

**Effects of water extracts of neem (*Azadirachta indica* L.) leaf,
wood ash and their mixture on soil chemical composition and
growth and yield of plantain (*Musa sapientum* L.)**

By

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ABSTRACT

Sustainable plantain production in the tropics is limited by continued decline in soil fertility, hence, an investigation was conducted between 2006 and 2009 to evaluate the efficiency of water extracts of neem (*Azadirachta indica* L.) leaf, wood ash and their 1:1 mixtures on soil chemical composition, growth and yield parameters of plantain (*Musa sapientum* L.) in Akure in the rainforest zone of Nigeria. There were treatments with water extracts of neem leaf, wood ash and their mixtures at 833.3 L ha⁻¹, NPK 15-15-15 fertilizer at 300 kg ha⁻¹ and a control (without any fertilizer or extract) replicated three times and arranged in a randomized complete block design. The results showed that there were significant ($P < 0.05$) increases in plantain plant height, leaf area, stem girth, leaf population, weight of plantain bunches, fingers weight, fingers diameter and population, total soil N, available P, exchangeable K, Ca

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Comment [D2]: What do these numbers mean? It should be explained.

24 and Mg under the different treatments compared to the control treatment. For the
25 growth parameters, the mixture of neem leaf and wood ash extracts increased
26 significantly ($P < 0.05$), the leaf area and stem girth of plantain by 49.24% and 12%
27 respectively compared to neem leaf extract. For the yield performance of plantain, the
28 mixture of water extracts of neem leaf and wood ash increased the bunch weight,
29 finger weight, diameter, length and finger population by 39%, 41%, 3%, 36% and
30 41.66% compared to neem leaf extract. Also, when compared with NPK 15-15-15
31 fertilizer, the mixtures of the two extracts increased plantain bunch weight, finger
32 weight, diameter, length and finger population by 29.7%, 31%, 6%, 8% and 25%
33 respectively. In addition, the mixture of water extract of neem leaf and wood ash
34 increased soil pH, organic matter (O.M), K, Ca, and Mg by 14%, 78%, 31%, 95.5%
35 and 94% compared to NPK 15-15-15 fertilizer except N and P. The soil K/Ca, K/Mg
36 and P/Mg ratios were higher under NPK 15-15-15 fertilizer than the liquid extracts
37 signifying nutrient imbalance. Mixture of water extracts of neem leaf and wood ash
38 gave the best growth and yield parameter of plantain and this was due to its nutrients
39 superiority compared to the other treatments.

40 **KEY WORDS:** Plantain (*Musa sapientum L*), low cost neem leaf, wood ash and 1:1
41 mixtures water extracts, improved soil chemical composition, growth and yield
42 performances..

Comment [D3]: It is not necessary.

Comment [D4]: Key words should be arranged alphabetically.

45 INTRODUCTION

46 | Plantain (*Musa sapientum* L.) belongs to the family Musaceae and it originated
47 from Malaysia. It is a herbaceous plant with short lived stalks which are corm like
48 rhizomes usually 1.8m tall. Plantain is a food crop eaten by people in the West, East
49 and Central Africa, it has become exportable crop which is consumed in Europe,
50 America and Asia. Plantain has high iron content, minerals and vitamins which
51 provide dietary needs of people for better health living and it is processed into
52 different food stuff such as plantain flour, snacks and chips which are highly sought
53 for in both local and international markets (1). Therefore, there is an enormous
54 increase in demand for the crop.

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55 Total world production of the plantain and banana is estimated to be over 16
56 million metric tonnes out of which estimated 12 metric tonnes are produced in Africa
57 annually. About 70million people in African region are estimated to derive more than
58 one quarter of their food energy requirements from plantain. (2). In Nigeria, there are
59 some yield reduction constraints such as decline in soil fertility, pests and diseases and
60 weeds infestation that limit expansion (3).

Comment [D6]: What does mean 'metric tonnes'? It is the same as 'tons'?

Comment [D7]: The same as above.

61 Apart from medicinal value, neem leaf extract has many uses in plant
62 protection and production. Neem leaf extract can inhibit soil nematodes (4). Products
63 derived from neem leaf can act as powerful Insect Growth Regulation (IGR) which
64 reduce insect growth in crops and plants. Thus, neem products can be used as neem
65 insecticide, neem pesticide, neem fumigant, neem fertilizer, neem manure, neem
66 compost, neem urea coating agent and neem soil conditioner (5), (6).Neem seed
67 extracts can reduce nitrification (7) of applied ammonium sulphate fertilizers and

68 leaching loss of nitrogen. Pot experiments showed that neem extract could increase
69 the use efficiency of chemical nitrogen significantly in soils (8).

