

Original Research Article

1
2

LIMING EFFECTS OF SAWDUST ASH AND LIME ON SUNFLOWER YIELD IN ACIDIC SOIL OF SOUTHEASTERN NIGERIA

ABSTRACT

A pot experiment was carried out to determine the effect of sawdust ash and lime ($\text{Ca}(\text{OH})_2$) on soil characteristics and yield of sunflower in acidic soil of southeastern Nigeria. The experiment was laid out in split-plot design, using sawdust ash (0, 1, 2, 3, 4 t ha⁻¹) as the sub plot and lime (0, 0.5, 1.0, 1.5 t ha⁻¹) as the main plot. Results showed that with the exception of organic carbon there was significant effect of treatments on all soil chemical properties. Lime and sawdust ash (SDA) as single and combined treatments significantly increased total nitrogen ($P=0.05$), available phosphorus ($P<0.010$), and base saturation ($P<0.012$). The interaction between SDA and lime significantly ($P=0.05$) increased total exchangeable bases and effective cation exchange capacity, while soil pH was significantly increased ($P=0.05$) by single applications. The increases in soil chemical properties led to significant positive response of the sunflower. With the exception of number of leaves, other plant parameters (Plant height, stem diameter, head weight, 50 seed weight, head diameter) had significant increases for sawdust ash alone at $P=0.05$. Correlation studies showed positive significant relationship between soil pH and sunflower yield. The study showed that sunflower performed best at the combination of 3 t ha⁻¹ SDA and 1.5 t ha⁻¹ lime producing a mean head weight of 45.4 g.

Keywords: sawdust ash, lime, soil acidity, sunflower

21

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the third most important oil seed crop next to soybean and groundnut as a source of edible oil in the world. It is cultivated globally [1] due to its adaptability to wide range of soil and climatic conditions. It is tolerant to high temperature and high humidity and will grow well in any light

26 textured, well drained sandy loam soil [2]. Sunflower is not highly drought tolerant; however its highly
27 branched tap root system allows it to extract more soil moisture. In Nigeria, sunflower is commonly
28 cultivated in the savannah regions having maximum annual rainfall of about 1500 mm [3]. Interestingly,
29 studies have shown encouraging yield results in humid high rainfall area with application of phosphorus
30 fertilizer [4], adjustments in planting time [5], and planting density [6, 7]. However production could be
31 greatly hindered by soil acidity in the highly weathered soils of this region.

32 Soil acidity is a limiting factor in sunflower production. A good example is a 10% decrease in sunflower
33 yield between soil pH of 4.7 – 5.3 [8]. One of the critical effects of soil acidity in highly weathered soils of
34 humid southeastern Nigeria is the unavailability of Phosphorus [9, 10, 11]. Phosphorus deficiency in
35 sunflower could affect physiological development such as leaf area and photosynthetic rate per unit of
36 leaf area [12] consequently affecting yield. In the attempt to improve yield in humid region of Nigeria,
37 Adebayo et al. [4] found good responses in sunflower yield from the application of phosphorus fertilizer. In
38 addition, significant responses of sunflower yield to liming have been reported in acid soils. Kovacevic et
39 al [13] recorded about 49 % increase in sunflower yield by liming. Similar finding was previously reported
40 by Blamey and Nathanson [14].

41 The use of lime for amelioration of acidic soils functions by increasing the availability of nutrients and
42 reducing toxicity of Al and Fe ions in such soils. Sawdust ash is a source of lime, but due to the
43 complementary qualities of mineral nutrients contained in sawdust ash and high calcium carbonate
44 equivalent of commercial lime, Clapham and Zibilske [15] suggest that sawdust ash be used as a
45 supplement rather than replacement for lime. Several studies have been conducted on sawdust/wood ash
46 for liming in the study region, but the effect of sawdust ash in combination with lime on sunflower has not
47 been previously investigated. Other studies on sunflower in the study area have focused on agronomic
48 practices such as plant population, intercropping and fertilizer management. The objective of this study
49 was to determine the effect of liming on sunflower yield in acidic soil of southeastern Nigeria.

50

51

Comment [XXXX1]: Citation different from the norms of the journal

Comment [XXXX2]: Citation different from the norms of the journal

Comment [XXXX3]: Citation different from the norms of the journal

Comment [XXXX4]: Citation different from the norms of the journal

52 **2. MATERIALS AND METHOD**

53 **2.1 Experimental site:** This study was conducted outdoors at Michael Okpara University of Agriculture,
54 Umudike, Abia State (Lat. 5° 29' N and Long.7° 32' E, 122 m.a.s.l), Southeastern Nigeria. Climate type is
55 generally humid tropic with rainforest vegetation type. It is characterized by uniform high temperatures
56 which changes slightly during the year. The average annual temperature and rainfall are 26.9 °C and
57 2046 mm respectively.

