10ml hot distilled water and transferred into a kjeldahl tube with addition of 0.20g sucrose and 10ml Conc. H_2SO_4 and 0.02g selenium for digestion to a colorless solution to determine %N by Kjeldahl distillation method. % Nitrogen got was converted to % total alkaloid by multiplying by a factor of 3.26 i.e % Total alkaloid = %N × 3.26

Flavonoids: One (1 g) of the sample was weighed into a 100ml beaker and 80ml of 95% ethanol was added and filtered into a 100ml volumetric flask and made up to mark with Ethanol. Furthermore, 1ml of the extract was pipetted into 50 ml volumetric flask, 4 drops of Conc. HCL was added via a dropping pipette after which 0.5g of magnesium turnings added to develop a magenta red coloration. Standard flavonoid solution of range 0-5ppm were prepared and treated in a similar way with HCl and magnesium turnings like sample. The absorbance of magenta red coloration of sample and standard solutions were read on a digital Jenway V6300 Spectrophotometer (520nm). The % flavonoid was calculated as shown;

Flavonoids = (Absorbance of sample × average gradient factor × dilution factor) / (Weight of sample × 10000)

Saponins: Two grams of the sample was weighed and 100ml of isobutyl alcohol was added. The mixture was shaken on a UDY shaker for 5 hours to ensure uniform mixing. The mixture was filtered and 20ml of 40% saturated solution of magnesium carbonate was added. The mixture obtained with saturated Magnesium carbonate was again filtered to obtain a clear colorless solution. One (1ml) of the colorless solution, was pipetted into 50ml volumetric flask and 2ml of 5% Iron (III) chloride solution was added and made up to mark with distilled water. It was allowed to stand for 45min for blood red color to develop. 0-10ppm standard Saponin solutions were prepared from saponin stock solution. The standard solutions were treated similarly with 2ml of 5% Iron (III) chloride solution as done for 1ml sample above after which absorbance of the sample and standard saponin solutions were read after color development in a Jenway V6300 Spectrophotometer (380mm).

% Saponin= (Absorbance of sample × gradient factor × dilution factor) / (Weight of sample × 10000)

Steroids: Three (3g) of the sample was weighed into a 100ml beaker and 20m1 of Chloroform-Methanol (2:1) was added to dissolve the extract after which the mixture was filtered. The resultant residue was treated repeatedly with Chloroform-Methanol until free of Steroids was obtained. One (1ml) of the filtrates was pipetted into a 30ml test tube and 5ml of alcoholic potassium hydroxide was added and shaken to obtain a homogenous mixture. The mixture was placed in a water bath (37°C-40°C) for 2hours, and 10 ml of petroleum ether was added followed by 5ml distilled water and later evaporated. Six (6ml) of Liebermann Burchard reagent was added to the residue and was absorbance was taken at 620nm on a Spectronic 21D digital Spectrophotometer. Standard Steroids of concentration of 0-4mg/mi was prepared from 100mg/mi stock steroid solution and treated similarly as above;

Steroids = (Absorbance of Sample × Gradient × Dilufion Factor) / (Weight of sample × 10000)

Statistical Analysis

Data were analyzed using statistical analysis system (SAS, 2013). Means were calculated using one way analysis of variance and separated using Duncan's Multiple Range Test (DMRT) at $p<.05$.

Results

The physical and chemical properties of the soil and wood ash liquid fertilizer

Production of crop-plants such as *Capsicum frutescens* is influenced by soil fertility and nutrient supply therefore, physical and chemical compositions of soil used for this study revealed that the soil was acidic (pH; 6.3) with appreciable quantities of organic carbon (17.4 g kg^{-1}), total nitrogen (2.3 g $kg^{-1)}$ and phosphorus (21.7 mg kg^{-1}). The soil was also sandy loam but characterized sandy (826 g kg^{-1}), clay (36 g kg^{-1}) and silt (129 g kg^{-1}) properties as well as average proportion of nutritional elements (Table 1). Also, S^{2+} (58.57cmol kg^{-1}) was the major exchangeable mineral observed in wood ash liquid fertilizer (WALF) followed by Mg^{2+} (40.54 cent/kg) while Cu^{2+} (1.26 mg/kg) was the least mineral observed (Figure 1).