70 In Bangladesh, wood ash is regularly used in banana plantations in terrace
71 areas. Farmers say wood ash prevents diseases and improves water use efficiency.
72 Wood ash is a good source of potash and lime; it also improves the pH of acidic soils
73 in a manner similar to agricultural lime (9). Wood ash had long been regarded as a
74 source of potassium for plant growth (1-13% K by weight) but it also contains
75 appreciable quantities of Ca (20-30%), P (0.3—0.4%), Mg (1—3%) and smaller
76 amounts of S, Mn, Fe, B, Cu and Zn (10).

77 Despite the economic importance of plantain to the nation, it is to note that
78 maximum yields of the crop have not been attained. This is because of the continuous
79 cultivation on the same piece of land without fertilizer application which has led to
80 decline in soil fertility (11). Besides, the present hectrage of plantain is very low
81 because of subsistence farming and poor agronomic knowledge on the part of farmers.

82 Efforts aimed at improving the yield and increasing the soil fertility led to the
83 uses of inorganic fertilizers but their use are limited by high cost especially by poor
84 farmers and the destruction of soil properties on continuous use (12). Further attempts
85 to find substitute for the use of chemical fertilizers led to the use of solid organic
86 fertilizers such as poultry, goat, pig and cattle manures to achieve sustainable
87 production but the problems of bulkiness and difficulty in the transportation of such
88 materials affected their adoption by farmers (13).

89 In view of the above facts, water extracts of wood ash, neem leaf and mixed
90 neem leaf and wood ash were applied at present to grow plantain. Except the works of

91 (14), (15) and (16) on the use of neem leaf and wood ash extracts to control pests in
92 maize and cowpeas and as source of fertilizers, there is scarcity of research
93 information on the uses of water extracts of neem leaf and their mixtures on the
94 growth and yield parameters of plantain.

95 The objectives of this study are to

- 96 i. Determine the effects of water extracts of wood ash, neem leaf + wood ash on
97 the growth and yield parameter of plantain.
- 98 ii. To determine the effect of the extracts on the soil chemical composition after
99 16 months of planting plantain.

100 **2.0 MATERIALS AND METHODS**

101 **2.1 Site description**

102 A field experiment to evaluate the effects of neem leaf extract , wood
103 ash extract and mixed extracts of neem leaf and wood ash on plantain in the
104 rainforest zone of Akure, Nigeria was conducted during 2006-2009.

105 The soil is sandy clay loam, skeletal, kaolintic,
106 isohyperthermicoxicpaleustalf (Alfisol) (17). The annual rainfall is between
107 1100 and 1500mm while the temperature ranged between 29^oC—32^oC.

108 **2.2 Collection and analysis of the extracts**

109 Wood ash and neem leaf were collected from the cassava processing unit and
110 neem leaf plantation in Federal College of Agriculture, Akure while the NPK 15-15-
111 15 fertilizer was purchased from Ondo State Agricultural Input Supply Agency. The
112 plantain suckers were collected from the Nigeria Institute for Agricultural Research,
113 Ibadan.

Comment [D8]: It should be explained.

114 | The preparation of neem leaf extract was done by weighing 10kg of fresh
115 | leaves, chopped into bits using a knife, immersed in a plastic container containing
116 | 50L of water, kept under a shade and properly covered. The solution was stirred
117 | every three days to allow proper leaching of the nutrients into the water until the 14th
118 | day. Thereafter, the leaf were carefully removed using a sieve of 2mm to obtain clean
119 | neem leaf extract and diluted at a ratio of 1:1 to reduce the concentration of extracts as
120 | well as preventing scorching of the plants. The application of the extracts is at 3L per
121 | plot (833.33L/ha).

Comment [D9]: Between values and units spaces should be introduced.

122 | Wood ash extract was prepared by weighing 10kg of sieved wood ash into
123 | 50L of water in a plastic container and thoroughly stirred with paddle every three
124 | days to enhance proper leaching of nutrients. This continued until the 14th day of
125 | setting up the experiment and the suspension was properly sieved to obtain clear wood
126 | ash extracts.

