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Liming Effects of Sawdust Ash and Lime on Sunflower (*Helianthus annuus* L.) Yield in Acidic Soil of Southeastern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author VEO designed the study and edited the manuscript. Author CVO performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript, managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: A pot experiment was carried out to determine the effect of sawdust ash and lime ($Ca(OH)_2$) on soil characteristics and yield of sunflower in acidic soil of southeastern Nigeria.
Study Design: 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.
Place and Duration of Study: Study was conducted outdoors at Michael Okpara University of Agriculture Umudike, Nigeria, during the 2010 planting season.
Materials and Methods: Treatment combinations were applied to the 60 buckets containing soil, mixed thoroughly and watered adequately. After 1 week of treatment application, two sunflower seeds were planted and later thinned to one seedling per bucket. Plant growth and yield data were collected. Pre planting and post-harvest soil samples were collected and analyzed for soil properties.

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Results: 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.

Conclusion: The study showed that sunflower performed best at the combination of 3 tha^{-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.

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

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

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

2. MATERIALS AND METHODS

2.1 Experimental Site

This study was conducted outdoors at Michael Okpara University of Agriculture, Umudike, Abia State (Lat. 5º29' N and Long.7^{o}32' E, 122 m.a.s.l), Southeastern Nigeria. Climate type is generally humid tropic with rainforest vegetation type. It is characterized by uniform high temperatures which changes slightly during the year. The average annual temperature and rainfall are 26.9ºC and 2046 mm respectively.

2.2 Pot Experiment

Bulk topsoil samples were collected from the Eastern farm of same institution, air dried and sieved through 2 mm sieve. The bulk soil was thoroughly mixed and 10 kg of soil weighed into each of the sixty 12-litre plastic buckets. Sunflower (*Helianthus annuus* L.) seeds were obtained from National Institute for Horticulture Research and Training, Ibadan. Sawdust was collected from timber shed, Umuahia Abia State and burnt to obtain ash. Factor levels comprised four rates (0, 0.5, 1.0, 1.5 tonnes per hectare) of commercial lime [$Ca(OH)_2$] and five rates (0, 1, 2, 3, 4 tonnes per hectare) of sawdust ash. They were arranged in a split- plot design and replicated three times. The different treatment combinations were applied to the 60 buckets containing soil, mixed thoroughly and watered adequately. After 1 week of treatment application, the seeds were planted. Two seeds were planted per bucket and later thinned to one seedling per bucket. Uniform watering and weeding were carried out as required throughout the growing season.

2.3 Statistical Analysis

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

3. RESULTS AND DISCUSSION

3.1 Properties of Soil and Sawdust Ash Used for the Study

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

The mean pH values were 5.48 and 4.40 in water and $CaCl_2$ respectively. The low pH also resulted to high exchangeable acidity. Soil pH values in salts are generally lower than those measured in water. The indication is that these soils at their natural pH are negatively charged [17]. Sunflower thrives best in near neutral soil pH between 6.5 and 7.5 [18]. The low pH values could generally reduce crop yield [19] and in particular, the performance and yield of sunflower [20].

Organic carbon content falls within the range for ultisols found in this region as indicated by Eswaran [21]. The soil organic carbon reflects soils' fertility status [22].

Available phosphorus was lower than the critical level of 15 mg kg^{-1} for most crops [23,24]. In acidic soils, phosphorus is known to be associated with secondary minerals such as Fe and Al (hydrous) oxides through sorption [25], however low effective cation exchange capacity obtained suggests small presence of secondary minerals having high specific surface [26]. Deficiency in available phosphorus results to stunted growth, purplish discoloration of leaves. It also affects flowering, fruit formation and seed production [2]. Uptake of major nutrients elements by sunflower has also been reported to be facilitated by phosphorus application in the forest zone [27].

Total nitrogen was also low and below the critical level of 0.15% for optimum crop production [28]. This may be attributed to heavy leaching caused by high rainfall pattern experienced in this region.

Basic cations were low however calcium exceeded the critical level of 2 Cmol kg^{-1} for most crops [29]. Base saturation had mean of 79.97 %, while exchangeable acidity was between 1.34 and 1.40 Cmol kg^{-1}.

Sawdust ash had pH values of 10.7 and 10.5 in water and $CaCl_2$ respectively (Table 2). It also contained 0.30% of total nitrogen, 17.33 ugg^{-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 [36,37,38,39,40].

3.2 Effect of Sawdust Ash and Lime on Soil Chemical Properties

Effects of sawdust ash and lime on soil chemical properties are shown in Table 3. Although there was no significant effect of sawdust ash (SDA) and lime on organic carbon as several researchers [36,37,38] have previously reported, there were increases relative to control. The highest mean value of 1.55% was obtained at treatment 1 tha^{-1} SDA × 1 tha^{-1} lime.

