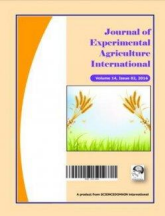

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Assessment of Wood Ash Application on Yield Advantage Indices of Maize and Lima Beans in an Intercrop

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Authors' contributions

This work was carried out in collaboration among all authors. Author ROA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAA and AJA managed the literature searches. Author BFD managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Alternate planting combinations of maize (*Zea mays* L.) with lima bean (*Phaseolus lunatus* L.) using wood ash as soil amendments were compared with the sole planting of each crop during the late 2014 and early 2015 planting seasons at the Teaching and Research Farm of the Federal University of Technology, Akure. The experiment in each season adopted three patterns of intercropping using ash as a soil amendment and laid out in a Randomized Complete Block Design (RCBD) with three replications. The experiment comprised 10 treatments: Sole planting of maize amended, sole planting of maize unamended, sole planting of lima beans amended and sole planting of lima beans unamended. Others were; 75:25 maize-lima beans amended, 75:25 maize-lima beans unamended, 50:50 maize-lima beans amended, 50:50 maize-lima beans unamended, 25:75 maize-lima beans amended and 25:75 maize-lima beans unamended. Wood ash was applied two weeks after planting at the rate of 2.4 kg (4 tons per hectare) to each plot. The combined yield advantage in terms of land equivalent ratio (LER) indices was greatest (1.95) in the case of 3 rows

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of maize and 1row of lima beans intercropping arrangements. Competition indices (CR) for all crops in all intercropping arrangements were more than 0.1 indicating that both crops were equally competitive. However, crop aggressivity (A) showed that maize was more dominant than lima beans due to plant population. Costs and returns analysis revealed that maize and lima beans intercropping at all proportions were more profitable than their corresponding monocrops.

Keywords: Costs and returns analysis; crop aggressivity; Intercropping; monocrop; land equivalent ratio.

1. INTRODUCTION

Farmers practice different cropping systems to increase productivity and sustainability [1]. Intercropping is the simultaneous growing of two or more crops in the same field and it is a common practice that dates back to ancient time in the tropics and rain-fed areas worldwide, [2]. Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources. Legumes can transfer fixed N which is a major nutrient required by intercropped cereals, [3].

It increases total productivity per unit area through maximum utilization of land, labour and growth resources. Intercropping system is commonly practised among smallholder farmers due to the ability of the legume to cope with soil erosion and with declining levels of soil fertility, [4].

Inorganic fertilizers, which are the principal source of N to farmers, are often times overused or applied incorrectly thereby leading to the buildup of phosphorus and potassium on the surface of the soil, [5]. This makes the soil to become acidic leading to a reduction in crop yields. Therefore, it became necessary to maintain and improve soil fertility with minimal damage to the soil, [6]. This cannot be exclusively carried out through the use of predictable inorganic fertilizers. A combination of inorganic fertilizers with available organic fertilizers such as wood ash, manure and herbaceous legume plant residues can be used with minimal damage to the soil, [7]. Wood ash adjusts soil pH and supplies a substantial amount of several plant nutrients especially calcium and potassium, [8]. When applied as a soil amendment, it improves crop to increase by decreasing the availability of heavy metals.

Competition in intercropping is a major factor which influences crop performance and yield relative to sole cropping, [9]. Various indices such as relative yield (RY), land equivalent ratios (LER), competitive ratios (CR), aggressivity (A), and cost and return analysis have been developed to describe the competition and possible economic advantage in intercropping, [10]. Therefore, the objectives of this study were to examine the effects of competition between maize and lima beans in an intercropping system using yield advantage indices and to determine the profitability of intercropping of both crops for better economic returns.

2. MATERIALS AND METHODS

2.1 Study Site

Field studies were carried out in 2014 and 2015 at the Teaching and Research Farm of the Federal University of Technology, Akure. Nigeria. The study area is situated at latitude $7^{o}16$ N and longitude 5°12 E located in the tropical rain forest vegetation zone of southwestern Nigeria. It has an average annual rainfall of about 1613mm per annum and an annual mean temperature of about 27°C. The first experiment was carried out in the late season (September to February 2014) while the second experiment was conducted in the early season (April to September 2015). The experimental site which was previously dominated by weeds was thoroughly ploughed to a depth of 30 cm, harrowed and later sprayed with herbicide to control weeds before the seeds were sown. There were 10 plots each measuring 2 m x 3 m (6 m^2) with 1m guard rows within experimental units and between blocks. Soil samples were collected randomly from the plots to a depth of 0-20 cm and bulked into a composite sample for laboratory analysis of the physical and chemical properties of the soil (Table 1).