Comment [D10]: All values in entire text (including tables) should be restricted to one place after coma. With the exception of table 6

Comment [D11]: All units must be corrected. It should be L ha⁻¹. All units needing correction is marked with yellow.

127 | The wood ash extract was also diluted at a ratio of 1:1 with water to reduce the
128 | concentration and applied at 3L per plot. The remnants of wood ash solid components
129 | was properly disposed to prevent contamination of the environment.

130 | —Mixed water extract of neem leaf and wood ash was prepared by taking
131 | 50% of undiluted neem leaf extract and 50% of undiluted wood ash by volume, diluted
132 | at a ratio of 1:1 with water and applied at 3L per plot while the NPK 15-15-15
133 | fertilizer was applied at 300kg/ha. 5ml each of the filtered extracts of neem leaf, wood
134 | ash and mixed neem leaf + wood ash was analyzed for %N using microkjedahlmethod
135 | (18)while soluble P, K, Ca and Mg contents were determined (19).

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136 | **TABLE 1: The chemical analysis of the extracts used for the experiment**

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Quantity applied per plot (36m ²)	Quantity applied Per hectare
Neem leaf extract	3.56	0.83	1.67	0.77	0.75	3L/36m ²	833.3L
Wood ash extract	0.15	0.53	2.60	15.00	1.00	3L/36m ²	833.3L
Mixed neem leaf + wood ash extract	3.69	1.10	3.20	15.66	1.53	3L/36m ²	833.3L

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138 Table 1 presents the data on chemical composition of the extracts used for the
139 experiment. Mixed water extract of neem leaf and wood ash had the highest values of
140 % N, P, K, Ca and Mg compared to wood ash and neem leaf extracts (sole forms). The
141 sole form of neem leaf had better values of % N and P than wood ash extract while the
142 wood ash extract had higher values of % K, Ca and Mg than the neem leaf.

143 **TABLE 2: Total amount of nutrients kg/ hectare supplied by each extract and**
144 **NPK 15-15-15 fertilizer**

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Treatments	N	P	K	Ca	Mg
	Total kg/hectare				
Neem leaf extract	148.327	34.58	69.58	32.08	31.25
Wood ash extract	6.25	22.88	108.33	624.98	41.67
Mixed neem leaf +	153.74	45.83	133.33	625.47	63.75

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wood ash extract					
NPK 15-15-15	45.00	45.00	45.00	0.20	0.10

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149 | The amount of nutrients(total **kg/nutrient**) supplied by each extract; mixed neem leaf +
150 | wood ash, neem leaf, wood ash and NPK 15-15-15 fertilizer is also presented in Table
151 | 2. More nutrients were supplied by the extracts particularly the mixed extract of neem
152 | leaf+ wood ash than the NPK 15-15-15 and control treatments.

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153 | The quantities of nutrients supplied by the extracts were adequate for
154 | sustaining growth and yield of plantain in the field as reflected in the soil chemical
155 | composition after harvest of plantain.

156 | **2.3 Field experiment**

157 | The land was cleared, ploughed and harrowed, divided into plots and each plot
158 | size is 6m X 6m (36m²). Hybrid plantain suckers treated with nemagon(a.i.1, 2
159 | Dibromo-3-chloropropane) to control nematode were planted in early July, 2006 at a
160 | spacing of 2m X 2m.

161 | There were five treatments namely: neem leaf extract, wood ash extract, mixed
162 | extract of neem leaf + wood ash applied at **3litres/36m²plot**, NPK 15-15-15 fertilizer
163 | applied at 300**kg/ha** and a control treatment (no fertilizer nor extract), replicated three
164 | times and arranged in a randomized complete block design.

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165 Weeding operation was first done after three weeks of planting and continued
166 at three weeks interval until harvest. Five plants of sprouted plantain suckers were
167 sampled in each plot on which parameters for plant height (cm), leaf area (cm²), stem
168 girth (cm) and leaf population or number were taken every week starting from 2
169 weeks after establishment and this continued till 20 weeks after establishment.

170 The plantain started bearing inflorescence between 10—12 months after
171 planting and the first harvest for matured plantain bunches was done at 15th month
172 after establishment (November, 2007) and continued till early 2008. The following
173 yield parameters were taken weight of plantain fingers, length of fingers (cm) plantain
174 fingers diameter and plantain finger population. After harvesting, the plantain plots
175 were properly weeded and the growth continued till the second harvest in late
176 October, 2008 and April 2009.