Table 1.
The physical and chemical properties of the soil used for the experiment

Parameters	Quantities
pH (H_2O) (1:1)	6.3±1.23
Organic Carbon (g kg^{-1})	17.4±1.74
Total N (g kg^{-1})	2.3±0.96
Available P (mg kg^{-1})	21.7±1.56
Particle size distribution (g kg^{-1})	
Sand	826±2.85
Clay	36±1.45
Silt	129±2.95
Textural class	Sandy Loam
Exchangeable Bases (cmol kg^{-1})	
Potassium	0.53±0.02
Calcium	5.34±1.45
Sodium	0.70±0.04
Magnesium	0.91±0.03

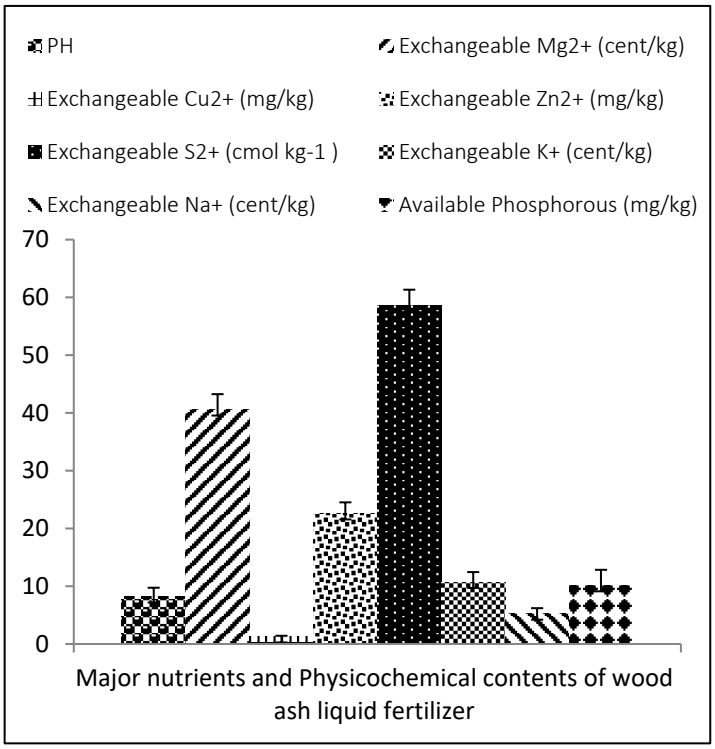

Figure 1.
Exchangeable nutrients of wood ash liquid fertilizer

Effect of wood ash liquid fertilizer on agronomic characters of *C. frutescens.*

WALF produced significant influence on height of *C. frutescens* from 2 through 4 weeks after treatment (WAT). Highest plant height (25.17 cm) was recorded in the pepper sprayed with 25 WALF % followed control (Table 2) while highest number of leaf (71.20) was observed in the seedlings sprayed with 50% WALF (Table 3).

Table 2.
Effect of different combinations of wood ash liquid fertilizer on height (cm) of *Capsicum frutescens*

WALF levels (%)	2WAT	3WAT	4WAT
100	2.80±1.24^{b}	7.40±3.50^{b}	17.00±6.08^{ab}
75	2.60±1.17^{a}	6.00±3.11^{bc}	10.40±4.61^{b}
50	6.40±2.50^{a}	14.80±4.35^{a}	25.17±2.30^{a}
25	2.40±1.69^{b}	9.40±2.78^{b}	18.60±5.38^{ab}
Control (W)	6.20±1.20^{ab}	13.00±3.44^{ab}	23.20±3.57^{ab}
p<.05	0.04	0.02	0.03

Mean ± standard error followed by different superscripts in the same column are significantly different at p<.05 using Duncan's Multiple Range Test (DMRT) WALF = Wood Ash Liquid Fertilizer, W = Water, WAT = Week After Treatment

Table 3.
Effect of different combinations of wood ash liquid fertilizer on number of leaves of Capsicum frutescens

