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Effects of Lime on Growth and Yield of *Mucuna flagellipes* (Vogel ex Hook) in an Acid Tropical Ultisol

O. A. Agba[1], J. E. Asiegbu[2], E. E. Ikenganyia[3*], M. A. N. Anikwe[3], T. E. Omeje[4] and J. O. Adinde[5]

[1]Department of Agronomy, Cross River University of Technology, Obubra, Cross River State, Nigeria.
[2]Department of Crop Science, University of Nigeria, Nsukka, Enugu State, Nigeria.
[3]Department of Agronomy and Ecological Management, Enugu State University of Science and Technology, Agbani, Enugu State, Nigeria.
[4]Department of Agricultural Technology, Enugu State Polytechnic, Iwollo, Enugu State, Nigeria.
[5]Department of Horticultural Technology, Enugu State Polytechnic, Iwollo, Enugu State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The effects of lime (calcium carbonate) on the growth and yield of *Mucuna flagellipes* were studied in 2012 and 2013 cropping season respectively at the Teaching and Research Farm of the Department of Agronomy, Cross River University of Technology, Cross River State, Nigeria. The experiment had six rates of calcium carbonate (0.0, 1.0, 1.5, 2.0, 2.5 and 4 0 t ha^{-1}) laid out in randomized complete block design with six replications. Calcium carbonate significantly ($p < 0.05$) increased the number of leaves per plant, number of branches per plant, nodules, vine length, leaf area index and dry matter of plant fractions. Soils amended with calcium carbonate shortened the period to anthesis, pod set, and increased the number of inflorescences, flowers and pod yield per plant. Calcium carbonate at the rate of 2.5 t ha^{-1} significantly ($p < 0.05$) reduced pod abortion, number of pods without seeds and produced the highest seed yield of 2.82 t ha^{-1} and 2.80 t ha^{-1} in

**Corresponding author: E-mail: eejike43@yahoo.com, emmanuel.ejike@esut.edu.ng;*

2012 and 2013 cropping season respectively. Farmers should cultivate *Mucuna flagellipes* with the application of 2.0 t ha^{-1}or 2.5 t ha^{-1} of calcium carbonate under an acid tropical ultisol as obtained in Obubra condition.

Keywords: Mucuna flagellipes; lime; growth; nodule; yield.

1. INTRODUCTION

Mucuna flagellipes (Vogel ex Hook) belongs to the family *Fabacea*, sub-family *Papilionoideae* [1]. It is one of the lesser known Nigerian indigenous legumes with high economic importance [2,3]. The seed is rich in protein, fat, carbohydrate and minerals [3,4]. The seed is used in soup preparation where it functions as a thickener and condiment [5]. In pharmaceutical industry, the gum extracted from the seed is use as a binder in the formulation of ephedrine hydrochloric tablet [6,7]. The leaves were reported as being used to formulate local hair dye [8]. Despite the economic importance, *Mucuna flagellipes* is only cultivated at a sub-subsistence level by the traditional peasant farmers in compound under trees [3] where the trees serve as live stakes for the crop to climb. Literature on the cultivation of the crop in commercial quantities in regular faming system is scanty. It was considered necessary to domesticate *Mucuna flagellipes* and integrate it into the regular farm for commercial exploitation.

Studies have shown that legumes benefits from lime application especially in acidic soils [3,2,9, 10,11]. Lime a common material for soil amendment in the humid tropical regions to correct soil pH [12,2,3]. The humid tropical soils are often exposed to high rainfalls and high amounts of leaching of bases, and hence there is usually the need for lime application [12] recommended 1.5 to 3.0 tonnes per hectare of lime for Nsukka ultisol, while [11] suggested 3.5 t $CaCO_3$/ha for South east region of Nigeria soils for optimum yield of crops. Generally there is scanty literature information on the appropriate rate of lime require for the optimum growth and yield of *Mucuna flagellipes*.

Therefore this work aimed to determine the appropriate rate of lime [Calcium carbonate ($CaCO_3$)] needed for optimum growth and yield of *Mucuna flagellipes* under a tropical acid ultisol of Obubra Cross River, South- South Nigeria.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

Field trials were conducted at the Teaching and Research Farm of the Department of Agronomy, Cross River State University of Technology, Obubra, Cross River State, Nigeria in 2012 and 2013 cropping season, respectively. Obubra is located at latitude 05° 59' N and longitude 8° 15' E. in the rainforest zone of Nigeria [13]. Rainfall distribution pattern in this region is bimodal with peaks in July and September and a short dry spell around mid August. The mean rainfall amount is 2250 - 2500 mm per annum and the mean annual temperature is 27° Celsius with a mean monthly relative humidity of 79%. The experimental site was under two years grass fallow which was cleared and the land ploughed and harrowed in April, 2012 and 2013 respectively. The soil is a degraded ultisol, which is characterized by low fertility and high acidity caused by over exploitation, erosion or leaching [13].