177 Necessary agronomic practices such as propping up the plantain with sticks to
178 prevent being fallen off during storms in early year, also, the plants were sprayed with
179 Avesthrin (Cypermethrin 10EC at 10ml/10L of water) to prevent insect attack on the
180 leaves.

181 **2.4 Soil collection and analysis**

182 Thirty core samples were collected randomly from 0-15cm depth on the site
183 using soil auger, mixed thoroughly and the bulk sample was taken to the laboratory,
184 air-dried and sieved to pass through a 2mm screen for chemical analysis.

185 The soil pH (1:1 soil:water) and (1:2 soil:0.01M CaCl₂) solution was
186 determined by using a glass calomel electrode system-(20) while organic matter was
187 determined by the wet oxidation chromic acid digestion-(21). The total nitrogen was

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188 determined by the microkjedahl method (19) while available soil phosphorus (P) was
189 extracted by the Bray P-1 extractant and measured by the Murphy blue colouration
190 and determined on a spectronic 20 spectrophotometer at 882nm(22). Exchangeable
191 soil K, Ca and Ma were extracted with 1M NH_4OAc pH 7 solution. The K, Ca and Na
192 contents were determined with flame photometer while Mg was determined with an
193 atomic absorption spectrophotometer (AAS)(23).

Comment [D13]: Should it be 'nm'?

Comment [D14]: The full name should be added in brackets.

194 The soil exchangeable acidity (H^+ and Al^{3+}) were determined using 0.01M
195 HCL extractant and titrated with 0.01M NaOH(24) while the micronutrients (Mn, Cu,
196 Fe and Zn) were extracted with 0.1MHCl(25). The mechanical analysis of the soil %
197 silt, % clay and % sand textural determination was done by the hydrometer method
198 (26). The soil bulk density was determined by core method as described by (27).

199 After the experiment, soil samples were taken from each plot, air dried, sieved
200 with 2mm sieve, and analyzed for soil pH, organic matter (O.M), total N, available P,
201 exchangeable K, Ca and Mg as described earlier.

Comment [D15]: It is not necessary. Moreover, 0 (null) is not the same as O.

202 The soil properties before application of the treatments (initial soil fertility)
203 were presented in Table 3. According to the established critical levels for soil in South
204 West Nigeria, the soil is acidic pH 5.80 and low in soil organic matter compared to
205 critical levels of 3% (28). The soil nitrogen (%N) is 0.07 which was less than 0.15%
206 total nitrogen considered as optimum for crops (29). The soil available P is
207 5.10 mg/kgp considered as adequate for crop production (28).

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208 Exchangeable K, Ca, Mg and Na values were much lower than the critical level
209 of 0.2 mg/kg while the micronutrients were more than the established critical levels of

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210 | 5mg/kg Fe, 1.0mg/kg Cu, 5.0mg/kg Mn and 3.0mg/kg Zn (30). The soil bulk density
211 | was 1.60mgm⁻³ while the soil textual class is sandy loam.

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213 **TABLE 3: Soil properties before planting plantain**

Particulars	Values	Methods
Soil pH (H ₂ O)	5.80	Glass calomel electrode system (1)
Soil pH (0.01M CaCl ₂)	5.32	
Organic matter (%)	0.43	Wet oxidation chromic acid digestion (2)
Nitrogen (%)	0.07	Microkjedahl method (3)
Available P (mg/kg)	5.26	Bray P extractant (4)
Exchangeable Bases		1M NH ₄ OAc pH 7 (5)
K (mmol/kg)	0.10	
Ca ²⁺ (mmol/kg)	0.11	
Mg ²⁺ (mmol/kg)	0.09	
Exchangeable Acidity		0.01M HCL extractant (6) and titrated against 0.1M NaOH
H ⁺ (mmol/kg)	4.30	
Al ³⁺ (mmol/kg)	1.45	
Micronutrients		0.1M HCL extractant (7)
Fe (mg/kg)	8.50	
Zn (mg/kg)	3.80	
Cu (mg/kg)	2.00	
Mn (mg/kg)	1.80	
Particle Size Analysis (Soil Texture)		Bouycous Hydrometer method (8)
Sand (%)	79.50	
Silt (%)	14.70	
Clay (%)	5.70	
Bulk density (Mgm ⁻³)	1.60	
% Porosity	41.81	Core method (9)

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217 **2.5 Statistical analysis**

218 Analysis of variance followed by Duncan Multiple Range Test was done
219 according to (31)

220 **3.0 RESULTS**

221 **3.1 Treatment effects on growth and yield parameters of plantain**

222 There were significant increases ($P<0.05$) in the plant height, leaf area, leaf
223 population/number and stem girth (Table 4) as well as plantain bunch weight,
224 diameter of plantain fingers, length and population for two cropping years (Table 5)
225 under different fertilizer extracts compared to the control treatment.

