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Effects of wood ash, nitrogen and intra- row spacing on plant height, number of leaves and total tuber yield of potato (*Solanum tuberosum* L.) at Kuru Nigeria

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Abstract
Field experiments were conducted during the 2008 and 2009 wet seasons at the experimental farm of the National Root Crops Research Institute, Potato programme, Kuru, (Lat 09° 44' N and Long 08° 44'E and with an elevation of 1,239.4 m above sea level) in the Northern Guinea Savanna ecological zone of Nigeria. The experiment was conducted to determine the effects of various rates of nitrogen (0, 60 and 120 kg N/ha), wood ash (0, 2.5 and 5.0 t/ha) and intrarow spacing (20, 30 and 40 cm) on the growth and yield of potato. A split plot design was used where the factorial combinations of N and intra-row spacing were assigned to the main plots, while wood ash was assigned to sub plots. The treatments were replicated three times. The result revealed that application of 60 - 120 kg N/ha and 2.5 - 5.0 t/ha wood ash enhanced crop growth and yield of potato VIZ: Plant height, number of leaves per plant and total tuber yield respectively. With the exception of plant height in 2008, all the growth parameters increased with intrarow spacing from 20—40 cm. The use of 30 or 40cm spacing resulted in higher total tuber weight and yields compared to closer spacing of 20cm. Factor interaction of nitrogen and intrarow spacing was significant for; plant height, number of leaves per plant, and total tuber yield.

Key words: wood ash, nitrogen, intrarow spacing, total tuber yield

Introduction
Potato (*Solanum tuberosum* L.) is a tuber crop belonging to the family *Solanaceae*. It ranks fourth as the world's economically valuable food crop after rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize (*Zea mays*) (USDA, 2000). Potato is undoubtedly of ancient origin; Kroschel (1995) reported that potato originated in the highlands of South America, where it has been consumed for more than 8000 years. Potato arrived Africa around the turn of the 20th century. British farmers introduced it to East Africa in the 1880s. Its introduction by Europeans to Nigeria was by the tin miners on the Jos Plateau and by Germans in Cameroon (Ifenkwe, 1981). Thus a plant confined to South America until the late sixteenth century, has in the course of time become a crop of world importance. The use of wood ash as soil amendment provides a unique opportunity to increase the competitive ability of crop growth by increasing soil pH and increasing soil fertility, well-nourished plants compete well with weed and smothers weed effectively (Hillary 2009). Plant height as well as number of leaves per plant is a vital growth parameter in potato since they boost total tuber yield. It is in view of the above that the present study investigated effects of wood ash, nitrogen and intrarow spacing on some growth and yield parameters.

Materials and Methods
Field experiments were conducted in 2008 and 2009 rainy seasons on the National Root Crops Research Institute, Potato programme farm Kuru in the Northern Guinea savanna ecological zone. Kuru is located on latitude 09° 44'E and longitude 08° 44'N

with an elevation of 1,239.4m above sea level, with an annual rainfall of 1,289.89mm received in 150 days from May to October. The minimum air temperature during the two seasons ranged from 17.2–21.2°C, while the maximum ranged from 23.0–27.7°C. The mean relative humidity ranged from 16.53—84. 45%.The soil is a sandy loam and of feralgilic origin, it was sampled and analyzed for its Physico – chemical properties, the result is presented in Table 1. Treatments evaluated included, nitrogen (0, 60 and 120 kg ha^{-1}), wood ash (0, 2.5 and 5.0 t ha^{-1}) and intrarow spacing (20, 30 and 40 cm). Factorial combination of nitrogen and intrarow spacing was assigned to main plot while wood ash was allocated to sub – plot. The gross plot size measured 24 m^2 while the net plot size was 12 m^2. The experiment was laid out in a split plot design replicated three times. Planting was done on the crest of the ridges spaced 100cm apart while the intrarow spacing was 20, 30 and 40 cm. The actual date of planting was 3rd May, 2008 and 16th May, 2009. The wood ash used in this experiment was from African birch (*Anogeissus leocarpus*) plant, it (wood ash) was incorporated on the crest of the ridges at planting, while urea fertilizer was applied manually by band method two weeks after planting. Weeds were controlled with pre-emergence herbicide, using a combination of Alachlor – EC at 1.92 kg a.i ha^{-1} and Atrazine 500Sc at the rate of 4 kg a.i ha^{-1} using CP-15 knapsack sprayer set at a pressure of 2.1kg cm^{-2} and by manual hoe weeding at 4 and 8 WAP, to keep the plots weed free. Tubers were harvested manually by lifting, using garden fork. The actual harvest dates were 26th July in 2008 and 4th August 2009. Five stands were selected and harvested; their tubers were counted to determine the mean number of tubers per plant. The weights of the randomly selected tubers were determined using electronic balance. Tubers harvested from each net plot (12 m^2) were weighed, tuber yield/stand determined and later the yield/net plot was expressed in tonnes per hectare. All the data was statistically analyzed using analysis of variance (ANOVA) according to the method described by Gomez and Gomez (1984), and treatment means were separated using Duncan Multiple Range Test (Duncan, 1955).