2.2 Experimental Design

The experiment consist of six rates of calcium carbonate ($CaCO_3$) namely, 0.0, 1.0, 1.5, 2.0, 2.5 and 4.0 t ha^{-1} laid out in randomized complete block design with six replications. Each plot measured 4 m x 4m (16 m^2). A total of 36 beds were made. Each of the beds was separated from one another by a spacing of 1 m and 1 m pathway between replications. $CaCO_3$ was applied on 10th April, 2012 and 2013 planting season respectively (two weeks after planting). The method of application was by broadcast ploughed-down, where the required quantity of $CaCO_3$ per plot was evenly spread on the plot and completely worked into the soil by the use of garden fork.

2.3 Field Operations

Mature healthy seeds of *Mucuna flagellipes* were soaked in water at room temperature for 24 hours before planting, to ensure good field emergence. Sowing of seeds was done on 25th of April, 2012 and 2013 cropping season respectively, at the rate of two seeds per hole at a plant spacing of 1.0 m by 0.6 m (inter and intra row spacing respectively). The seedlings were thinned to one seedling per stand at two weeks after field emergence. Vertical staking of seedlings was done at three weeks after planting using bamboo stake. Weeding was done manually by the use of hoe.

2.4 Soil Sample Collection

Soil samples were collected with steel auger from the top soil to a depth of 0 to 20 cm before planting and at four and eight weeks after planting. Three representative soil samples were randomly collected per plot and bulked to form a composite soil sample for each plot. A total of 36 composite soil samples were collected.

2.5 Soil Sample Analysis

Samples were air dried, ground and passed through a sieve of 2 mm standard mesh size. The soil pH was determined with a pH meter using 1:2.5 soil to water ratio and 1: 2.5 soil to 0.1 N KCl (potassium chloride) suspension according to [14]. Organic carbon was determined using the Walkley and Black wet digestion method [15]. Soil organic matter content was obtained by multiplying the value of organic carbon by 1.724 (Van Bemmeler factor). Total nitrogen was determined by micro-kjeldahl procedure [14]. Available phosphorus was extracted with Bray II extractant as described by [16] and determined colorimeterically using ascorbic acid method [17]. Exchangeable potassium was extracted using 1 N ammonium acetate (NH_4OAC) solution and determined by the flame emission spectroscopy as outlined by [18]. Aluminum and Hydrogen content (exchangeable acidity) were determined by titrimetric method after extraction with 1.0 N KCl [19]. The cation exchange capacity was determined by NH_4OAC displacement method [20]. Calcium and magnesium were determined by the complexiometeric titration method as described by [21]. Particle size distribution analysis was done by the hydrometer method [22] and the corresponding textural class determined from the United States Department of Agriculture Soil Textural Triangle. Base saturation was determined by the method outline by [14].

2.6 Growth and Yield Data Collection

In both 2012 and 2013 cropping seasons, records were taken on growth and yield parameters at 45, 60, 75, 90 and 164 days after planting. Number of leaves per plant and number of branches per plant were determined by taking a visual count of the green leaves and the branches, plant height was determined by measuring the length of the plant from the soil level to the tip of the topmost leaf using a measuring tape, Leaf area per plant was obtained by destructive sampling of the leaves per plant taken to the laboratory for leaf area determination using leaf area meter (model Mk – 2). Leaf area index was determined as total leaf area per plant divided by the feeding area available for the plant (inter row spacing multiplied by intra row spacing of each plant) according to [23]. The destructively sampled plants were separated into fractions (leaves, stems, nodules and roots) and put in a paper envelope and oven dried at 80° Celsius to a constant weight for three days for the dry matter determination of, nodules and root. Crop growth rates (nodule growth rate and root growth rate) were determined by the equation stated below.

Crop growth rate (CGR)

$$CGR = \frac{W_2 - W_1\ (g/m^2/\ day)}{SA\ (t_2 - t_1)}$$

Where:

CGR = Crop growth rate.

W_1 and W_2 = Dry weight at beginning and end of the interval of growth period.

t_1 and t_2 = Sampling time 1 and 2.

SA = The area occupied by the plant at sampling.

Yield data were collected after harvest (full maturity). Each plant was harvested separately. Number of pods per plant was obtained by visual counting of pods per plant, number of seeds per plant was determined by visual counting of the seeds in the pod per plant and number of pods without seeds was determined by visual counting pods without seeds. Pod yield per plant, seed yield per plant and seed yield per hectare were recorded at harvest using electronic weighing balance. Days to first and 50% anthesis and pod formation (days to first pod set and 50% pod set)was calculated by counting the number days starting from the day of planting to anthesis and pod formation respectively. Number of inflorescences per plant, number of flowers per plant and number of flowers aborted per inflorescence were computed by visual counting of the inflorescences, flower and flower abortion.