WALF levels (%)	1 WAT	2WAT	3WAT	4WAT
100	15.80±3.89^{c}	16.20±3.20^{b}	28.80±9.81^{ab}	44.60±13.58^{ab}
75	22.60±1.86^{ab}	22.80±4.87^{ab}	25.60±7.07^{b}	29.20±7.53^{b}
50	24.40±4.58^{a}	31.60±7.73^{a}	57.00±13.93^{a}	71.20±13.66^{a}
25	16.60±1.53^{d}	19.80±2.39^{ab}	29.00±5.03^{ab}	49.80±8.76^{ab}
Control (W)	20.20±.66^{b}	32.80±3.47^{a}	44.25±9.23^{ab}	58.16±8.47^{ab}
p<.05	0.01	0.03	0.04	0.01

Mean ± standard error followed by different superscripts in the same column are significantly different at p<.05 using Duncan's Multiple Range Test (DMRT) WALF = Wood Ash Liquid Fertilizer, W = Water.

Effect of wood ash liquid fertilizer on physiological indices of *C. frutescens*

Different levels of WALF modulate significant effects on physiological indices of the pepper. Leaf area (100.62 cm), specific leaf area (67.14 m^2kg^{-1}) and leaf area index (0.31 m^2m^{-2}) were recorded in the leaf of the *C. frutescens* treated with 50% WALF. Highest leaf area ratio (0.07 m^2kg^{-1}) and net assimilation rate (0.0078 $gm^{-2}day^{-1}$) were recorded in *C. frutescens* sprayed with 100% WALF while highest relative growth rate (0.05 mg $g^{-1}day^{-1}$) was recorded in pepper sprayed with 75% WALF (Table 4). Various percentage of WALF influenced number of fruits produced by the pepper grown under the treatments. 50% WALF produced the highest number of fruits (38) while least number of fruits (20) was produced in the pepper sprayed with 100% WALF (Figure 2).

Table 4.

Effect of different combinations of wood ash liquid fertilizer on leaf area (cm) of Capsicum frutescens

WALF levels (%)	LA (cm)	SLA (m^2kg^{-1})	LAI (m^2m^{-2})	LAR (m^2kg^{-1})	NAR ($gm^{-2}day^{-1}$)	RGR ($mgg^{-1}day^{-1}$)
100	72.20±13.86^{d}	47.23±4.43^{b}	0.13±0.04^{d}	0.07±0.03^{a}	0.00783±0.0027^{a}	0.02±0.01^{a}
75	89.60±12.01^{b}	67.14±6.75^{a}	0.26±0.03^{b}	0.06±0.01^{ab}	0.0021±0.0054^{a}	0.05±0.02^{a}
50	100.62±13.69^{a}	53.57±4.16^{ab}	0.31±0.01^{a}	0.03±0.01^{bc}	0.0018±0.00139^{a}	0.04±0.00^{a}
25	77.80±5.27^{c}	55.49±4.04^{ab}	0.22±0.01^{c}	0.04±0.01^{abc}	0.001±0.0040^{a}	0.03±0.01^{a}
Control (Water)	99.60±3.85^{ab}	53.54±3.50^{ab}	0.28±0.04^{ab}	0.02±0.00^{c}	0.00604±0.0018^{a}	0.03±0.01^{a}
p<.05	0.04	0.04	0.04	0.03	0.03	0.04

Mean ± standard errors followed by different superscripts in the same column are significantly different at p<.05 using Duncan's Multiple Range Test (DMRT). WALF = Wood ash liquid fertilizer, W = Water, LA = Leaf Area, SLA = Specific Leaf Area, LAI = Leaf Area Index, LAR = Leaf Area Ratio, NAR = Net Assimilation Ratio, RGR = Relative Growth Ratio.