58 **2.2 Pot experiment:** Bulk topsoil samples were collected from the Eastern farm of same institution, air
59 dried and sieved through 2 mm sieve. The bulk soil was thoroughly mixed and 10kg of soil weighed into
60 each of the sixty 12-litre plastic buckets. Sunflower (*Helianthus annus* L.) seeds were obtained from
61 National Institute for Horticulture Research and Training, Ibadan. Sawdust was collected from timber
62 shed, Umuahia Abia State and burnt to obtain ash. Factor levels comprised four rates (0, 0.5, 1.0, 1.5
63 tonnes per hectare) of commercial lime [Ca(OH)₂] and five rates (0, 1, 2, 3, 4 tonnes per hectare) of
64 sawdust ash. They were arranged in a split-plot design and replicated three times. The different
65 treatment combinations were applied to the 60 buckets containing soil, mixed thoroughly and watered
66 adequately. After 1 week of treatment application, the seeds were planted. Two seeds were planted per
67 bucket and later thinned to one seedling per bucket. Uniform watering and weeding were carried out as
68 required throughout the growing season.

69 **2.3 Statistical analysis:** Data collected were subjected to Analysis of Variance (GENSTAT) and their
70 means compared using least significant difference at 5% level of probability, while Pearson correlation
71 was performed using SPSS 13.0.

Comment [XXXX5]: Put the soil chemical attributes at the beginning of the experiment

Comment [XXXX6]: Put the chemical attributes of ash

Comment [XXXX7]: the experimental design was in a factorial arrangement 3x4 three doses of limestone x four doses of ashes, plus one control group (zero)

Comment [XXXX8]: What?
 $3 \times 4 = 12 + 1(\text{control}) = 13$
 $13 \times 3 = 39$ plots
No?
Why 60?

Comment [XXXX9]: What is the average test? What is the level of significance?
I suggest doing regression analysis for each level of limestone and ash.
Test your polynomials.

72
73
74
75
76

77 **3. RESULTS AND DISCUSSION**

78 **3.1 Properties of soil and sawdust ash used for the study**

79 Textural class of the soil is loamy sand with low clay content. Clay play important roles in water and
80 nutrient retention capacity of soils. Soils low in clay content could lead to heavy leaching of soil nutrients,
81 even when fertilizer is applied [16].

Comment [XXXX10]: this information is in the material and methods

82 The pH values ranged from 5.36 - 5.64 and 4.37 - 4.45 in water and CaCl₂ respectively. The low pH also
83 resulted to high exchangeable acidity. Soil pH values in salts are generally lower than those measured in
84 water. The indication is that these soils at their natural pH are negatively charged [17]. Soil pH
85 requirement for sunflower ranges between 6.5 and 7.5 (in water). The low pH values could generally
86 reduce crop yield [18] and in particular, the performance and yield of sunflower [19].

Comment [XXXX11]: Where is this information?
Any table?

87 Organic carbon content falls within the range for ultisols found in this region as indicated by Eswaran [20].
88 The soil organic carbon reflects soils' fertility status [21].

Comment [XXXX12]: cite the source

89 Available phosphorus was lower than the critical level of 15 mg kg⁻¹ for most crops [22, 23]. In acidic soils,
90 phosphorus is known to be associated with secondary minerals such as Fe and Al (hydrus) oxides
91 through sorption [24], however low effective cation exchange capacity obtained suggests small presence
92 of secondary minerals having high specific surface [25]. Deficiency in available phosphorus results to
93 stunted growth, purplish discoloration of leaves. It also affects flowering, fruit formation and seed
94 production [2]. Uptake of major nutrients elements by sunflower has also been reported to be facilitated
95 by phosphorus application in the forest zone [26].

Comment [XXXX13]: Citation different from the norms of the journal

96 Total nitrogen was also low and below the critical level of 0.15 % for optimum crop production [27]. This
97 may be attributed to heavy leaching caused by high rainfall pattern experienced in this region.

98 Basic cations were low however calcium exceeded the critical level of 2 Cmol kg⁻¹ for most crops [28].
99 Base saturation had mean of 79.97 %, while exchangeable acidity was between 1.34 and 1.40 Cmol kg⁻¹.