2.7 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) as outlined [24]. Significant means were separated using Fishers least significant difference (F-LSD) at 5% probability level. Statistical analysis was executed using GENSTAT Release 7.2DE Discovery Edition 3 [25] statistical software.

3. RESULTS

Monthly rainfall amount was high enough to support crop growth. In all the months, May to October had the highest rainfall amount. 312.6 mm rainfall amount was observed in July in 2012 and 345.5 mm in July in 2013 (Table 1).The highest average maximum air temperature was 30.10°C observed in March in 2012 and 34.2°C in 2013 respectively. The highest soil temperatures were observed in February (30.10°C in 2012 and 30.70°C in 2013). While the lowest minimum soil temperature was in the months of June (25.40°C in 2012 and 25.30°C in 2013) and December (24.60°C in 2012 and 24.70°C in 2013) and were adequate to support crop growth. Relative humidity and air temperature maintain similar trend as the soil temperature.

The soil of the experimental site was characterized as sandy loam with low pH of 4.1 (2012) and 4.3 (2013) in water and 3.4 (2012) and 3.2 (2013) in potassium chloride, at the start of the experiment in 2012 and 2013 planting season respectively (Table 2). Hence, the soil requires the application of lime to raise the soil pH and reduce acidity. The total soil nitrogen contents were 0.00567% in 2012 and 0.0064% in 2013, organic matter content was 1.32% (2012) and 1.24% (2013), organic carbon was 0.65% in 2012 and 0.72% in 2013. The exchangeable bases (magnesium, calcium potassium and sodium) were low, but exchangeable acidity like hydrogen and aluminum were high in both cropping season.

Table 3 shows that soil pH increased with incremental application of $CaCO_3$ to the soil. The highest application rate of 4.0 t ha^{-1} of $CaCO_3$ at four weeks after planting (6.11 in water and 6.32 in potassium chloride in 2012 and 6.21 in water and 6.42 in potassium chloride in 2013) and at eight weeks after planting (6.75 in water and 5.14 in potassium chloride in 2012 and 6.65 in water and 5.34 in potassium chloride in 2013) was found to be significantly ($p < 0.05$) the highest in comparison with the control treatment which had the lowest values of soil pH at four weeks after planting (4.32 in water and 3.71 in potassium chloride in 2012 and 4.25 in water and 3.84 in potassium chloride in 2013) and at eight weeks after planting (4.91 in water and 3.89 in potassium chloride in 2012 and 4.94 in water and 3.92 in potassium chloride in 2013) respectively.

Early in the life (45, 60 and 75 days after planting) of *Mucuna flagellipes,* soil amended with $CaCO_3$ did not produced effect on the number of leaves per plant and number branches per plant in 2012 and 2013 cropping season respectively as showed in (Table 4). But at 75 days after planting (DAP), the number of leaves per plant increased significantly ($p < 0.05$) with increase in $CaCO_3$ rate up to 4 t ha^{-1}. The highest number of leaves (341.3 in 2012 and 367.6 in 2013), branches 38.2 (2012) and 37.4 (2013) per plant were produced in plots that had 2.5 t ha^{-1}at 164 days after planting. Similarly, leaf area index was significantly ($p < 0.05$)the highest in the plot amended with2.5 t ha^{-1} and 4 t ha^{-1}respectively of $CaCO_3$ compared with the other rates at the same period of observation in 2012 and 2013 planting season respectively. Also in Table 4, plant height determined as the length of the longest vine per plant showed that *Mucuna flagellipes* vine length increased significantly with increase in the rate of $CaCO_3$. The longest main vine length (553.7 cm in 2012 and 511.3 cm in 2013) were recorded in 165 days after planting in plots that were treated with 4.0 t ha^{-1} of $CaCO_3$.

Application of $CaCO_3$ did not produced significant ($p < 0.05$) effect on the leaf dry weight per plant at the early stage (45 DAP) of growth of *Mucuna flagellipes* (Table 5). However, as from 60 -164 DAP, the effects of$CaCO_3$on vine dry weight per plant and leaf dry weight per plant became significant ($p < 0.05$), as they increased with increase in the application rate of $CaCO_3$ up to 2.5tha^{-1} but beyond this rate, there was significant ($p < 0.05$) decreased in the leaf dry weight per plant and vine dry weight per plant of *Mucuna flagellipes* in 2012 and 2013 cropping season respectively. Leaf growth rate between 90-164 DAP was greater than the Leaf growth rate between 45- 60 DAP, showing a greater growth rate at a later period than earlier stage of growth as influenced by $CaCO_3$ (Table 6). The soil treated with 2.5 t $ha^{-1}$of $CaCO_3$ significantly ($p < 0.05$) gave the highest leaf growth rate at 90-165 DAP in 2012 and 2013 cropping season respectively. Root growth rate (Table 6) was higher in $CaCO_3$ treated plots than the untreated plot at all periods of observation. Treating the soil with $CaCO_3$ at the rate of 2.5 t ha^{-1} recorded higher root dry matter per plant than the other $CaCO_3$ rates.