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

Main and interaction effects of SDA and lime had positive significance (*P*=0.05) on available phosphorus. This may be attributed to the fact that lime [$Ca(OH)_2$] contains Ca^{2+} which increases pH thereby releasing adsorbed P, as well as the high presence of P and Ca in SDA. Odedina et al. [36] found that SDA and other plant derived ashes increased soil N, P, K, Ca, Mg contents of soils.

Basic cations (K, Mg, Na and Ca) significantly increased (*P*=0.05) with all treatments. This finding is in line with that of several other researchers [38,39,41]. This confirms the positive effect of ash and lime on cationic nutrients. The implication of this observation is that the nutrient contained in the treatments were mineralized by microbial activities [42] and made available in soil solution for subsequent plant uptake. The highest exchangeable bases was observed at treatment combination 3 tha^{-1} SDA × 1.5 tha^{-1} lime. From these results, it could be suggested that ash be added as a supplement to lime and not as a replacement. This corroborates the finding of Clapman and Zibilske [15].

Significant increases (*P*<0.012) were recorded for total exchangeable bases, base saturation and ECEC. Percent increases for ECEC and exchangeable bases were up to 200% with reference to control. These results indicate that application of lime and SDA on acidic soil could have positive influence on both soil and crops being grown.

Expected reductions were observed for exchangeable acidity relative to control. This could be as a result of replacement of H^+ and Al^{3+} by the basic cations present in SDA and lime occurring at the exchange sites. This consequently increased the pH of soil solution. Increase in soil pH upon SDA application affirms

Table 1. Soil physico-chemical properties

Properties	Soil	Methods
Sand	73.0%	Hydrometer method [30]
Clay	12.8%	
Silt	14.2%	
pH (1:2.5 sample:H_2O)	5.48	Glass electrode pH meter [31]
pH (1:2.5 sample:$CaCl_2$)	4.40	
Organic Carbon	1.37%	Wet oxidation [32]
Available Phosphorus	11.00 μgg^{-1}	Bray 1 [33]
Total Nitrogen	0.10%	Micro kjeldahl [34]
Exchangeable Acidity	1.36 $Cmolkg^{-1}$	KCl extraction [35]
Potassium	0.09 $Cmolkg^{-1}$	NH_4^+-acetate extraction
Calcium	2.80 $Cmolkg^{-1}$	
Magnesium	2.00 $Cmolkg^{-1}$	
Sodium	0.10 $Cmolkg^{-1}$	
Total exchangeable bases	4.99 $Cmolkg^{-1}$	
ECEC	6.24 $Cmolkg^{-1}$	
Base Saturation	79.97%	

**ECEC: Effective cation exchange capacity*

Table 2. Chemical composition of sawdust ash

Properties	Saw dust ash	Methods
pH (1:2.5 sample:H_2O)	10.7	[31]
pH (1:2.5 sample:$CaCl_2$)	10.5	
Available Phosphorus	17.33 μgg^{-1}	[33]
Total Nitrogen	0.30%	[34]
Potassium	34.78%	NH_4^+-acetate extraction
Calcium	5.53%	
Magnesium	2.13%	
Sodium	0.12%	
Total exchangeable bases	42.56%	

that ash has a liming effect. Several researchers [38,41,43] have successfully used plant ash as liming material.

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. [41].

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 × 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 [44] which is manifested in plant height during vegetative growth.