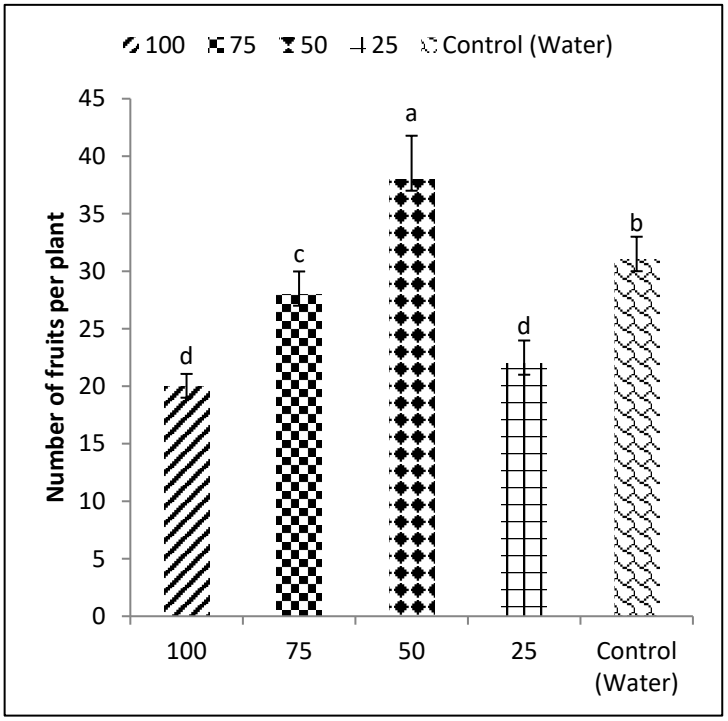

Figure 2.

Effect of different combinations of wood ash liquid fertilizer on number of fruits per plant (yield) of Capsicum frutescens. Differences in lowercase letters on bars in each week indicate significant differences among treatments at p<.05

Effect of wood ash liquid fertilizer on nutritional compositions of *C. frutescens* fruits.

Vitamin A (64.01 mg/100g), vitamin B3 (1.73 mg/100g), vitamin B5 (1.30 mg/100g), vitamin B6 (0.27 mg/100g) vitamin C (14.83 mg/100g), vitamin E (0.82 mg/100g) and vitamin K (44.15 mg/100g) were higher in the fruits of *C. frutescens* treated with 50% WALF (Table 5) Similar observation was noticed in sodium (11.17 mg/100g), potassium (363.92 mg/100g), calcium (108.14 mg/100g), magnesium (58.11 mg/100g) and phosphorus (81.00 mg/100g) in the fruits pepper (Table 6). In addition, moisture (68.32 %), dry matter (14.36 %) and fat (2.77 %), ash (3.55 %), crude fibre (2.49 %), crude protein (4.43 %) and carbohydrate (9.20) recorded in the fruits of the plant treated with 5 0% WALF (Table 7).

Effect of different percentage WALF on Phytochemical contents of *Capsicum frutescens*

Alkaloids (6.28 %), saponins (5.32 %), flavonoids (5.62%) and steroids (6.44 %) were higher in the fruits of the pepper treated with 75% WALF compared with other combinations of WALF (Table 8). This observation indicates that WALF had positive effects on the phytochemical contents of *C. frutescens* fruits.

Table 5.

Effect of different combinations of wood ash liquid fertilizer on Vitamin composition of Capsicum frutescens

WALF levels (%)	Vitamin Composition (mg/100g)						
	Vit A	Vit B3	Vit B5	Vit B6	Vit C	Vit E	Vit K
100	30.70±0.05^{e}	1.47±0.04^{b}	0.09±0.01^{b}	0.22±0.03^{b}	12.05±0.03^{e}	0.72±0.03^{b}	39.71±0.04^{e}
75	36.77±0.03^{d}	1.53±0.03^{ab}	0.07±0.00^{b}	0.22±0.03^{b}	12.81±0.01^{d}	0.75±0.06^{ab}	41.28±0.06^{d}
50	64.01±0.32^{a}	1.73±0.03^{a}	1.20±0.00^{a}	0.27±0.01^{a}	14.83±1.18^{a}	0.82±0.03^{a}	44.15±0.03^{a}
25	58.20±0.03^{b}	1.59±0.04^{ab}	0.10±0.01^{b}	0.23±0.01^{b}	13.97±0.00^{c}	0.75±0.05^{ab}	42.77±0.02^{c}
Control (W)	54.63±0.04^{c}	1.61±0.03^{ab}	0.09±0.00^{b}	0.20±0.00^{b}	14.73±0.03^{b}	0.76±0.00^{ab}	42.95±0.02^{b}
p<.05	0.04	0.02	0.01	0.01	0.02	0.04	0.01