Table 1. Meteorological data of 2012 and 2013 cropping season

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2012 weather records												
Total rainfall (mm)	2.00	0.00	118.60	147.40	153.75	224.54	312.60	198.50	253.30	132.70	12.90	0.00
Rain days	1.00	0.00	3.00	7.00	13.00	19.00	23.00	16.00	20.00	16.00	3.00	0.00
Max. air temperature (°C)	30.00	32.10	33.40	31.30	30.20	29.60	28.50	27.70	27.90	30.20	29.10	28.30
Min. air temperature (°C)	23.10	25.20	23.10	22.80	22.40	22.20	20.70	21.40	20.10	22.80	22.90	22.10
Soil temperature (°C)	27.20	30.50	30.10	29.90	26.70	25.40	26.50	28.20	25.80	26.40	27.30	24.60
Relative humidity (%)	65.60	63.70	73.40	74.60	75.65	80.60	85.10	78.80	80.10	78.20	72.30	67.80
2013 weather records												
Total rainfall (mm)	1.37	0.00	126.30	157.20	171.41	324.80	345.50	203.20	238.70	164.70	4.28	0.00
Rain days	1.00	0.00	4.00	10.00	15.00	18.00	24.00	22.00	20.00	15.00	5.00	0.00
Max. air temperature (°C)	31.20	33.50	34.20	32.10	30.30	29.40	28.90	28.50	27.30	30.90	29.70	28.10
Min. air temperature (°C)	22.40	26.30	24.10	23.40	22.50	22.60	21.10	22.30	21.80	23.40	20.50	20.20
Soil temperature (°C)	27.60	30.70	29.60	29.30	28.50	25.30	25.80	27.20	26.70	26.40	25.80	24.70
Relative humidity (%)	64.30	60.90	70.80	75.50	77.80	85.50	86.80	80.70	80.30	72.40	70.40	65.90

Source: Department of Agronomy Metrological Unit, Cross River University of Technology, Obubra Cross River State Nigeria

Table 2. Initial soil characteristics before planting in 2012 and 2013 cropping season

Parameters	2012	2013
Particle size distribution (%)		
Coarse sand	45	46
Fine sand	29	28
Clay	23	24
Silt	3	2
Textural class	Sandy loam	Sandy loam
pH (water)	4.1	4.3
pH (KCl)	3.4	3.2
Organic carbon (%)	0.65	0.72
Organic matter (%)	1.32	1.24
Total nitrogen (%)	0.0057	0.0064
Available phosphorus (ppm)	7.9	8.8
Exchangeable bases (meg/100 g soil)		
Calcium	1.2	1.0
Magnesium	0.7	0.9
Potassium	0.17	0.16
Sodium	0.9	0.8
Exchangeable acidity (meg/100 g soil)		
Hydrogen	2.6	2.4
Aluminum	3.2	3.6
Cation exchangeable capacity (meg/100 g soil)	8.1	7.0
Base saturation (%)	46	44

Table 3. Effect of calcium carbonate ($CaCO_3$) application on soil pH at four and eight weeks after planting in 2012 and 2013 planting season

$CaCO_3$ rates (t ha^{-1})	pH in water		pH in KCL	
	4 WAP	8 WAP	4 WAP	8 WAP
2012 cropping season				
0.0	4.32	4.91	3.71	3.89
1.0	5.14	5.93	4.94	4.93
1.5	5.52	6.05	5.02	4.61
2.0	5.71	6.21	5.18	4.78
2.5	5.93	6.53	5.52	4.93
4.0	6.11	6.75	6.32	5.14
F-LSD $_{(0.05)}$ for 2 rates	0.03	0.11	0.02	0.18
2013 cropping season				
0.0	4.25	4.94	3.84	3.92
1.0	5.37	5.98	4.25	4.98
1.5	5.63	6.21	5.34	4.84
2.0	5.62	6.46	5.19	4.77
2.5	5.93	6.53	5.52	4.96
4.0	6.21	6.65	6.42	5.34
F-LSD $_{(0.05)}$ for 2 rates	0.03	0.12	0.13	0.10

F-LSD $_{(0.05)}$- Fishers least significant at 0.05 probability level, WAP- weeks after planting

The result in Table 7 reveals that $CaCO_3$ did not have a significant ($p < 0.05$) effect on nodule production in *Mucuna flagellipes* at 45 – 60 days after planting. Nodulation was delayed in the crop till 75 days after planting, when nodule number per plant increased significantly ($p < 0.05$) with incremental $CaCO_3$ treatment up to 2.5 t ha^{-1}. Amending the soil with $CaCO_3$ at the rate of 2.5 t ha^{-1} produced the highest nodule dry weight of 41.2 g $plant^{-1}$ in 2012 and 36.2 g $plant^{-1}$ in 2013. The application $CaCO_3$ above the rate of 2.5t ha^{-1} resulted in a decrease in the nodule dry weight per plant in the 2012 and 2013 planting season.