226 Among the leaf extracts, the mixed of neem leaf + wood ash had the highest
227 values of plantain leaf area and stem girth while the neem leaf and wood ash extracts
228 (sole forms) had the highest values of plant height and leaf population/number
229 respectively. For example, mixed extract of neem leaf + wood ash treatment increased
230 the leaf area and stem girth by 49.24% and 12% respectively compared to neem leaf
231 extract. When compared with NPK 15-15-15 Fertilizer, the mixed extracts of neem
232 leaf + wood ash treatment increased slightly plantain plant height and stem girth by
233 1.0%, 32.60%, 13.8% and 13.8% respectively.

234 In 2007/2008 cropping season, the mixed extract of neem leaf + wood ash
235 treatment increased the plantain bunch weight, finger weight, diameter length and
236 finger population significantly ($P<0.05$) compared to other extracts. For example,
237 mixed extract of neem leaf + wood ash increased plantain bunch weight, finger
238 weight, diameter, length of fruit and population by 29.7%, 31%, 6%, 8% and 25%
239 respectively.

240 Generally, the plantain bunch weight, diameter and length of fingers increased
241 significantly in 2008/2009 cropping season under the mixed extract of neem leaf +
242 wood ash more than 2007/2008 except plantain finger population and weight of
243 fingers.

244 **TABLE 4: Effect of the treatments on the growth parameters of plantain**

Treatments	plant height(cm)	Leaf area(cm²)	leaf population/ number	Stem girth(cm)
Control	45.60a	1454.60a	4.60a	17.68a
Wood ash extract	81.30b	4790.59d	8.20cd	29.39bc
NPK 15-15-15	85.90bc	3601.51c	6.30b	28.41b
Neem leaf extract	91.20d	2712.81b	6.83b	28.08bc
Mixed neem leaf + wood ash extract	86.50c	5344.17e	7.31c	32.96d

245

246 Treatment means within each group followed by the same letters are not
247 significantly different from each other using Duncan Multiple Range test at 5% level.

248

249 **Table 5: Effect of the treatments on the yield parameters of plantain**

Treatments	Cropping year	Weight of plantain bunch (kg/ha)	Weight of plantain fingers (kg/ha)	Diameter of plantain fruit finger (cm)	Length of fruit finger (cm)	Plantain finger population
Control	Nov 2007	2772.70a	2221.60a	2.2a	10.90a	9.0a
Wood ash	/Mar 2008	11529.45c	10555.25d	6.5b	20.30dc	28.00cd
NPK15-15-15		12496.5d	11215.65d	6.4b	17.80b	27.00c
Neem leaf		10833.30b	9580.65b	6.6bc	18.60bc	21.00b
Mixed neem		17777.5d	16495.45e	6.8d	19.3d	36.00c
leaf + wood ash extract						
Control	Nov 2008	2752.70a	2220.60a	2.8a	13.60a	10.00a
Wood ash	/Mar 2009	11941.10c	10833.33c	6.9bc	29.8c	27.00d
NPK15-15-15		12079.95d	10833.33c	5.8b	26.3b	26.00c
Neem leaf		9580.65b	8611.00b	6.3d	27.8c	23.00b
Mixed neem		24165.95e	11944.10d	7.7d	28.3cd	29.00c
leaf + wood ash extract						

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250 Treatment means within each column followed the same letters are not

251 significantly different from each other using Duncan Multiple Range Test at 5%

252 **3.2 Treatment effects on soil properties after harvest of plantain**

253 There were significant increases ($P<0.05$) in the total N, available P,
254 exchangeable K,Ca, Mg and organic matter (0.4) under different fertilizer extract
255 compared to the control treatment after harvest of plantain (16 months after
256 establishment) Table 6.