100
101
102
103
104

Table 1: Soil and sawdust ash physico-chemical properties

Properties	Soil	Sawdust ash	Method
Sand	73.0 %	-	Hydrometer method [29]
Clay	12.8 %	-	
Silt	14.2 %	-	
pH (1:2.5 sample:H ₂ O)	5.48	10.7	Glass electrode pH meter [30]
pH (1:2.5 sample:CaCl ₂)	4.40	10.5	
Organic Carbon	1.37 %	-	Wet oxidation [31]
Available Phosphorus	11.00 µgg ⁻¹	17.33 µgg ⁻¹	Bray 1 [32]
Total Nitrogen	0.10 %	0.30 %	Micro kjeldahl [33]
Exchangeable Acidity	1.36 Cmolkg ⁻¹	-	KCl extraction [34]
Potassium	0.09 Cmolkg ⁻¹	34.78 %	NH ₄ ⁺ -acetate extraction
Calcium	2.80 Cmolkg ⁻¹	5.53 %	
Magnesium	2.00 Cmolkg ⁻¹	2.13 %	
Sodium	0.10 Cmolkg ⁻¹	0.12 %	
Total exchangeable bases	4.99 Cmolkg ⁻¹	42.56 %	
ECEC	6.24 Cmolkg ⁻¹	-	
Base Saturation	79.97 %	-	

*ECEC: Effective cation exchange capacity

Sawdust ash had pH values of 10.7 and 10.5 in water and CaCl₂ respectively (Table 1). It also contained 0.30 % of total nitrogen, 17.33 µgg⁻¹ available phosphorus, and 5.53, 2.13, 0.12, 34.78 Cmol kg⁻¹ of Ca, Mg, Na and K respectively. Data indicate alkalinity and higher concentrations of nutrients compared to initial soil sample. Hence, plant ash is a potential improver of acidic soils for better crop yield. Similar results have been obtained by several authors [35, 36, 37, 38, 39].

Comment [XXXX14]: Call the table in the text.

Example:

... as shown in Table 1.

Put right after the paragraph 59.

This information belongs to the material and methods

Comment [XXXX15]: This information belongs to the material and methods

108 3.2 Effect of sawdust ash and lime on soil chemical properties

109 Effects of sawdust ash and lime on soil chemical properties are shown in Table 2. Although there was no
110 significant effect of sawdust ash (SDA) and lime on organic carbon as several researchers [37, 36, 35]
111 have previously reported, there were increases relative to control. The highest mean value of 1.55 %
112 was obtained at treatment 1 tha⁻¹ SDA × 1 tha⁻¹ lime.

Comment [XXXX16]: Table 2 should appear next to your call in the text.

113 There were significant increases in total N as a result of the application of treatments. Increase in soil pH
114 encourages increases in microbial activities which are responsible for the breakdown of crop residues,
115 contributing to the availability of nitrogen, phosphorus and sulphur in soils.

Comment [XXXX17]: Where is this information?

116 Main and interaction effects of SDA and lime had positive significance ($P=0.05$) on available
117 phosphorus. This may be attributed to the fact that lime $[Ca(OH)_2]$ contains Ca^{2+} which increases pH
118 thereby releasing adsorbed P, as well as the high presence of P and Ca in SDA. Odedina *et al.*[35]
119 found that SDA and other plant derived ashes increased soil N, P, K, Ca, Mg contents of soils.

Is it on any table?
Which?

120 Basic cations (K, Mg, Na and Ca) significantly increased ($P=0.05$) with all treatments. This finding is in
121 line with that of several other researchers [40, 38, 37]. This confirms the positive effect of ash and lime
122 on cationic nutrients. The implication of this observation is that the nutrient contained in the treatments
123 were mineralized by microbial activities [41] and made available in soil solution for subsequent plant
124 uptake. The following treatment combinations had the highest levels of K, Mg, Na and Ca respectively: 4
125 tha⁻¹ SDA × 1.5 tha⁻¹ lime, 2 tha⁻¹ SDA × 1 tha⁻¹ lime, 0 tha⁻¹ SDA × 0.5 tha⁻¹ lime and 1 tha⁻¹ SDA × 0
126 tha⁻¹ lime. From these results, it could be suggested that ash be added as a supplement to lime and not
127 as a replacement. This corroborates the finding of Clapman and Zibilske [14].

Comment [XXXX18]: Citation different from the norms of the journal

128 Significant increases ($P<0.012$) were recorded for total exchangeable bases, base saturation and ECEC.
129 Increases ranged from 9.26 to 56.74 % for total exchangeable bases, 4.94 to 10.32 % for base
130 saturation, and 1.48 to 50.50 % for ECEC. These results indicate that application of lime and SDA on
131 acidic soil could have positive influence on both soil and crops being grown.