Table 4. Effects of calcium carbonate ($CaCO_3$) rates on vegetative growth of *Mucuna flagellipes* in 2012 and 2013 cropping season

$CaCO_3$ rates (t ha^{-1})	Number of leaves per plant					Leaf area index					Number of branches per plant					Plant height (cm)				
	45	60	75	90	164	45	60	75	90	164	45	60	75	90	164	45	60	75	90	164
	DAP					DAP					DAP					DAP				
2012 cropping season																				
0.0	11.3	16.3	19.3	27.4	205.4	0.18	0.23	0.29	0.38	4.86	1.5	1.8	3.4	9.9	22.3	136.0	204.9	250.6	490.0	460.8
1.0	12.9	17.8	21.1	30.0	277.5	0.19	0.28	0.34	0.46	5.51	1.6	1.3	3.4	13.1	27.7	117.0	204.8	266.1	313.0	473.0
1.5	12.5	18.6	22.2	30.0	333.1	0.22	0.29	0.38	0.47	6.23	1.7	2.2	3.7	14.8	33.2	123.8	206.8	270.4	338.7	488.7
2.0	13.1	19.2	23.1	32.1	335.2	0.24	0.32	0.41	0.52	6.31	1.9	2.4	3.9	15.2	35.1	125.2	213.1	281.1	338.2	489.2
2.5	14.2	22.1	24.3	34.2	341.1	0.32	0.42	0.53	0.54	7.22	2.3	2.5	4.3	17.2	38.2	132.1	224.3	311.3	341.1	501.3
4.0	14.1	22.3	24.2	34.2	341.3	0.34	0.42	0.53	0.53	7.24	2.3	2.4	4.1	17.3	33.1	133.3	227.4	321.4	356.3	553.7
F-LSD $_{(0.05)}$ for 2 rates	NS	NS	1.4	2.0	11.2	0.01	0.02	0.01	0.03	0.1	NS	NS	NS	1.1	1.4	NS	NS	2.2	2.3	2.3
2013 cropping season																				
0.0	8.1	12.1	15.2	20.3	171.4	0.13	0.20	0.23	0.34	3.47	1.1	1.3	2.1	7.4	18.2	101.8	153.4	216.4	286.4	411.4
1.0	10.3	14.2	18.1	26.1	215.3	0.16	0.24	0.30	0.40	4.61	1.2	1.1	2.3	10.2	22.1	109.7	161.3	231.5	303.6	437.5
1.5	11.4	16.3	20.2	28.1	340.1	0.19	0.27	0.34	0.43	5.37	1.1	1.2	2.5	12.4	29.5	113.4	163.1	252.7	327.3	458.2
2.0	12.2	18.3	22.4	29.3	354.6	0.23	0.29	0.44	0.46	6.41	1.7	1.4	3.4	15.3	31.4	124.3	210.2	267.1	346.2	471.2
2.5	13.1	19.4	23.2	32.3	367.2	0.18	0.31	0.47	0.44	6.63	1.6	3.7	3.3	16.4	22.3	127.2	246.7	261.6	362.3	481.3
4.0	13.5	23.1	25.5	33.2	378.2	0.24	0.28	0.45	0.48	5.35	2.2	2.5	4.3	17.5	24.3	134.3	228.3	332.2	349.4	511.3
F-LSD $_{(0.05)}$ for 2 rates	NS	NS	1.4	2.0	9.3	0.01	0.02	0.02	0.03	0.1	NS	NS	NS	1.1	1.2	NS	NS	2.1	2.2	2.3

F-LSD $_{(0.05)}$- Fishers least significant at 0.05 probability level, NS – Non significant at 0.05 probability level, DAP – Days after planting

Table 5. Effects of calcium carbonate ($CaCO_3$) rates on leaf dry weight per plant, vine dry weight per plant and root dry weight per plant of *Mucuna flagellipes* in 2012 and 2013 cropping season