Mixed extract of neem leaf + wood ash treatment increased the soil organic matter (0.4), N, P, K, Ca and Mg by 16.00%, 15.7%, 19% and 16.9% compared to the neem leaf extract. When compared with NPK 15-15-15 fertilizer, the mixed extract of neem leaf + wood ash increased soil pH, 0.4, K, Ca and Mg by 14%, 2.78%, 31%, 95.3% and 94% except N and P.

The NPK 15-15-15 fertilizer decreased significantly the soil Ca and Mg while the control treatment had the least values of the soil parameters (soil pH, 0.4, N, P, K, Ca and Mg). The soil K/Ca, K/Mg and P/Mg ratios were 5:1, 6:1 and 346:1 respectively under NPK 15-15-15 Fertilizer compared to soil K/Ca 1:3, 1:2, 10:1 under mixed extract of neem leaf + wood ash respectively.

Table 6: Effect of the treatments on soil properties after harvest of plantain

Treatments	Soil pH	0.4 %	N %	P mg/kg	K mmol/kg	Ca mmol/kg	Mg mmol/kg
Control	5.20a	0.28a	0.03a	1.60a	0.03a	0.03a	0.06a
Wood ash extract	6.60e	1.45c	0.06b	7.00cd	0.36cd	1.15d	0.75c
NPK15-15-15	5.36ab	0.37d	0.23d	11.73ab	0.29b	0.06ab	0.05a
Neem leaf extract	6.20c	1.4c	0.06b	6.83c	0.34c	0.85c	0.69b
Mixed neem leaf + wood ash extract	6.24d	1.68d	0.08c	8.10e	0.42e	1.29e	0.83de

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Treatments within each column followed by the same letters are not significantly different from each other using Duncan Multiple Range Test at 5%

271 4.0 DISCUSSION

272 The fact that NPK 15-15-15 fertilizer improved the vegetative growth
273 parameters such as plant height, leaf area, leaf population of plantain is consistent
274 with its better soil N and P nutrients which are made much more readily available in
275 mineralised forms than the organic forms in the neem leaf, wood ash extracts and
276 mixed extract of neem leaf + wood ash.

277 The decrease in soil Ca and Mg in plots treated with NPK 15-15-15 fertilizer
278 could be due to nutrient imbalances reflected in high K/Ca, K/Mg and P/Mg
279 ratios which consequently affected uptake of Ca and Mg by plantain. In addition, the
280 low values of soil organic matter (O.M), Ca and Mg under the NPK 15-15-15 fertilizer
281 plot signified low base saturation, and the sandy loam texture also encouraged soil
282 leaching activities and poor nutrients retention.

283 These observations could explain the reduction in values of plantain growth
284 and yield parameters i.e. plant height, leaf area, stem girth, leaf population, weight of
285 plantain bunches, weight of plantain fingers and fingers population under the NPK 15-
286 15-15 fertilizer compared to the mixed extract of neem leaf + wood ash treatment
287 which contained Ca, Mg and organic matter (O.M) and subsequently increased soil
288 fertility status for higher values of growth and yield parameters of plantain. (32)
289 reported that continuous use of ammonium sulphate and NPK 15-15-15 Fertilizer
290 decreased soil pH, K and macronutrients in okra, also (33) reported that arbitrary
291 use of inorganic fertilizers resulted into signs of toxicities, poor yield responses and
292 deterioration of soil properties in okra.

293 The performance of neem leaf extract in improving the growth and yield
294 parameters of plantain could be traced to its high N, P, K, Ca and Mg nutrients
295 | supplied to the soil which subsequently increased the soil [organic matter0.4](#), total N,
296 available P, exchangeable K, Ca and Mg.

297 This also reflected in the increased values of the plant height, leaf area, stem
298 girth, leaf population, plantain bunch weight, fingers weight, length, diameter and
299 population. The finding was also supported by (8) who reported that neem seed extract
300 enhanced the nitrogen use efficiency in soils as well as increasing the yield of crops.
301 Also, (34) also reported the use of neem leaf extract increased soil nutrients, growth
302 and yield parameters of tomato.

303 In addition, the moderate potassium content of neem leaf extract also
304 contributed to better performance of plantain yield parameters and this was supported
305 by (35) who reported the vital role of potassium in crop production.

306 The wood ash extract increased the values of plantain bunch weight, weight of
307 fingers, diameter, length and finger population more than neem leaf and this could be
308 traced to its very high K, Ca and Mg nutrients which subsequently increased the soil
309 | [organic matter0.4](#), K, Ca and Mg for uptake by plantain. This finding was supported
310 by (36) who reported that wood ash is a good source of potash and lime which
311 encouraged the growth and yield of plantain.