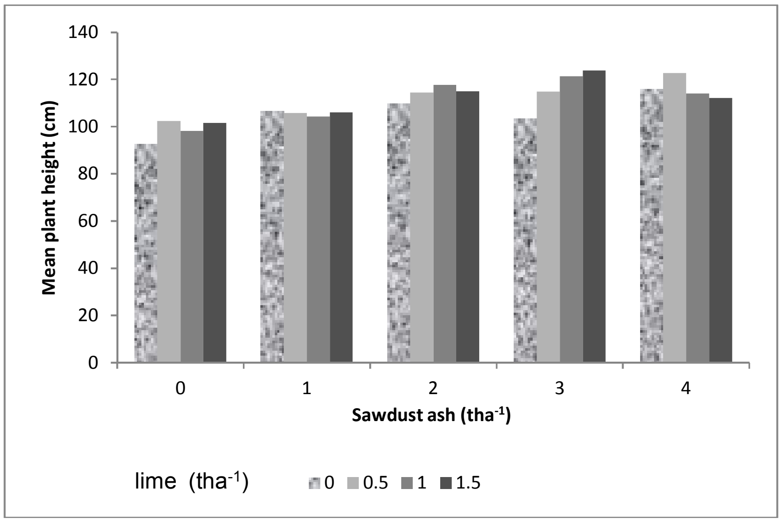

Fig. 1. Effects of sawdust ash and lime on plant height

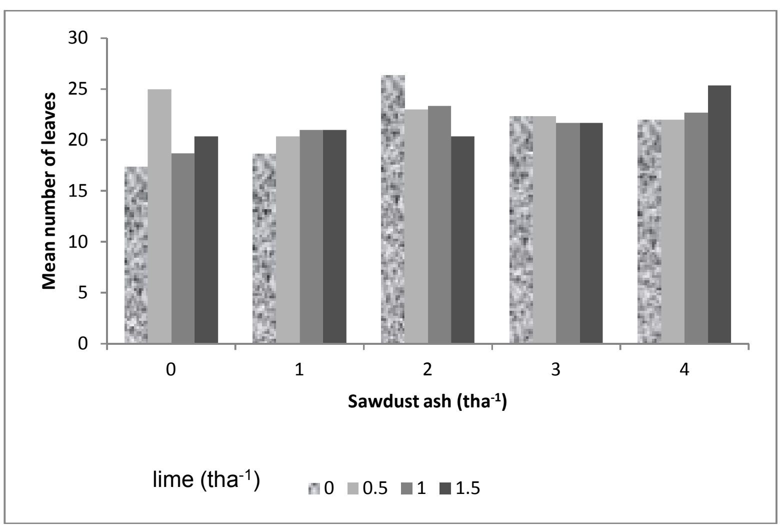

Fig. 2. Effects of sawdust ash and lime on number of leaves

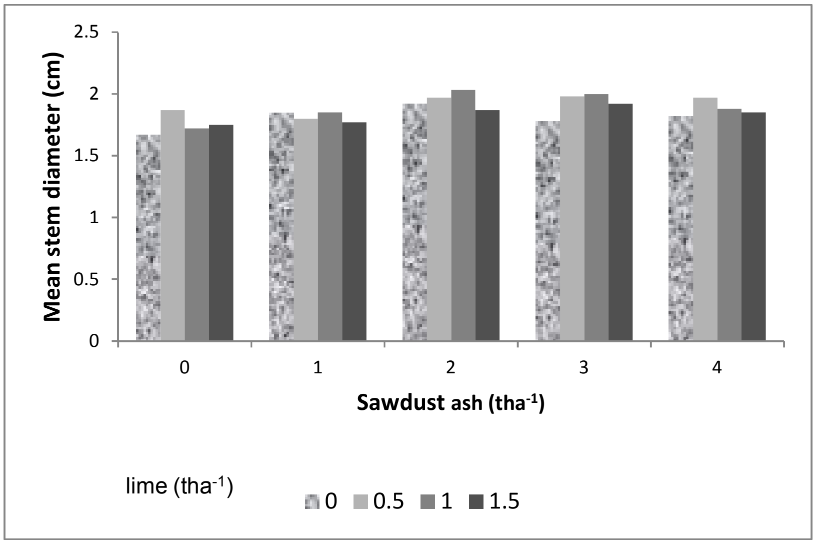

Fig. 3. Effects of sawdust ash and lime on stem diameter

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 × 1 tha^{-1} lime (Fig. 3).

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 tha^{-1} SDA × 1.5 tha^{-1} lime, 3 tha^{-1} SDA × 1.5 tha^{-1} lime and 4 tha^{-1} SDA × 1.5 tha^{-1} lime, for head weight (Fig. 4), 50 seed weight (Fig. 5) and head diameter (Fig. 6) respectively. This corresponded with increases in soil nutrient as seen in Table 3 above. The highest yields with treatment combinations indicate a synergy between SDA