$CaCO_3$ rates (t ha^{-1})	Leaf dry weight per plant (g)				Vine dry weight per plant (g)				Root dry weight per plant (g)			
	45	60	75	90	45	60	75	90	45	60	75	90
	DAP				DAP				DAP			
2012 cropping season												
0.0	1.47	4.32	7.41	16.62	0.67	2.35	4.34	12.12	0.31	1.01	4.23	16.11
1.0	2.31	5.54	8.65	21.54	1.24	3.56	5.43	16.33	0.32	2.11	7.28	19.33
1.5	2.53	6.42	8.83	23.38	1.58	4.11	6.34	20.11	0.31	2.57	8.43	22.43
2.0	2.02	6.82	9.71	34.24	1.94	4.74	6.86	25.27	0.32	3.43	10.31	26.62
2.5	2.41	7.43	11.42	38.55	2.12	5.13	7.37	27.45	0.31	4.15	14.11	29.64
4.0	2.75	6.24	9.86	24.17	1.73	4.26	6.24	21.32	0.31	3.44	9.06	23.12
F-LSD $_{(0.05)}$ for 2 rates	NS	0.21	0.32	1.21	0.01	0.32	0.51	2.12	NS	0.02	0.71	1.11
2013 cropping season												
0.0	1.38	3.96	6.87	15.87	0.58	1.21	2.32	4.13	0.28	1.03	3.89	15.68
1.0	2.35	5.43	8.03	20.95	1.28	2.36	3.54	7.34	0.34	2.13	6.76	18.86
1.5	2.35	6.36	8.78	24.08	1.67	3.75	4.22	9.32	0.35	2.67	8.25	21.55
2.0	2.43	6.59	10.10	32.76	1.86	4.11	4.67	11.32	0.36	3.64	10.33	24.48
2.5	2.39	7.39	11.31	37.15	2.23	4.35	5.12	12.17	0.35	4.23	13.86	26.29
4.0	2.33	6.19	8.59	23.58	1.81	3.22	4.11	7.21	0.32	2.14	8.96	22.37
F-LSD $_{(0.05)}$ for 2 rates	NS	0.22	0.30	1.19	0.01	0.53	0.02	0.12	NS	0.03	1.52	2.11

F-LSD $_{(0.05)}$- Fishers least significant at 0.05 probability level, NS – Non significant at 0.05 probability level, DAP – Days after planting

Table 6. Effects of calcium carbonate ($CaCO_3$) rates on leaf growth rate, vine growth rate and root growth rate of *Mucuna flagellipes* in 2012 and 2013 cropping season

$CaCO_3$ rates ($t\ ha^{-1}$)	Leaf growth rate ($g/m^2/day$)				Vine growth rate ($g/m^2/day$)				Root growth rate ($g/m^2/day$)			
	45-60	60-75	75-90	90 -164	45 -60	60-75	75-90	90-164	45-60	60-75	75-90	90-164
	DAP				DAP				DAP			
2012 cropping season												
0.0	0.21	1.13	2.16	5.23	0.31	1.02	2.12	3.12	0.12	0.34	2.13	4.12
1.0	1.04	1.74	2.57	7.14	0.54	1.76	3.43	5.44	0.13	0.65	4.12	6.35
1.5	1.76	2.32	4.12	8.33	1.27	2.06	3.89	6.23	0.12	0.96	4.88	6.87
2.0	2.32	3.44	5.47	11.47	1.84	2.49	4.06	6.89	0.13	1.14	5.33	8.11
2.5	2.68	4.22	7.23	12.23	2.31	2.89	4.87	7.27	0.13	1.37	6.23	9.22
4.0	1.36	3.34	4.12	9.12	1.36	2.03	3.32	6.34	0.13	0.78	4.55	6.35
F-LSD $_{(0.05)}$ for 2 rates	0.02	0.14	0.23	0.43	0.01	0.02	0.41	0.04	NS	0.02	0.12	0.62
2013 cropping season												
0.0	0.32	1.09	2.09	4.87	0.02	0.21	1.46	2.32	0.11	0.32	2.11	4.05
1.0	1.11	1.68	2.61	6.98	0.05	0.34	3.04	4.76	0.12	0.46	4.17	6.21
1.5	1.69	2.17	4.07	8.21	0.06	0.38	4.21	6.24	0.13	0.89	5.11	7.32
2.0	2.28	3.29	5.38	10.88	0.07	0.53	5.35	6.98	0.13	1.17	5.89	8.14
2.5	2.72	4.11	6.98	11.90	0.08	0.71	6.12	7.33	0.13	1.38	7.23	9.34
4.0	1.28	3.28	4.09	8.32	0.06	0.41	4.11	5.21	0.13	0.81	4.48	6.22
F-LSD $_{(0.05)}$ for 2 rates	0.02	0.13	0.18	0.42	0.01	0.03	0.61	0.52	NS	0.03	0.13	0.41

F-LSD $_{(0.05)}$- Fishers least significant at 0.05 probability level, NS – Non significant at 0.05 probability level, DAP – Days after planting