Results and discussion

Nitrogen and wood ash in 2008 and in addition, intra – row spacing in 2009 significantly influenced plant height (Tables 2 and 3). At 3 WAP in 2008, application of nitrogen at the rate of 60 and120 kg N/ha were at par and increased plant height over 0 kg N/ha nitrogen, while in the same period in 2009, 60 kg N/ha significantly increased plant height over the other treatments. This was followed by 120 kg N/ha. At 6 and 9 WAP in both years of trial, application of 60 and 120 kg N/ha significantly increased plant height over the untreated control. The increase in plant height per plant in each year could be attributed to the low N status of the soil of the experimental site (Table 1). This is in consonance with reports that N in the presence of P and K stimulate canopy growth, development of leaves and branches and need to be available from seedling emergence to flowering so as to promote rapid canopy development, haulm weight, stollon growth as well as increased potato leaves area, relative growth rate and final yield of potato crop (Chapman and Carter, 1976; Okonkwo *et al*., 1988; Juzl 1990 and 1991; Huet and Dattmann 1991; Rogozinska and Pinka, 1991; Zrust and Mica,1992).The significant response to applied N, by plant height explained the importance of N on growth and development of potato, Beukema and Van de Za'ag 1990 and Harris, (1992).

Wood ash at 2.5 and 5.0 t/ha significantly enhanced plant height over the 0 t/ha rate at 3 and 6 WAP in 2008 (Table 2). At 9 WAP, 5.0 t/ha wood ash increased plant height over the control in 2009 (Table 3), application of 5.0t/ha wood ash depressed plant height at 3 WAP but enhanced it at 9 WAP. The significant positive response of potato to the application of wood ash in these trials in terms of plant height and number of leaves explained the importance of the material as a source of P and K as earlier reported by Beukema and Za'ag (1990) and Harris (1992). The progressive rise in plant height, with corresponding increase in wood ash rate (0 – 0.5 t/ha) is in consonance with the findings of Obi, (2000), Obi and Ekperegin (2001), Ojeniyi *et al*., (2001), Ojeniyi and Adejobi, (2002), Reula and Janssen, (1996) who reported that wood ash is an effective source of plant nutrients such as Calcium, Phosphorus, Potassium, Magnesium and other secondary elements. Wood ash is also a fast liming material that rapidly dissolves and neutralizes acid soil, apart from providing plant nutrients (Jerome, 2004). Sokoto *et al*. (2007) reported positive effect of wood ash on sweet potato. Therefore, this study confirms that wood ash contains K and P and each element has a specific role in potato growth and development, and absence of any in the soil may retard potato growth and decrease yield. In 2008 (Table 2), plant height of potato was not significantly affected by intrarow spacing while in 2009 (Table 3), the parameter decreased with increase in spacing from 20 – 40 cm at 3 WAP. At 6 and 9 WAP, 20 and 40 cm spacing gave taller plants than 30 cm spacing.

The use of 20 cm intrarow spacing gave the tallest but less robust plants. This is probably because with 20 cm intrarow spacing, there was competition between plants, for solar radiation which led to etiolation; plants grew narrower with less branching. At the later stage for stands spaced 40 cm plants had enough space for vegetative growth and branching and overtook the 20 cm stands. This could be attributed to less competition for environmental resources necessary for plant growth.

Nitrogen, wood ash and spacing significantly influenced number of leaves per plant of potato in 2008 and 2009 except wood ash at 9 WAP in 2008. (Tables 4 and 5). At 3 WAP in both years and 6 WAP in 2009, number of leaves per plant increased with increase in N rate. This is probably because, in addition to enough space, both nitrogen and wood ash have to be there for leaves to increase in number. Application of 120 kg N/ha nitrogen increased the number of leaves per plant over 60 kg N/ha and the untreated control at 6 and 9 WAP in (2008), probably in potato at 6 and 9 WAP most of growth parameters have reached advance stage. This is in consonance with the findings of Van de Za'ag, 1990 and Harris (1992), who reported significant response to applied N by plant height and number of leaves. The in ability of wood ash to increase number of leaves at 9 WAP is probably because at 9 WAP potato plant requires the wood ash above the applied rate.