Table 1. Nutrients status of experimental site before planting and after harvest of maize and lima beans

Year		Soil physical properties						Soil chemical properties			Ca	Mg	Na
		Sand	Silt	Clay	pH	Org.Matter	Org. Carbon	Total N	Avail. P	K			
		(g/kg^{-1})	(g/kg^{-1})	(g/kg^{-1})		(%)		(g/kg^{-1})	(mg/kg^{-1})	Exchangeable cations ($cmol/kg^{-1}$)			
2014	Before planting	40.8	22	37.2	5.87	2.28	1.32	0.42	26.67	0.62	11.4	5.2	0.46
	After harvest	32.8	20	47.1	6.32	1.42	0.82	0.14	7.93	0.25	2.4	1.1	0.34
2015	Before planting	56.87	32.29	40.11	6.25	8.32	11.45	1.05	37.59	0.72	15	7.34	3.4
	After harvest	48.87	30.37	52.54	8.74	6.3	9.81	0.79	19.06	2.35	6	2.94	3.12

2.2 Sample Collection

Yellow maize variety (Pop 66- SR/Acr 91 Suwan 1- SR) were procured from the school farm of Federal University of Technology, Akure, while lima beans seeds were obtained from a reputable seed store in Isua Akoko Local Government Area, Ondo state, Nigeria.

2.3 Collection and Chemical Analysis of Wood Ash

Wood ash was collected from a saw mill at Orita Obele in Akure South Local Government Area. The ash was air dried and sieved to pass a 2-mm sieve in order to remove dirt. The ash was analyzed before planting and after harvesting for organic carbon, N, P, K Ca, and Mg (Table 2).

2.4 Experimental Design

Maize and lima beans were the two crops used in this study. Two seeds of each crop were sown on the same day per hole and later thinned to one per stand at a spacing of 75 cm x 25 cm and 70 cm x 25 cm, respectively. The experimental treatments were: (1) sole maize amended; (2) sole maize unamended; (3) sole lima beans amended; (4) sole lima beans unamended; (5) 75:25 maize-lima beans amended; (6) 75:25 maize-lima beans unamended; (7) 50:50 maize-lima beans amended; (8) 50:50 maize-lima beans unamended; (9) 25:75 maize-lima beans amended and (10) 25:75 maize-lima beans unamended. Sole maize and lima beans were established to determine the productivity of the system. There were three replicates arranged in a Randomized Complete Block Design. Maize and lima bean plants were randomly selected and labelled appropriately for measurement. Weeding was done at 3, 6, 9, and 12 weeks after planting (WAP). The experiment each year was terminated at 12 weeks after planting when the maize cobs were fully matured for consumption, while the lima beans pods were harvested 24 weeks after planting.

At maturity, the following yield components of both crops were determined: number of fresh cobs per plant, the weight of 1000 grains per cob and grain yield of maize plants. Also collected were data on lima beans: number of pods per plan, the weight of seeds and legume grain yield.

Crop mixture productivity from the mean yield data of both sole and intercropping systems was determined using the following indices:

Relative yield (RY): The relative yield of a crop is its yield or biomass in an intercrop expressed as a ratio as its yield in monoculture, [11]. It is expressed as:

$$RY = \frac{Ya}{Sb}$$

Where Ya is the individual component crop yield in the mixture and Sb is the individual component crop yield in the sole crop.

Land Equivalent Ratio (LER): The concept of land equivalent ratio is the total land area or growth resources of a monocrop required to achieve the same yield as a bi-crop or intercrop, [12].

$$LER = Lx + Ly = \ Ax/Px + \ Ay/Py$$

Where, Lx and Ly are the individual LER's of crops x (maize) and y (lima beans); Ax and Px are yields of intercropped maize and lima beans, respectively, while Ay and Py are yields of sole maize and lima beans, respectively. The values of LER greater than 1 indicate a yield advantage [13].