Mean ± standard error followed by different superscripts in the same column are significantly different at p<.05 using Duncan's Multiple Range Test (DMRT) WALF = Wood Ash Liquid Fertilizer, W = Water

Table 6.
Effect of different combinations of wood ash liquid fertilizer on Mineral composition of Capsicum frutescens

WALF levels (%)	Mineral composition (mg/100g)					
	Sodium	Potassium	Calcium	Magnesium	Phosphorus	Zinc
100	9.59±.04^{d}	294.44±.04^{e}	93.46±.05^{e}	49.10±.04^{e}	76.31±.04^{d}	3.41±.03^{ab}
75	9.96±.06^{c}	304.69±.03^{d}	97.97±.03^{d}	49.74±.03^{d}	76.65±.03^{d}	3.41±.03^{b}
50	11.17±.03^{a}	363.92±.03^{a}	108.14±.10^{a}	53.11±.06^{a}	81.00±.33^{a}	3.50±.01^{ab}
25	10.75±.02^{b}	349.16±.02^{b}	107.41±.01^{b}	51.65±.02^{c}	78.04±.03^{c}	3.52±.03^{a}
Control (W)	10.73±.03^{b}	337.83±.02^{c}	106.24±.01^{c}	51.85±.01^{b}	79.53±.07^{b}	3.50±.04^{ab}
p<.05	0.01	0.00	0.04	0.02	0.03	0.01

Mean ± standard error followed by different superscripts in the same column are significantly different at p<.05 using Duncan's Multiple Range Test (DMRT), WALF = Wood Ash Liquid Fertilizer, W = Water

Table 7.
Effect of different combinations of wood ash liquid fertilizer on proximate of Capsicum frutescens

WALF levels (%)	Proximate (%)						
	Moisture	Dry Matter	Fat	Ash	Crude Fibre	Crude Protein	Carbohydrate
100	62.55±0.58^{ab}	9.40±0.03^{c}	2.46±0.13^{c}	3.09±0.00^{c}	2.34±0.01^{b}	4.14±0.01^{b}	7.06±0.01^{b}
75	60.82±0.01^{ab}	11.29±0.08^{ab}	2.69±0.00^{ab}	3.12±0.00^{c}	2.49±0.00^{a}	4.40±0.03^{a}	7.20±0.03^{b}
50	68.32±2.64^{a}	14.36±0.01^{a}	2.77±0.02^{a}	3.55±0.03^{a}	2.49±0.00^{a}	4.43±0.02^{a}	9.20±0.03^{a}
25	62.68±0.03^{ab}	10.49±0.03^{b}	2.54±0.02^{bc}	3.25±0.03^{b}	2.19±0.02^{c}	3.91±0.03^{c}	6.60±.003^{bc}
Control (W)	61.61±0.03^{ab}	10.48±0.03^{b}	2.68±0.03^{ab}	3.53±0.03^{a}	2.38±0.03^{b}	4.22±0.03^{b}	6.90±0.03^{bc}
p<.05	0.04	0.00	0.02	0.00	0.03	0.02	0.00

Mean ± standard error followed by different superscripts in the same column are significantly different at p<.05 using Duncan's Multiple Range Test (DMRT)WALF = Wood Ash Liquid Fertilizer, W = Water

Table 8.
Effect of different combinations of wood ash liquid fertilizer on Phytochemical contents of Capsicum frutescens

WALF levels (%)	Phytochemical contents (%)			
	Alkaloids	Saponins	Flavonoids	Steroids
100	5.82±0.11^{d}	2.33±0.01^{b}	5.57±0.2^{b}	6.35±0.11^{b}
75	6.28±0.31^{a}	5.32±0.02^{a}	5.62±1.01^{a}	6.44±0.2^{a}
50	6.08±1.20^{b}	2.33±0.00^{b}	5.54±0.5^{b}	6.32±1.1^{c}
25	6.87±1.01^{c}	2.34±0.03^{b}	5.51±0.2^{c}	6.34±1.01^{b}
Control (W)	3.45±0.23^{e}	1.12±0.12^{bc}	3.56±0.86^{d}	4.13±0.45^{d}
p<.05	0.04	0.04	0.00	0.01

Mean ± standard error followed by different superscripts in the same column are significantly different at p<.05 using Duncan's Multiple Range Test (DMRT)WALF = Wood Ash Liquid Fertilizer.