Total tuber yield

The effects of nitrogen, wood ash and intrarow spacing of potato on total tuber yield is presented in (Table 6). Nitrogen, wood ash and intrarow spacing significantly affected total tuber yield. In 2008, N at 60 and 120 kg N/ha increased total tuber yield over the control. In 2009, 60 kg N/ha yielded more than the control and 120 kg N/ha. Total tuber yield increased with N rate from 0 – 120 kg N/ha in the two years of trials and the combined data. This is in line with the findings of D'amanto *et al*., (1989), Sharma (1990), Guerra *et al*.,(1990) and Porta and Sission (1991a and 1991b) who observed that tuber size, number, weight and marketable tubers yield per hectare increased with N application.

In 2008, 2.5 and 5.0t/ha wood ash increased total tuber yield over the untreated control. In 2009, tuber yield increased with wood ash rate, while in the combined data, the 2.5 t/ha level produced greater tuber yield than the control. This agreed with the report of Sokoto *et al.,* (2007) who reported that, wood ash tend to boost the yield of sweet potato and he recommended 6t/ha of wood ash for potato production under irrigated condition.

The use of intrarow spacing of 30cm increased total tuber yield compared to 20 cm and 40cm spacing in 2008. In the combined data, tuber yield increased with intrarow spacing. In 2009, intrarow spacing did not exert significant effect on this parameter. This is probably because, with closer spacing, there was etiolation hence more seed tubers were formed from thin stands while with wider spacing (40 cm) few but large tubers were formed but could not compensate the yield. This study, further observed that, total tuber yield increased with increase in intrarow spacing this is in line with reports by Wurr (1974), White *et al.*(1976) and Pavlista (1995), who observed that increase in intrarow spacing decreased the yield of seed tubers and increased the proportion and yield of large tubers. However increase in the average size of the tubers by wide spacing (40 cm) did not quite compensate for the reduction in total yield as spacing was increased and stands were reduced, although the trend was not quite consistent.

Conclusion

Nitrogen and wood ash significantly enhanced crop growth and yield. Nitrogen at 60 kg N/ha and wood ash at 5.0 t/ha were most ideal for total tuber yield. Combination of 120 kg N/ha and 40 cm intrarow spacing produced the highest plant height while the use of 40 cm intrarow spacing was most ideal for potato growth and 30 cm spacing for total tuber yield.

Table 1: Physico-chemical properties of soils of the experimental sites during 2008 and 2009 cropping seasons.

	2008		2009	
	Soil depths (cm)		Soil depths (cm)	
	0-15	15-30	0-15	15-30
Particle size distribution (%)				
Sand	16.70	18.30	19.80	20.12
Silt	28.60	26.40	27.60	27.18
Clay	54.70	55.30	52.60	52.70
Textural characteristics				
pH in water	5.21	6.0	5.11	6.00
pH in 0.01 $Mcacl_2$	4.41	4.71	4.40	4.70
Organic carbon (%)	0.98	0.39	0.73	3.00
Total nitrogen (%)	0.08	0.04	0.07	0.03
Available P (Bray)ppm	3.56	1.02	3.48	0.88
Exchangeable bases(Meq/100g)				
Ca	4.50	4.90	4.46	3.33
Mg	2.32	3.00	2.04	2.40
K	0.53	0.60	0.55	0.48
Na	0.07	0.03	0.06	0.06
Exchangeable acidity (H+A1)	0.30	0.30	0.30	0.30
CEC	7.70	8.40	7.65	8.42

Analysis: Federal College of Land Resources Technology, Kuru, Plateau state.

Table 2: Effects of nitrogen, wood ash and intra-row spacing on plant height of potato during the 2008 cropping season.

Treatment	Plant height (cm)		
	3 WAP	6 WAP	9 WAP
Nitrogen kg/ha (N)			
0	31.29b	40.96b	50.26b
60	36.78a	46.26a	55.26a
120	37.00a	46.29a	55.48a
SE ±	0.333	0.361	0.358
Wood ash t/ha (W)			
0	33.67b	42.85b	52.59b
2.5	35.44a	44.85a	53.67ab
5.0	35.96a	45.81a	54.74a
SE ±	0.579	0.677	0.668
Spacing cm (S)			
20	35.67	45.26	54.22
30	34.81	43.77	53.69
40	34.59	44.48	53.19
SE ±	0.333	0.361	0.358
Interactions			
N x W	NS	NS	NS
N x S	NS	*	NS
W x S	NS	NS	NS
N x S x W	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not significantly different using DMRT ($P \leq 0.05$). NS=Not significant . * = Significant at ($P \leq 0.05$). WAP = Weeks after planting.