Competitive Ratio (CR) is proposed as a measure of intercrop to indicate the number of times by which one component crop is more competitive than the other. In a two-crop association, the competitive ratio (CR) is calculated by simply dividing the individual LER of one crop by that of the other crop, and correcting the result according to the space assigned to each crop, [12].

$$CRx = \ (Ax/Mx)\ (Ay/My)\ \ (Sy/Sx)\ )$$

Where, Ax and Ay are the yields of crops maize and lima beans in the association, and Mx and My represent the respective single culture yields. Sy is the relative space occupied by crop y (lima beans), and Sx is the relative space occupied by crop x (maize).

Crop Aggressivity (A) is another index to test yield advantages of two crop species when grown in multiple cropping systems. Yield advantages of two crop species grown together can be calculated by using the following equation described by Ghosh et al., [14]:

$$A_{ab\ Cereal}=\left(\frac{Yab}{Yaa\ X\ Zab}\right)-\left(\frac{Yba}{Ybb\ X\ Zba}\right) \quad A_{ba\ Legume}=\left(\frac{Yba}{Ybb\ X\ Zba}\right)-\left(\frac{Yab}{Yaa\ X\ Zab}\right)$$

Table 2. Nutrients composition of wood ash

Year	Total N (g/kg-1)	Available P (mg kg^{-1})	Exchangeable cations (cmol kg^{-1})			
			K	Ca	Mg	Na
2014	0.06	9.12	9.70	52.47	3.60	4.20
2015	0.48	12.47	11.74	65.90	5.93	6.00

Central Laboratory, Federal University of Technology, Akure, Nigeria

Where, Yaa and Ybb are yields of maize and lima beans as sole crops, while Yab and Yba are the yields of maize and lima beans as intercrops. zba and Zab are the sown proportions of maize and lima beans. An aggressivity value of zero indicates that the component species are equally competitive. For any other situation, if the value of A_{ab} is positive, then maize is dominant in the intercrop, but if the value of A_{ba} is negative, then lima beans are the dominated crop in the mixture. The greater the numerical value, the wider the difference in competitive abilities [14].

The area-time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercrops

$$ATER = \frac{(RY_a \times Ta) + (RY_b \times Tb)}{T}$$

Where

RY_a = Relative yield of component A (maize) in mixture

Ta and Tb = duration (in days) of components A and B

RY_b = Relative yield of component B (lima beans) in mixture

T = Total duration of the intercropping system in days

ATER > 1 implies yield advantage while ATER < 1 indicates yield disadvantage

Cost and return analysis: Farm budgeting analysis was employed to determine the profitability of maize and lima beans base on their various crop proportions in the intercropping system. The costs incurred from planting to harvesting the component crops which include variable costs and fixed costs of production were specified.

The total cost component is expressed as:

TC=TFC+TVC
TR=PQ
II=TR-TC

Where, TC=Total cost of producing maize and Lima beans in Naira per hectare, Profit (II) = Net return on maize and lima beans production in Naira per hectare.

TVC= Total variable cost of production per hectare in Naira. It includes the costs of seeds, ploughing and harrowing, herbicide application, labour use, harvesting and transportation.

TFC= Total fixed cost of production which include interest on the land rental value in Naira per hectare.

TR= Total revenue from maize- lima beans production in Naira. P= Unit price of maize and lima beans in Naira.

The Q= Total quantity of maize and Lima beans in a kilogram.

2.5 Statistical Analysis

All the data collected during the experimental period were statistically analyzed using two-way analysis of variance (ANOVA). Means were compared using Duncan's New Multiple Range Test at 5% level of probability.

3. RESULTS

3.1 Yield and Yield Components

Results of data analysis show that there were significant differences ($p<0.05$) amongst the treatments in the number of cobs for both seasons (Table 3). On the average, two cobs per plants were observed during the early season planting, however, one cob per plant was observed during the late season. This may be due to the short supply of rainfall. For the weight of 1000 grains, significant differences were observed between each treatment with the least weight obtained from the unamended 25:75 maize-lima bean intercrop (Table 3). Essentially, in terms of yield components, maize monocrop gave more yield than all the intercrops. This may be due to the effect of no competition for growth resources like water and sunlight.