Discussion

The physical and chemical properties of the soil and wood ash liquid fertilizer

The assessment which indicted the soil used for growing the vegetable was acidic and although contain nutritional contents such as potassium, calcium, sodium and magnesium but at a low level informs that the soil needed nutritional supplements to augment the survival of the vegetable therefore, appreciable level of macro elements recorded in the wood ash liquid fertilizer may be used to augment the depleted nutritional contents of the soil (Verma et al., 2017). This observation denotes that wood ash liquid fertilizer can be an effective and sustainable soil amendment for *C. frutescens* cultivation. Sustainable soil management practices, such as the use of organic soil amendments have been recommended as proactive approach to address these challenges (Oyelade, 2015). One of such amendment is the use of wood ash being a by-product of wood industry rich in nutrients and minerals as observed by this study.

Effect of wood ash liquid fertilizer on agronomic characters of *C. frutescens.*

Higher growth parameters such as plant height and number of leaves observed to be significantly improved by the application of WALF most especially 50% WALF may indicate that the treatment contained higher nutritional contents required for maximum development of the morphological characters. Also, increase observed in the quantities of these nutrients in the soil might have contributed to the improvements observed in the agronomic characters of the pepper. This observation is in agreement with the submission of Parveen (2016) which revealed that wood ash can supply essential nutrients necessary for plant growth and development.

Effect of wood ash liquid fertilizer on physiological indices of *C. frutescens*

Higher physiological characters recorded in *C. frutescens* sprayed with 50% WALF could be attributed to the availability of nutrients in the 50% WALF. The increase observed in leaf area and specific leaf area could indicate that 50% WALF modulated surface area, enhanced formation of photosynthetic pigments, increased photosynthetic apparatus and yield of the pepper (Thakur & Connellan, 2013). The observation is also in agreement with the findings of Subedi & Ma (2005) and Rasheedat et al. (2017) who reported that leaf area is one of the major components influencing plant productivity, dry matter production and yields of plants.

Effect of wood ash liquid fertilizer on nutritional compositions of *C. frutescens* fruits.

Results indicate that nutritional compositions of the *C. frutescens* fruits were affected by varying percentage of wood ash liquid fertilizer. The fruits produced by pepper treated with 50% WALF produced higher levels of essential minerals such as potassium, calcium and magnesium as well as vitamins which are important for the development of flora. This result is consistent with findings of Thakur and Connellan (2013) and Achikanu et al. (2013) who opined that wood ash improved nutrient contents of crops.

Effect of different percentage WALF on Phytochemical contents of *Capsicum frutescens*

Substantial quantities of alkaloids, saponins, flavonoids and steroids observed in the fruits of the pepper treated with 50% WALF could indicate that fruits of the vegetable are hosts of appreciable therapeutic potential of *C. frutescens* as influenced by the treatments. This could be of high benefits to consumers (Odeyemi et al., 2021). The results of this study suggest that application of the varying percentage of WALF as a soil amendment can be a sustainable and effective approach towards the enhancement of growth and nutrition composition of *C. frutescens* fruits.

Conclusion and Recommendations

Results of this study demonstrated that although all the varying percentages of WALF investigated produced beneficial effects on the pepper, however, 50 and 75% WALF improved better the growth, yield and nutritional quality of *C. frutescens* fruits. Phytochemical contents were also recorded highest in *C. frutescens* fruits treated with 75% WALF. Therefore, sustainable usage of the forest product is advocated in commercial and subsistence farming practices to alleviate pepper demand.

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