132 Expected reductions were observed for exchangeable acidity relative to control. This could be as a result
133 of replacement of H^+ and Al^{3+} by the basic cations present in SDA and lime occurring at the exchange
134 sites. This consequently increased the pH of soil solution. Increase in soil pH upon SDA application
135 affirms that ash has a liming effect. Several researchers [42, 37, 40] have successfully used plant ash as
136 liming material.

137

138

139

140

141

142

143

144

145

146

147

148

149

150

151

UNDER PEER REVIEW

Table 2: Effect of sawdust ash and lime on soil chemical properties

Comment [XXXX19]: Put right after the paragraph 112.

		SAW DUST ASH (tha ⁻¹)					
	LIME(th ^{a-1})	0	1	2	3	4	LSD (0.05)
pH (water)	0	5.510	5.577	5.727	5.870	5.927	Lime NS
	0.5	5.573	5.827	5.780	6.007	6.087	SDA 0.1595
	1.0	5.823	5.790	5.913	6.070	6.167	L×S NS
	1.5	5.953	5.917	5.587	6.220	6.063	
pH (CaCl ₂)	0	4.073	4.093	4.377	4.663	4.637	Lime 0.2107
	0.5	4.320	4.563	4.587	4.780	4.987	SDA 0.2070
	1.0	4.513	4.727	4.677	5.023	5.450	L×S NS
	1.5	4.620	4.790	4.290	5.117	5.383	
Exchangeable Acidity	0	6.64	20.19	15.47	8.15	7.24	Lime NS
	0.5	11.78	11.30	11.59	12.99	12.20	SDA 0.2254
	1.0	13.71	11.59	17.60	6.84	10.87	L×S NS
	1.5	14.76	14.58	9.92	19.66	10.02	
ECEC	0	6.64	20.19	15.47	8.15	7.24	Lime NS
	0.5	11.78	11.30	11.59	12.99	12.20	SDA 2.756
	1.0	13.71	11.59	17.60	6.84	10.87	L×S 5.635
	1.5	14.76	14.58	9.92	19.66	10.02	
Base Saturation	0	79.10	94.01	91.93	92.68	91.84	Lime 2.483
	0.5	90.39	92.92	93.59	95.22	95.48	SDA 2.136
	1.0	92.23	94.32	94.32	91.42	95.10	L×S 4.323
	1.5	94.27	92.58	92.58	97.31	94.02	
Exchangeable bases	0	5.24	18.99	14.53	7.55	6.64	Lime NS
	0.5	10.64	10.50	10.58	12.39	11.67	SDA 2.756
	1.0	12.64	10.93	16.66	6.31	10.34	L×S 5.635
	1.5	13.96	13.85	9.19	19.13	9.49	
Available Phosphorus	0	20.67	20.67	24.00	24.00	24.67	Lime 2.404
	0.5	23.67	24.67	18.67	27.00	23.67	SDA 3.514
	1.0	27.00	21.00	20.00	26.00	24.00	L×S 6.564
	1.5	20.67	26.67	26.60	32.67	20.67	
Total Nitrogen	0	0.080	0.107	0.080	0.067	0.080	Lime 0.01152
	0.5	0.100	0.080	0.097	0.047	0.077	SDA 0.01063
	1.0	0.067	0.060	0.080	0.053	0.080	L×S 0.02117
	1.5	0.137	0.067	0.067	0.097	0.080	
Organic Carbon	0	1.335	1.493	1.453	1.397	1.353	Lime NS
	0.5	1.500	1.493	1.340	1.540	1.377	SDA NS
	1.0	1.493	1.547	1.387	1.343	1.370	L×S NS
	1.5	1.493	1.413	1.417	1.490	1.397	

Comment [XXXX20]:
I suggest doing a regression analysis, presenting its results with linear or quadratic equations.
Do not forget to put the level of significance after R2
* (5%); ** (1%) or NS
Example at the end of the file

- ECEC = effective cation exchange capacity
- SDA = sawdust ash
- L×S = lime and sawdust ash interaction

3.3 Effect of sawdust ash and commercial lime on growth and yield of sunflower

Growth parameters (Plant height, number of leaves, stem diameter), were obtained at the 10th week after planting. As expected, these parameters had increases relative to control. These increases were not significant for number of leaves (Fig. 2). However, there were significant ($P<0.05$) increases in plant height and stem diameter. Similar finding was observed by Patterson *et al* [40].

The main effect of SDA resulted to significant increases in plant height (Fig. 1). The tallest plants of mean value, 123.70 cm were obtained at treatment combination 3 tha^{-1} SDA \times 1.5 tha^{-1} lime. Presumably, the highest increase in plant height at this treatment may be due to the increases observed in available phosphorus and other nutrients. Phosphorus promotes cell division [43] which is manifested in plant height during vegetative growth.