Table 3. Yield components of maize and lima beans in the alternate row intercropping system in 2014 and 2015 cropping seasons

Crop	Yield	Amended 100% M	Unamended 100%M	Amended 75M:25L	Unmended 75M:25L	Amended 50M:50L	Unamended 50M:50L	Amended 25M:75L	Unamended 25M:75L	Amended 100%L	Unamended 100%L
2014											
Maize	Number of cobs per plant	1.67ab	1.56ab	1.67ab	1.56ab	2.00a	1.67ab	1.78ab	1.78ab	-	-
	Weight of grains per cob	67.56a	59.11ab	55.11b	52.22bc	50.89bc	47.33c	28.49cd	22.22d	-	-
	Grain yield ($^{-1}$)	1910.23	1906.18	1877.96	1815.11	1757.38	1718.92	1542.74	1536.32	-	-
Lima beans	Number of pod per plant	-	-	74.33ab	70.56b	65.11c	60.33d	55.67ef	52.89f	80.89a	77.78ab
	Weight of pods per plant	-	-	25.21abc	21.86bc	19.87a	16.90abc	13.83bc	10.36d	30.95ab	27.94cd
	Legume grain yield ($^{-1}$)	-	-	591.59	585.63	378.08	321.19	262.52	222.40	675.46	593.77
2015											
Maize	Number of cobs per plant	2.00a	2.00a	2.00a	2.67b	2.00a	2.00a	1.78ab	1.78ab	-	-
	Weight of grains per cob	90.89a	89.33a	74.81b	72.56b	70.11b	69.43b	62.26bc	54.89c	-	-
	Grain yield ($^{-1}$)	18665.12	18612.88	18226.64	18191.90	18081.75	18021.78	15644.00	18310.42	-	-
Lima beans	Number of pod per plant	-	-	66.11c	61.44c	89.00b	86.22ab	92.22b	90.56b	99.89a	97.78b
	Weight of pods per plant	-	-	27.71d	25.47d	32.76c	30.90cd	38.20b	34.86bc	47.93a	41.94b
	Legume grain yield ($^{-1}$)	-	-	592.05	585.21	628.44	605.35	742.59	711.91	908.03	893.67

Means having the same letters in the column were not significantly different

Amended and unamended lima beans monocrop recorded significant results more than the corresponding intercrops in the number of pods (Table 3). For the weight of pods, amended 75:25 lima bean-maize differed significantly than the other intercrops. However, there were no significant differences observed between the amended and unamended 50:50 lima bean-maize intercrop. This might be due to the equal number of rows and plant population in the intercropping system. Amended monocrop lima beans recorded significantly highest values for legume grain yields while the unamended 25:75 lima bean-maize recorded the lowest values.

3.2 Crop Productivity

The RY of both crops recorded low values in the late season growth but progressively increased during the early season. Amended 75% maize recorded high RY of 1.03 while 50% and 25% had the same value of 1.00. However, in all lima beans combinations, the RY was lower than one, with the lowest from 25:75 lima beans-maize intercrop.

As shown in Table 4, the LER substantially exceeded that of the sole production of both maize and lima beans during the two seasons of growth. The results obtained with respect to the Land Equivalent Ratios (LER) showed that combinations of the component species in the mixture namely, maize and lima beans were more productive (1.95) than the same species when grown as sole crops. The LER in most cases were greater than one which can be interpreted as an advantage of intercropping over the sole. More land area was saved by intercropping irrespective of treatments and crop mixture. The percentage land saved from intercropping ranged from 33% to 46% in the early season and from 16% to 47% during the late season.

The competitive ratio calculated showed that in 2014 cropping season, maize at all combination competed better than their corresponding intercrop. The unamended 25:75 maize-lima beans intercrop combination had lower values, indicating that lima bean was more competitive in this mixture.

Table 4. Combined yield advantage and competitive indices of maize-lima beans in an alternative row intercropping system in 2014 and 2015 cropping seasons