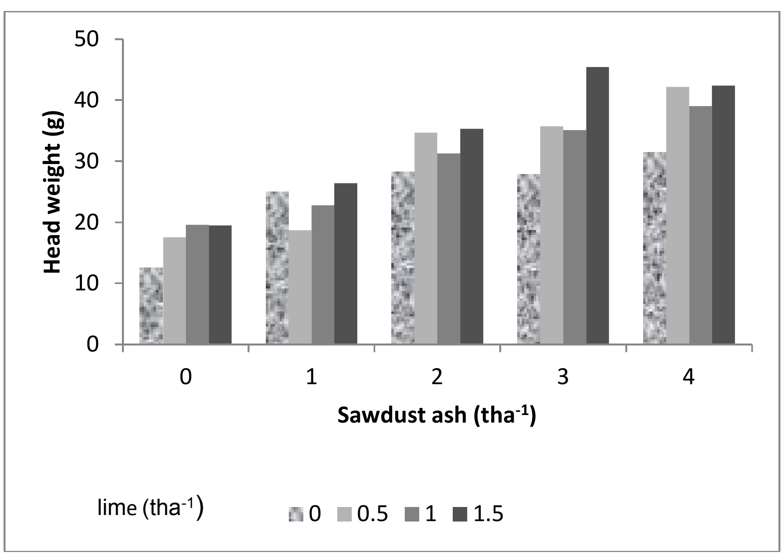

Fig. 4. Effects of sawdust ash and lime on 50 seed weight

Table 3. Effect of sawdust ash and lime on soil chemical properties

	Lime(tha^{-1})	Saw dust ash (tha^{-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 ($cmolkg^{-1}$)	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 ($cmolkg^{-1}$)	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 ($cmolkg^{-1}$)	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 P (μgg^{-1})	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	Lime0.01152
	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×S0.02117
	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	

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

and lime [15]. The positive response of sunflower to SDA and lime is similar with the earlier results obtained with several crops such as Cowpea [38, 45], Tomato [37], Amaranthus [46], Okra [37] and maize [39]. These studies attributed crop responses to SDA application which increased soil pH and nutrients such as N, P, K, Ca, Mg.

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 [20]. 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

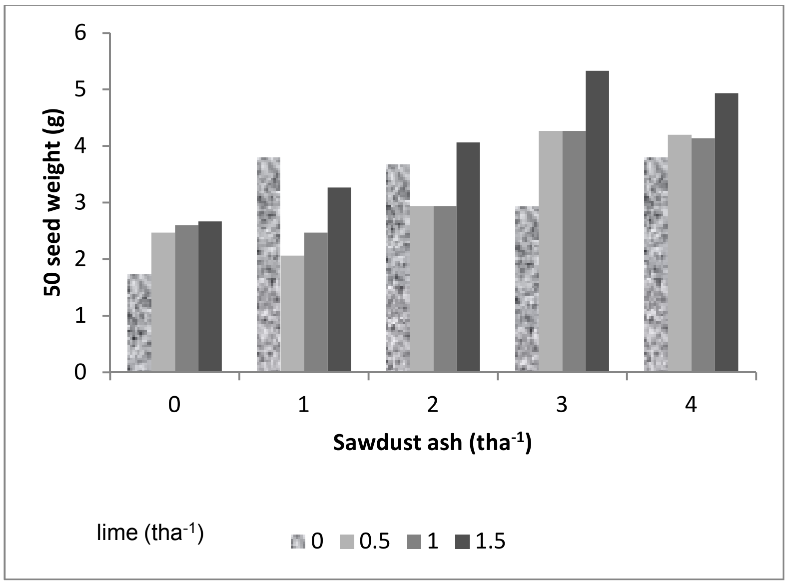

Fig. 5. Effects of sawdust ash and lime on 50 seed weight

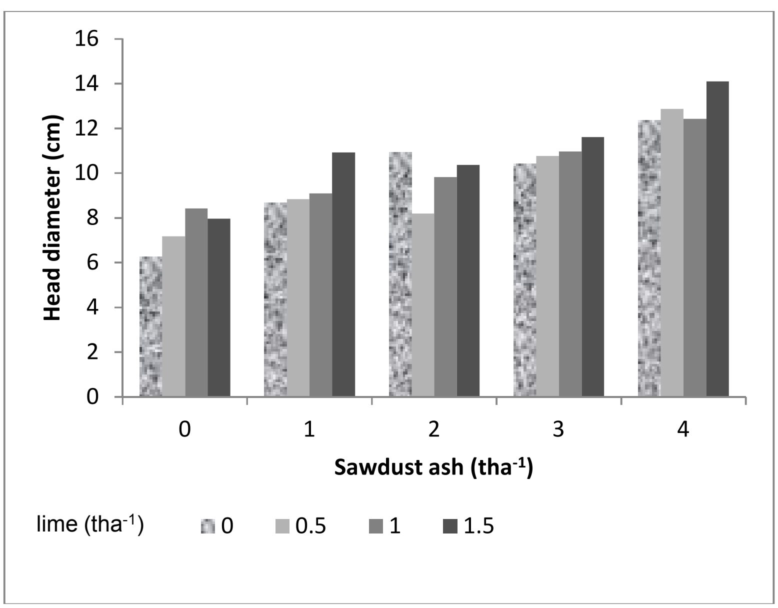

Fig. 6. Effects of sawdust ash and lime on head diameter

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.

4. 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 × 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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