For stem diameter, significant differences were observed in the main effects of SDA and lime. The highest mean value of 2.03 cm was recorded at the application rates of 2 tha^{-1} SDA \times 1 tha^{-1} lime (Fig. 3).

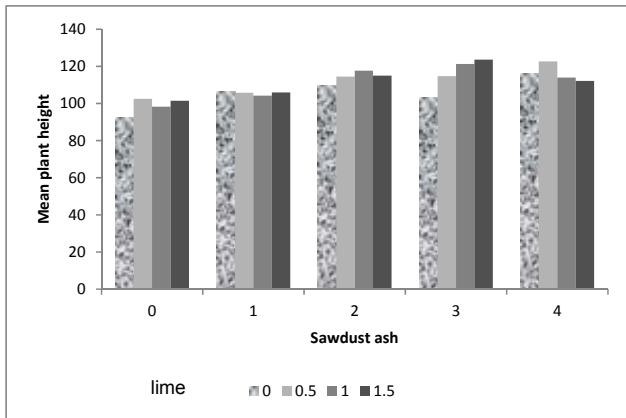


Fig.1. Effects of sawdust ash and lime on plant height

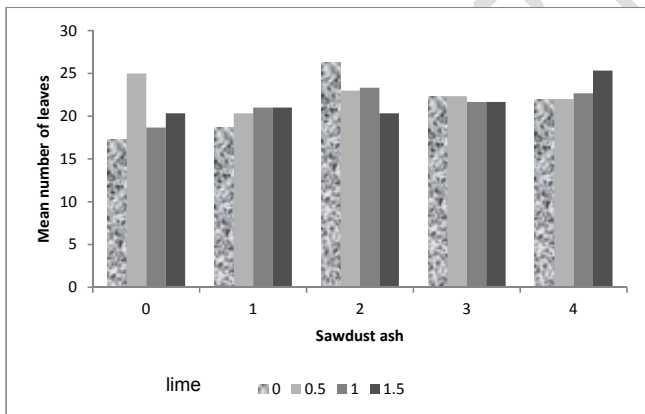


Fig.2. Effects of sawdust ash and lime on number of leaves

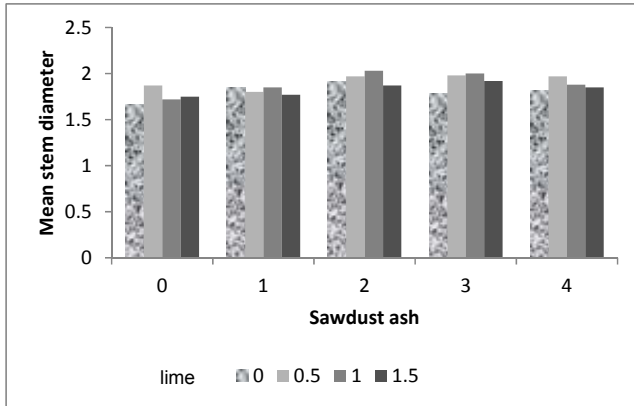


Fig. 3: Effects of sawdust ash and lime on stem diameter

After harvesting, yield parameters were obtained and analyzed. The control had the least yield, indicating increases with treatment application. Only main effects of SDA had positive significant impact on these yield parameters. This suggests that SDA was able to release nutrients for improved sunflower yield. These increases in yield may be attributed to the increases in soil pH and nutrients provided by SDA.

The yield mean values ranged from 12.6 to 45.4 g, 1.73 to 5.33 g and 6.27 to 14.10 cm, with the highest yields recorded at application rates of $3 \text{ tha}^{-1} \text{ SDA} \times 1.5 \text{ tha}^{-1} \text{ lime}$, $3 \text{ tha}^{-1} \text{ SDA} \times 1.5 \text{ tha}^{-1} \text{ lime}$ and $4 \text{ tha}^{-1} \text{ SDA} \times 1.5 \text{ tha}^{-1} \text{ lime}$, for head weight (Fig. 4), 50 seed weight (Fig. 5) and head diameter (Fig. 6) respectively. The positive response of sunflower to SDA and lime is similar with the earlier results obtained with several crops such as Cowpea [44, 37], Tomato [36], Amaranthus [45], Okra [36] and maize [38]. These studies attributed crop responses to SDA application which increased soil pH and nutrients such as N, P, K, Ca, Mg.