Treatments	Relative yield (RY)		Land equivalent ratio (LER)		Competitive ratio (CR)		Aggressivity (A)		Area time equivalent ratio (ATER)
	M	L	M	L	M	L	M	L	
2014									
Amended 100% M	-	-	-	-	-	-	-	-	-
Unamended 100% M	-	-	-	-	-	-	-	-	-
Amended 75 M:25 L	0.99	0.88	1.95	1.95	0.21	0.08	2.09	-2.09	0.91
Unmended 75 M:25 L	0.96	0.99	1.87	1.87	0.18	0.08	1.87	-1.87	0.98
Amended 50 M:50 L	0.92	0.56	1.48	1.48	0.30	0.06	1.28	-1.28	0.68
Unamended 50 M:50 L	0.91	0.55	1.46	1.46	0.31	0.07	2.17	-2.17	0.67
Amended 25 M:75 L	0.81	0.39	1.20	1.20	0.39	0.07	-0.36	0.36	0.53
Unamended 25 M:75 L	0.81	0.38	1.19	1.19	0.39	0.08	-0.32	0.32	0.52
Amended 100% L	-	-	-	-	-	-	-	-	-
Unamended 100% L	-	-	-	-	-	-	-	-	-
2015									
Amended 100% M	-	-	-	-	-	-	-	-	-
Unamended 100% M	-	-	-	-	-	-	-	-	-
Amended 75 M:25 L	1.03	0.82	1.85	1.85	0.23	0.09	2.27	-2.27	0.89
Unmended 75 M:25L	1.03	0.79	1.82	1.82	0.25	0.10	2.30	-2.30	0.86
Amended 50 M:50 L	1.00	0.64	1.69	1.69	0.29	0.06	0.62	-0.62	0.76
Unamended 50 M:50 L	1.00	0.68	1.69	1.69	0.28	0.06	0.65	-0.65	0.78
Amended 25 M:75 L	0.87	0.66	1.53	1.53	0.25	0.05	-1.09	1.09	0.73
Unamended 25 M:75 L	0.85	0.66	1.43	1.43	0.24	0.04	-1.12	1.12	0.72
Amended 100% L	-	-	-	-	-	-	-	-	-
Unamended 100% L	-	-	-	-	-	-	-	-	-

Table 5. Cost and return analysis per hectare

Treatments		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Grain Yield(kg/ha)	Lima	908.03	893.67	742.59	711.81	628.44	605.35	593.05	585.21	-	-
	Maize	-	-	15644.00	15310.42	18085.50	18021.78	18226.64	18191.90	18665.12	18612.88
Revenue		N454,015	N446,835	N2,717,895	N2,632,468	N3,027,087	N3,005,942	N3,030,521	N3,021,255	N2,799,768	N2,791,932
Variable Cost		-	-	-	-	-	-	-	-	-	
seed		13.84	13.84	11.45	11.45	7.73	7.73	3.82	3.82	3.79	3.79
Ploughing & Harrowing		N12,000	N12,000	N12,000	12,000	N12,000	N12,000	N12,000	N12,000	N12,000	N12,000
Weeding		N15,000	N15,000	N15,000	N15,000	N15,000	N15,000	N15,000	N15,000	N15,000	N15,000
Herbicide Application		N10,00//0	N10,000	N10,000	N10 ,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000
Harvesting & Transportation		N10,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000
Marketing & Miscellaneous		N10,000	10,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000	N10,000
Total VC		57,013.84	57,013.84	57,011.45	57,011.45	57007.73	57,007.73	57003.82	57,003.82	57,003.79	57,003.79
Fixed TC		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Total Cost		67,013.84	67,013.84	67,011.45	67,011.45	67,007.73	67,007.73	67,003.82	67,003.82	67,003.79	67,003.79
Profit		387,001.16	379,821.16	2,650,883.55	2,565,456.55	2,960,079.27	2,938,934.27	2,963,517.18	2,954,221.18	2,732,764.21	2,724,928.21
Grain Equivalent		871.70	857.93	14,792.49	14,462.72	16,277.21	16,219.61	16,403.98	16,372.71	16,798.61	16,751.56

Legend: T1 = Maize monocrop with ash; T2= Maize monocrop without ash; T3=75:25 maize-lima beans intercrop with ash; T4=75:25 maize-lima beans intercrop without ash; T5=50:50 maize-lima beans intercrop with ash; T6= 50:50 maize-lima beans intercrop without ash; T7=25:75 maize-lima beans intercrop with ash; T8=25:75 maize-lima beans intercrop without ash

Aggressivity values showed that maize crops were the dominant species at 75:25 and 50:50 maize-lima bean intercrops while negative values were recorded in the amended and unamended 25:75 maize-lima beans intercrop indicating that lima bean was the dominated species in this combination (Table 4). Lima beans equally had negative values for all the treatments except at 25:75 lima bean-maize intercrop which recorded positive values of 1.09 and 1.12 indicating that lima beans were the dominant species in these combinations.