Table 3: Effects of nitrogen, wood ash and intra-row spacing on plant height of potato during the 2009 cropping season.

Treatment	Plant height (cm)		
	3 WAP	6 WAP	9 WA P
Nitrogen kg/ha (N)			
0	31.26c	40.74b	51.11b
60	36.55a	44.78a	55.19a
120	32.96b	46.26a	55.41a
SE ±	0.341	0.379	0.538
Wood ash t/ha (W)			
0	33.78a	43.07b	52.55b
2.5	35.00a	43.59ab	53.70b
5.0	32.00b	45.11a	55.44a
SE ±	0.532	0.616	0.493
Spacing cm (S)			
20	36.63a	44.04ab	53.78ab
30	33.93b	42.59b	52.81b
40	33.22c	45.15c	55.11a
SE ±	0.341	0.379	0.538
Interactions			
N x W	NS	NS	NS
N x S	NS	*	NS
W x S	NS	NS	NS
N x S x W	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not significantly different using DMRT (P≤0.05). NS=Not significant. * = Significant at (P≤ 0.05). WAP = Weeks after planting.

Table 4: Effects of nitrogen, wood ash and intra-row spacing on number of leaves per plant of potato during the 2008 cropping season.

Treatment	Number of leaves/plant		
	3 WAP	6 WAP	9WAP
Nitrogen kg/ha (N)			
0	183.4c	397.4b	400.8b
60	275.5b	395.8b	390.3b
120	312.3a	504.5a	474.59a
SE ±	11.941	9.419	11.605
Wood ash t/ha (W)			
0	240.1b	385.1b	431.7
2.5	253.7b	349.0b	420.7
5.0	277.4a	385.1a	445.6
SE ±	7.906	8.413	5.70
Spacing cm (S)			
20	194.5c	333.3c	335.0c
30	254.1b	464.4b	450.4b
40	322.6a	493.9a	480.4a
SE ±	11.941	9.419	11.605
Interactions			
N x W	NS	NS	NS
N x S	NS	*	NS
W x S	NS	NS	NS
N x S x W	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not significantly different using DMRT (P≤0.05). NS=Not significant. * = Significant at (P≤ 0.05). WAP = Weeks after planting.

Table 5: Effects of nitrogen, wood ash and intra-row spacing on number of leaves per plant of potato during the 2009 cropping season.

Treatment	Number of leaves/ plant		
	3WAP	6WAP	9WAP
Nitrogen kg/ha (N)			
0	199.78c	339.70c	400.89b
60	300.04b	364.93b	490.37a
120	329.00a	415.30a	474.59a
SE ±	10.390	7.554	6.566
Wood ash t/ha (W)			
0	252.74b	349.11b	414.70
2.5	268.11b	365.96b	421.89
5.0	307.96a	404.85a	431.26
SE ±	8.112	8.101	7.493
Spacing cm (S)			
20	207.26c	309.78c	335.00c
30	268.15b	390.00b	450.44b
40	353.41a	420.15a	480.41a
SE ±	10.390	7.554	6.566
Interactions			
N x W	NS	NS	NS
N x S	NS	*	NS
W x S	NS	NS	NS
N x S x W	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not significantly different using DMRT (P≤0.05). NS=Not significant. * = Significant at (P ≤ 0.05). WAP = Weeks after planting.

Table 6: Effects of nitrogen, wood ash and intra-row spacing on total tubers yield of potato during the 2008 and 2009 cropping seasons and combined data.

Treatment	Total tuber yield (t/ha)		
	2008	2009	Combined
Nitrogen kg/ha (N)			
0	12.37b	13.64b	13.00c
60	13.11a	14.31a	13.71a
120	13.10a	13.59b	13.35b
SE ±	0.125	0.068	0.096
Wood ash t/ha (W)			
0	12.15b	13.71c	13.08b
2.5	13.12a	14.15b	13.64a
5.0	12.89a	14.17a	13.52ab
SE ±	0.098	0.076	0.071
Spacing cm (S)			
20	12.45b	13.77	12.96b
30	13.10a	13.82	13.46a
40	12.71b	13.95	13.33a
SE ±	0.125	0.068	0.096
Interactions			
N x W	NS	NS	NS
N x S	NS	*	*
W x S	NS	NS	NS
N x S x W	NS	NS	NS

Means followed by the same letter(s) within a treatment group and column are not statistically significant using DMRT (P≤0.05). NS=Not significant. * = Significant at (P ≤ 0.05). WAP = Weeks after planting.

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