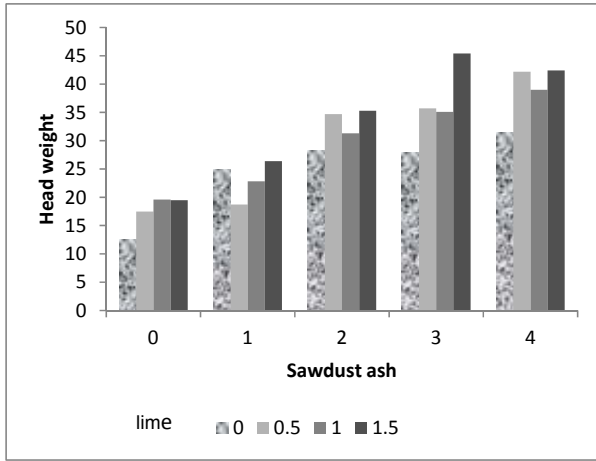


Figure 4: Effects of sawdust ash and lime on head weight

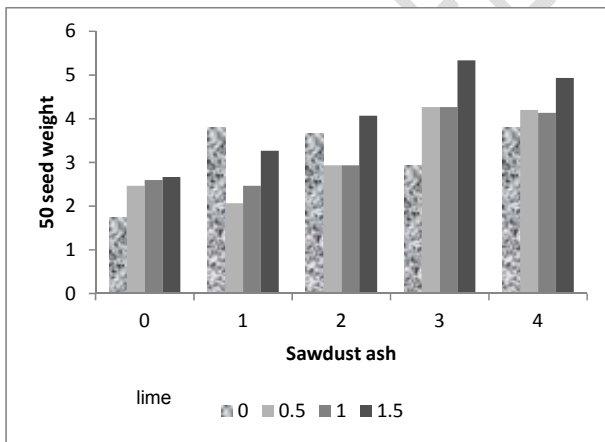


Figure 5: Effects of sawdust ash and lime on 50 seed weight

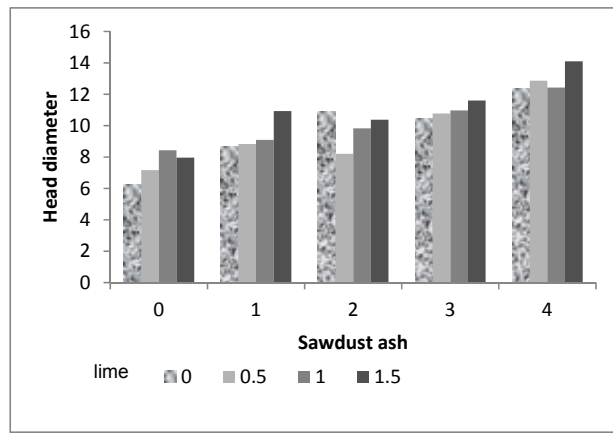


Figure 6: Effects of sawdust ash and lime on head diameter

3.4 Relationships between growth and yield parameters of sunflower and soil chemical properties

Pearson correlation study was used to determine relationships between growth and yield parameters of sunflower and some soil chemical properties (Table not shown). Results showed that soil pH had positive relationship with all parameters obtained from pot experiment, indicating that increase in soil pH led to increases in these parameters. This finding corroborate earlier studies that grain yield of sunflower was highly positively correlated with soil pH [19]. The results ascertain that in soils of low pH, increment in pH through liming enhanced sunflower yield.

There was an expected inverse relationship between plant parameters and exchangeable acidity. However, this negative relationship was not significant for number of leaves. Data also showed that increases in plant height, head diameter, head weight and 50 seed weight were dependent on available Phosphorus. However, their dependence was not significant for plant height and head diameter.

Comment [XXXX21]: Improve discussion

Comment [XXXX22]: Why not put the correlation table?

You need to put the correlation table

Conclusion

In southeastern Nigeria, where soil acidity poses a threat to sustainable crop production, acid sensitive and heavy feeder crop such as sunflower cannot be successfully grown without soil amelioration. The imbalance created by the use of chemical fertilizers alone has resulted to a quest for alternative sources of nutrients such as sawdust ash. The combined use of commercial lime and sawdust ash is expected to advance both economic and environmental management strategies in agriculture.

The present study showed that the soil was acidic, nutrient deficient and available phosphorus was below the optimum level required by sunflower. However, results indicated that application of sawdust ash and commercial lime based on agronomic principles such as lime requirement or for improving soil nutrient status have the potential to increase yield of sunflower in acidic, nutrient deficient soils of southeastern Nigeria.

Treatment combination of 3 tha^{-1} SDA \times 1.5 tha^{-1} lime gave the most satisfactory yield of sunflower with regards to head weight and 50 seed weight by supplying soil nutrients and increasing pH.

Comment [XXXX23]: As they prove that these doses are the best if they have not made a derivation of the regressions of the doses.