The Area Time Equivalent Ratio (ATER**)** provides a more realistic comparison of the yield advantage of intercrops over sole cropping regarding variation in time taken by the component crops of different intercropping systems. The data presented in Table 4 show that ATER values were influenced by intercropping arrangements. In all maize-lima bean intercropping arrangements, the ATER values were lower than LER values and also lower than one indicating yield disadvantage perhaps due to the wide variations in the maturity periods of the crops of which lima beans stayed longer on the land and had enough time to compensate for the maize competition.

Table 5 shows the cost and returns analysis of both crops. It was observed that the intercropping combinations were more profitable than sole crops. Amended and unamended 75:25 maize-lima bean intercrops had the highest profit in the two cropping seasons.

4. DISCUSSION

Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources [4]. Yield reduction under the intercropping system as observed in this study could be associated with the competition effect by the component crops for nutrients, moisture and space [15]. The yield of intercropped lima beans in this study was generally low (262.20-908.9 kg/ha), especially in the late season growth. This might be because of some inherent genetic properties/constraints, or due to the superiority in competition by the maize component, [16,17]. Another reason as observed by Thobatsi [18] could be due to dry conditions that occur especially during the flowering stage.

Weights of grains were heaviest in the amended plots. The increase might be attributed to the wood ash applied to the plots and subsequently, its competitive abilities were enhanced or due to no competition effect. Egbe [19] had observed similar results in pigeon pea/maize intercropping systems. Higher seed yields were obtained from sole plots of maize and lima beans in all the experimental plots. The result was consistent with similar studies by Lithourgidis et al., [20] who reported that yields of intercropping were often higher than sole cropping systems.

The productivity of maize-lima beans mixture and land equivalent ratios (LEDs) were assessed in terms of yield throughout the two growing seasons and it was observed that the LER values of maize and lima beans yields mixtures substantially exceeded that of their corresponding monoculture which recorded zero values. The mean LER values for all intercropped treatments were greater than 1.0. This showed that land utilization efficiency for maize-lima beans intercropping was more advantageous than for sole crops. Dariush et al*.,* [21] confirmed that LER of 1.5 indicated that 50% more land would be required as a sole crop to produce the same yield as intercropping. The competitive ratio and aggressivity values obtained from this study proved that maize was more competitive than lima beans. Competitive ratio (CR) is only used as a measure of intercrop competition (inter-specific competition). The data presented in Table 4 clearly showed that the CR values for maize crops in all intercropping arrangements for both seasons were greater than 0.01 indicating that maize crops were competitive. Muhammad et al*.,* [22] also recorded similar CR values from the research conducted on Canola based intercropping, where all the intercrops had greater CR values. Similarly, lima beans had higher CR values in some of the intercrops in both seasons, especially in 75:25 lima beans-maize intercrop. This could probably be attributed to the beneficial complementarities of the component crop with regard to mineral elements, light, moisture and the creation of shade by the cereal [23].

Wood ash produced by combustion of woody vegetation is low in N but comprises cations such as K, Ca and Mg [24]. The pH values of the soils for both seasons gradually increased. This result agreed with Ojeniyi [6] who reported that wood ash also has a pH-increasing effect. In this study, the addition of wood ash generally increased maize and lima beans grain yield relative to the

control in both seasons. Mbah and Nkpaji [9] indicated that there was the great potential of reducing fertilizer application in maize production of an acidic soil by replacing it with the application of wood ash. He further stated that wood ash, when used as soil amendment, can reduce soil acidity to levels required for crop production.

Returns to investment for all the cropping patterns were high, with amended 75:25 maize-lima beans intercrop cropping pattern recording the highest return for both seasons. Mbah and Nkpaji [9] recorded similar findings from the research conducted on sweet corn and vegetable cow pea.

5. CONCLUSION

From this study, it was observed that individual monocrops performed better than the corresponding intercrops in terms of yields, but the cost analysis revealed that intercrop maize and lima beans were more profitable than their corresponding monochrome. In addition, more profits will be made from either 75:25 lima bean-maize or 75:25 maize-lima bean intercrops using wood ash, but not as sole crops. For optimum productivity and maintenance of soil fertility, it is better to grow these crops using wood ash as soil amendment which raises the pH values of the soil to meet the requirements of both plants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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