Table 7. Effects of calcium carbonate ($CaCO_3$) rates on nodulation of *Mucuna flagellipes* in 2012 and 2013 cropping season

$CaCO_3$ rates (t ha^{-1})	Number of nodules per plant			Nodule dry weight (g $plant^{-1}$)			Nodule growth rate ($g/m^2/day$)	
	75	90	164	75	90	164	45-90	90-164
		DAP			DAP		DAP	
2012 cropping season								
0.0	2.9	6.1	21.3	0.01	0.55	3.60	0.004	1.121
1.0	4.0	7.2	25.2	0.02	0.61	4.64	0.006	3.242
1.5	4.6	7.5	32.2	0.02	0.70	7.36	0.007	4.133
2.0	5.1	8.1	36.1	0.05	0.82	9.10	0.008	5.211
2.5	6.2	9.1	41.2	0.07	0.91	11.22	0.009	6.092
4.0	5.0	8.0	35.1	0.05	0.71	8.41	0.011	4.123
F-LSD $_{(0.05)}$ for 2 rates	0.01	0.01	0.3	0.01	0.01	0.3	0.001	0.010
2013 cropping season								
0.0	1.2	4.5	16.4	0.01	0.43	2.62	0.003	1.130
1.0	1.9	5.5	20.2	0.02	0.49	3.44	0.006	3.141
1.5	2.1	6.3	24.5	0.02	0.64	5.21	0.007	4.223
2.0	4.2	7.3	33.1	0.03	0.64	6.11	0.008	5.134
2.5	6.3	9.3	36.2	0.04	0.78	7.24	0.012	6.110
4.0	5.0	8.1	33.5	0.06	0.57	8.16	0.009	4.086
F-LSD $_{(0.05)}$ for 2 rates	NS	0.1	0.2	NS	0.01	0.3	0.001	0.010

F-LSD $_{(0.05)}$- Fishers least significant at 0.05 probability level, NS – Non significant at 0.05 probability level, DAP – Days after planting

Application of $CaCO_3$ in the soil significantly ($p < 0.05$) reduced the number of days to first and 50% anthesis, pod set and percentages of pod set per plant than untreated plot (Table 8) in 2012 and 2013 planting season respectively. $CaCO_3$ significantly ($p < 0.05$) gave higher number of pods per plant compared with plots that were not treated with $CaCO_3$. *Mucuna flagellipes* grown on soil treated with 2.5 t ha^{-1} produced lesser number of pods without seeds than the other rates of$CaCO_3$ (Table 9). Similarly pod yield per plant was significantly ($p < 0.05$) the greatest at 2.5 t ha^{-1} than the other $CaCO_3$ rates. Seed yield per plant and seed yield per hectare increased significantly ($p < 0.05$) with progressive increase in rates of $CaCO_3$. The highest seed yield of 2.82 t ha^{-1} (2012) and 2.80 t ha^{-1} (2013) was obtained in plots treated with 2. 5 t ha^{-1} of $CaCO_3$.

4. DISCUSSION

The study site was characterized with high temperature, relative humidity and rainfall amount thus, this could have resulted in leaching, low soil pH and low soil nutrients. These were also reported by earlier researchers [12,26]. Rainfall was high enough to support crop growth throughout the cropping seasons of 2012 and 2013. Result of this study indicated that $CaCO_3$ remarkable raised soil pH. The highest effects of $CaCO_3$ on soil pH was obtained in plot amended with 4.0 t ha^{-1} at eight weeks after planting in 2012 and 2013 cropping season. This support the findings of [12] who reported increase in soil pH with the application of 4.0 t $ha^{-1}$of $CaCO_3$.

In the present study, $CaCO_3$ at the rate of 2.0 t ha^{-1}or 2.5 t ha^{-1} was sufficient to raise the soil pH levels that reduced the soil acidity.. Earlier researchers [12,2,3] recommended the liming of Obubra soil especially when pH in water is below 5.0 to improve the soil nutrient status for increase growth and yield of crops.

The delay in the effect of $CaCO_3$ on leaf, branches, vine and nodulation in the early period up to 60 days after planting and started at 75 to 165 days after planting when $CaCO_3$ was applied produced the highest number of leaves, branches and nodules per plant. This delay appeared to be related to the large seed cotyledon that serves as the source of nitrate for the young seedling. Similarly, [1,6] observed late responses of *Mucuna flagellipes* to $CaCO_3$. The effects being obvious at 90 days after planting when $CaCO_3$ produced the highest dry matter yield of leaf, vine and nodules per plant. They attributed the lack of responses of the crop to $CaCO_3$ early in the life of the plant to the large dependence of the young seedling on the store of the food reserve in its cotyledons that took 30 to 40 days before atrophy and drop from the plant.