References

- [1] Groove JH, Summer ME. Yield and leaf composition of sunflower in relation to NPK, and lime treatments. *Nutrient Cycling in Agroecosystems*. 2005; 3/4: 367-378.
- [2] Aduayi EA, Chude VO, Adebusuyi BA, Olayiwola SO. Fertilizer use and management practices for crops in Nigeria. Abuja, Nigeria: Federal Ministry of Agriculture and Rural Development; 2002.
- [3] Aladodo SS, Mathew DE, Otu JO, Najib Y, Akoshile CO. Diurnal and interannual variability of rainfall in Nigeria climatic zones as seen from in-situ and satellite measurements. *Journal of Environment and Earth Science* 2018; 8(2): 9-18

- [4] Adebayo AG, Akintoye HA, Olatunji MT, Shokalu AO, Aina OO. Growth response and flower yield of sunflower to phosphorus fertilization in Ibadan, southwestern Nigeria. Report and Opinion. 2010; 2(4): 29-33
- [5] Lawal BA, Obigbesan GO, Akanbi WB, Kolawole GO. Effect of planting time on sunflower (*Helianthus annuus* L.) productivity in Ibadan Nigeria. African Journal of Agricultural Research. 2011; 6(13): 3049-3054
- [6] Ogunremi EA . The effect of plant population on sunflower seed yield in south western Nigeria. Ife Journal of Agriculture. 1979; 1: 51-56
- [7] Olowe VIO. Effect of plant population density on growth and yield of sunflower (*Helianthus annuus* L.) in the transition zone of south west Nigeria. Tropical Agricultural Research & Extension. 2005; 8: 37-44
- [8] Sutradhar A, Lollato RP, Butchee K, Arnall DB. Determining Critical Soil pH for Sunflower Production. International Journal of Agronomy. 2014; Accessed 25 June 2019. Available: <https://doi.org/10.1155/2014/894196>
- [9] Ibia TO, Effiong GS, Ogban PI, Obi JC. Relationships between phosphorus forms and parent materials in soils of southeastern Nigeria. Acta Agronomica Nigeriana. 2008; 8(2): 104-112
- [10] Osodeke VE. Determination of the residual value of applied phosphorus in some soils of southern Nigeria. J. Sustain, Agric. Environ. 2000; 2(1):139-143
- [11] Ohaeri JE, Eshett ET. Phosphorus forms and distribution in selected soils formed over different parent materials in Abia state of Nigeria. Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension. 2011; 10(3): 28 - 37
- [12] Rodriguez D, Zubillaga MM, Ploschuck E, Keltjens W, Goudriaan J, Lavado R. Leaf expansion and assimilate prediction in sunflower growing under low phosphorus conditions. Plant Soil. 1998; 202: 133-147
- [13] Kovacevic V, Kovacevic J, Lalic A, Jurkovic, Krizmanic M. Influences of liming on maize, sunflower and barley. Cereal Research Communications. 2006; 34(1): 1-13

- [14] Blamey FPC, Nathanson K. Relationships between aluminum toxicity and sunflower yields on an Avalon medium sandy loam *Agrochimica*. 1977; 9: 59-65
- [15] Clapham WM, Zibilske LM. Wood ash as liming amendment. *Communications in Soil Science and Plant Analysis*. 1992; 23(11): 1209-1227
- [16] Brad NC, Weil RR. *The nature and properties of soils*. 12th ed. New Jersey: Prentice Hall Inc.; 1999.
- [17] Villapando RR, Graetz DA. Phosphorus sorption and desorption properties of the spodic horizon from selected Florida Spodosols. *Soil Sci. Soc. Am. J.* 2001; 65:331-339
- [18] Stevenson FJ, Cole MA. *Cycles of soils: Carbon, Nitrogen, Phosphorus, Sulfur, Micronutrients*. 2nd ed. Canada: John Wiley and Sons; 1999.
- [19] Ungaro MG, Ouaggio JA, Gallo PB, Dechen SCF, Neto FL, Melo de Castro O. Sunflower response to soil acidity. *Bragantia*. 1985; 44(1): 41-48
- [20] Eswaran H. Assessment of global resources: Current status and future needs. *Pedologie*. 1993; 43(1): 19-39.
- [21] Woomer PL, Ingram JSJ. *The biology and fertility of tropical soils. The Tropical Soil Biology and Fertility*. Nairobi, Kenya: Report; 1990
- [22] Enwezor WO, Ohiri AC, Opuwaribo EE, Udo EJ. Literature review on soil fertility investigations in Nigeria. Lagos: Federal Ministry of Agriculture and Natural Resources; 1990.
- [23] Osodeke VE, Uba AF. Determination of phosphorus fraction in selected soils of southeastern Nigeria. *International Journal of Natural and Applied Sciences*. 2005; 1(1): 10-14.
- [24] Bridgham SD, Johnston CA, Schubauer-Berigan JP, Weishampel P. Phosphorus sorption dynamics in soils and coupling with surface and pore water in riverine wetlands . *Soil Sci. Soc. Am. J.* 2001; 65: 577-588
- [25] Lin C, Banin A. Effect of long-term effluent recharge on phosphate sorption by soils in a wastewater reclamation plant. *Water, Air and Soil Pollution*. 2005; 164: 257-273.