312 The increase in soil pH under wood ash extract compared to others was traced
313 to its high K, Ca and Mg and could be effective as a liming material (37) unlike the
314 NPK 15-15-15 fertilizer which with the continuous use could decrease soil pH. The
315 soil pH been reported to influence nutrient uptake and availability. (38) reported that

oil palm bunch ash, wood ash and cocoa pod husk improved soil K, Ca and Mg nutrients and corrected soil acidity in an Alfisol grown to coffee and maize. (39) also reported that industrial wood ash was a good soil amendment for crop production.

The highest values of plantain bunch weight, weight of fingers, diameter of finger, length of fingers and finger population under the mixed extract of neem leaf + wood ash treatment could be due to the fact that it had the combined nutrient superiority of P, K, Ca Mg and N compared to neem leaf and wood ash extracts applied in sole forms. Therefore, the positive impact of extract of neem leaf + wood ash also reflected in the increase in soil pH, organic matter~~O-M~~, N, P, K, Ca and Mg and the subsequent uptake by the plantain.

Hence, the impact of the mixed extract on the soil properties has been responsible for high yield parameters, plantain bunch weight, finger weight, diameter and length of fingers and finger population which further signified higher economic returns, food security and profitability for plantain farmers as well as providing raw materials to establish plantain flour, chips and biscuit industries. It is believed that this would promote plantain values chain development for export trade.

The observation was supported by (34) who reported superior performance of mixed extract of neem leaf + wood ash treatment in maize and water melon intercrop. ~~Beside~~Besides, the uptake of nutrients (N, P, K, Ca and Mg) in a liquid form from the mixed extract of neem leaf + wood ash could also be responsible for better plantain yield performance over the solid organic fertilizers which must be ~~mineralised~~mineralized with adequate moisture before uptake by plant roots. Also, it has residual values which would have contributed to plantain bunch weight in the

339 | 2nd cropping year which NPK 15-15-15 fertilizer did not ~~posses~~[possess](#) for subsequent
340 cropping.

341 The poor growth and yield performance of plantain in the control treatment was
342 consistent with the fact that the soil was very low in nutrient contents and this
343 observation was supported by (13) who reported poor growth and yield responses of
344 crops in soils that are not fertilized. The lowest values of soil N, P, K, Ca and Mg in
345 the control treatment were a reflection of poor soil fertility status, hence, there is need
346 to ensure fertilization of soils for bumper crop productivities in the tropical region
347 | where soils are low in organic matter, K, Ca, Mg and low soil pH- (12).

348 In term of nutritional status, plantain has high iron, minerals and vitamins
349 contents which helped to build up both physiological and metabolic activities in the
350 body when consumed by people. This will reduce money spent on purchase and
351 consumption of iron and vitamins based drugs and this observation was in line with
352 meeting millennium development goals (MDGs) in food security and sound health for
353 people in the world.

354

355 5.0 CONCLUSION

356 It could be concluded from the research work that mixed extract of neem leaf +
357 wood ash treatment gave the highest values of plantain growth and yield parameters
358 | and also improved the soil nutrients (soil N, P, K, Ca, Mg and [organic matter](#)~~0.4~~^{0.4})
359 compared to NPK 15-15-15 fertilizer, neem leaf and wood ash extracts (sole forms)
360 respectively. It is recommended that for better performance of plantain bunch weight,
361 finger weight, finger diameter and length, growth parameters and improvement of soil

362 | fertility status, application of mixed extract of neem leaf + wood ash at 833.3L/ha is
363 | appropriate.

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364 | Hence, the use of mixed extract of neem leaf + wood ash could substitute for
365 | 300kg/ha of NPK 15-15-15 Fertilizer and it also reduced the problems of high cost of
366 | purchasing the inorganic fertilizer as well as solving problems of bulkiness and
367 | difficulty in the transportation of solid organic waste. Finally, it will help to prevent
368 | environmental pollution and deterioration of soil properties associated with
369 | continuous use of inorganic fertilizers such as NPK 15-15-15 fertilizers.

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Comment [D17]: The reference list must be accurately checked and prepared according to AJEA requirements.

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COMPETING INTERESTS

There is no competing interests exist.

AUTHORS' CONTRIBUTION

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ETHICAL APPROVAL

The study is not against the public interest.