Table 8. Effects of calcium carbonate ($CaCO_3$) rates on flower and pod formation of *Mucuna flagellipes* in 2012 and 2013 cropping season

$CaCO_3$ rates (t ha^{-1})	Days to first anthesis	Days to 50% anthesis	Days to first pod set	Days to 50% pod set	Number of inflorescence per plant	Number of flowers per inflorescence	Number of flowers aborted per inflorescence	Percentage of flowers aborted per inflorescence	Percentage of pod set per inflorescence
2012 cropping season									
0.0	136.8	153.5	159.6	178.6	27.6	8.4	6.0	71.42	28.58
1.0	127.4	148.2	154.3	169.5	31.3	8.3	4.3	51.81	48.19
1.5	125.0	145.3	152.1	165.3	40.1	8.4	4.1	48.81	51.19
2.0	123.3	141.1	150.0	162.4	43.4	8.5	4.0	47.06	52.94
2.5	120.2	138.2	148.4	159.3	38.1	8.7	3.2	35.78	64.22
4.0	123.1	144.2	151.2	163.4	40.3	8.5	4.4	51.76	48.24
F-LSD $_{(0.05)}$ for 2 rates	0.70	1.01	1.13	1.28	0.6	NS	0.02	1.5	1.3
2013 cropping season									
0.0	142.0	162.7	169.1	184.9	30.1	8.4	6.2	73.81	38.50
1.0	135.5	153.8	160.4	178.7	33.4	8.4	4.0	47.62	52.38
1.5	128.1	151.9	161.6	172.6	41.1	8.6	3.8	44.17	55.83
2.0	124.2	143.1	151.3	163.3	44.2	8.3	3.4	40.96	59.04
2.5	120.1	136.3	149.2	158.4	45.1	8.5	3.2	37.65	62.35
4.0	129.3	138.2	157.3	165.2	41.2	8.3	4.3	51.81	48.19
F-LSD $_{(0.05)}$ for 2 rates	0.95	1.01	1.32	1.45	0.5	NS	0.3	1.62	1.3

F-LSD $_{(0.05)}$- Fishers least significant at 0.05 probability level, NS – Non significant at 0.05 probability level, DAP – Days after planting

Table 9. Effects of calcium carbonate ($CaCO_3$) rates on the yield of *Mucuna flagellipes* in 2012 and 2013 cropping season

$CaCO_3$ rates (t ha^{-1})	Number of pods per plant	Number of pods without seed per plant	Percentage of pod without seeds per plant	Number of seeds per pod	Average number of seeds per plant	Pod yield per plant (g $plant^{-1}$)	Seed yield per plant (g $plant^{-1}$)	Seed yield per hectare (t ha^{-1})
2012 cropping season								
0.0	18.3	11.3	61.74	3.2	39.7	184.1	162.1	1.39
1.0	26.1	11.2	42.91	3.1	50.1	250.6	202.9	2.01
1.5	30.2	12.3	40.72	2.7	59.4	265.9	233.4	2.32
2.0	34.3	9.2	26.82	3.1	63.2	312.4	256.2	2.51
2.5	53.2	10.3	19.36	3.2	67.1	437.3	321.3	2.82
4.0	37.2	9.3	25.00	2.6	57.2	271.1	213.7	2.01
F-LSD $_{(0.05)}$ for 2 rates	2.7	0.4	1.03	NS	1.15	5.6	9.6	0.04
2013 cropping season								
0.0	20.1	12.4	61.69	3.0	37.5	175.7	136.9	0.79
1.0	22.8	11.3	49.56	3.1	54.0	246.2	213.5	1.67
1.5	26.0	10.4	40.00	3.0	60.0	258.7	231.4	1.89
2.0	39.2	9.5	24.23	3.4	66.2	301.3	273.2	2.24
2.5	51.3	11.1	21.64	3.1	68.1	428.4	331.3	2.80
4.0	35.4	10.3	29.10	3.2	55.4	266.2	208.2	2.00
F-LSD $_{(0.05)}$ for 2 rates	2.1	0.3	2.00	NS	2.0	2.8	8.8	0.03

F-LSD $_{(0.05)}$- Fishers least significant at 0.05 probability level, NS – Non significant at 0.05 probability level, DAP – Days after planting

Application of lime increased flower production in terms of the number of inflorescence per plant and pod set. High numbers of pods without seeds were recorded especially in the unamended plots. [6] similarly reported cases in which $CaCO_3$ led to high pod yield of *Mucuna flagellipes*.

5. CONCLUSION

Based on the result of this investigation, *Mucuna flagellipes* should be integrated into the regular farm field and be cultivated on a commercial scale with the application of either, 2.0 t ha^{-1} or 2.5 t ha^{-1} of $CaCO_3$ for optimum growth and yield of the crop and for reduction in soil acidity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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