- [26] Fagbayide JA, Adeoye GO. Sunflower growth and mineral uptake as influenced by fertilizer phosphorus. *Tropical oilseeds Journal*. 1999; 4: 21-28.
- [27] Adeoye GO, Agboola AA. Critical level for soil pH, available P, K, Zn and Mn and maize content of P, Cu, and Mn in the sedimentary soils of southeastern Nigeria. *Fertilizer Research*. 1984; 6: 65-71
- [28] Agboola AA, Corey RB. The relationship between soil pH, organic matter, available phosphorus, exchangeable calcium, magnesium and nine elements in the maize tissue. *Soil Sci*. 1973; 115(5): 367-375.
- [29] Bouyoucos GH. A recalibration of the hydrometer method for mechanical analysis of soil. *Agron. Journ*. 1951; 43: 434-438
- [30] Mclean EO. Exchangeable aluminium. In: Black CA, editor. *Methods of soil plant II. Chemical methods*. Madison: ASA; 1965.
- [31] Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid and titration method. *Soil sci*. 1934; 37: 29-38
- [32] Bray RH, Kurtz LT. Determination of total organic and available forms of phosphorus in soils. *Soil Sci*. 1945; 59: 39-45
- [33] Jackson ML. *Soil chemical analysis*. Englewood cliffs, NY: Prentice Hall; 1962
- [34] Kamprath EJ. (1967). *Soil acidity and response to liming*. Int. Soil Testing Series N. C. State University: Tech Bull. No. 4; 1967
- [35] Odedina SA, Odedina JN, Ayeni SO, Arowojolu SAA, Adeyeye SD, Oyeniyi SO. Effect of types of ash and soil fertility nutrient availability and yield of tomato and pepper. *Nig. J. Soil Sci*. 2003; 13: 61-67
- [36] Owolabi O, Ojeniyi SO, Amodu AO, Hassan K. (2003). Response of cowpea, okra and tomato to sawdust ash manure. *Moor Journal of Agricultural Research*. 2003; 4(2): 178-182
- [37] Awodun MA. Influence of sawdust ash on soil chemical properties and cowpea performance in southwest Nigeria. *Intl. J. Soil Sci*. 2007; 2(1) :78-81

- [38] Onwuka MI, Osodeke VE, Okolo NA. Amelioration of soil acidity using cocoa husk ash for maize production in Umudike area of south east Nigeria. *Tropical and Subtropical Agroecosystems*. 2007; 7: 41-45.
- [39] Ewulo BS, Babadele OO, Ojeniyi SO. Sawdust ash and urea effect on soil and plant nutrient content and yield of tomato. *Am-Eurasian J. Sustain. Agric*. 2009; 3(1): 88-92
- [40] Patterson SJ, Acharya SN, Thomas JE, Bertschi AB, Rothwell RL. Barely biomass and grain yield and canola seed yield response to land application of wood ash. *Agron. J*. 2004; 96: 971-977
- [41] Baath E, Arnebrant K. Growth rate and response of bacteria communities to pH in ash treatment forest soils. *Soil Biol. Chem*. 1994; 26: 995-1001.
- [42] Ayeni LS, Ayeni OM, Oso OP, Ojeniyi SO. Effect of sawdust and wood ash applications in improving soil chemical properties and growth of cocoa (*Theobroma cacao*) seedlings in the nurseries. *Agric. J*. 2008; 3: 323-326.
- [43] Ugese FD and Avav T. Response of mungbean (*Vigna radiata*) to phosphorus application in a southern guinea savanna location of Nigeria. *Nigeria Journal of Sustainable Tropical Agricultural Research*. 2005; 13: 77-80
- [44] Obi O, Ekperigin J. Effects of wastes and soil pH on growth and yield of crops. *African Soils*. 2001; 33: 3-5.
- [45] Ojeniyi SO, Adejobi KB. Effect of ash and goat dung manure on leaf nutrient composition growth and yield of Amaranthus. *Niger Agric J*. 2002; 33: 46-57

Example: for Base Saturation

