**GROWTH AND YIELD TRAITS VARIATION OF CANARY MELON (*Cucumis melo* L. *var. Inodorus*) ON LIMED ACID SOIL IN A HUMID TROPICAL AGROECOLOGY**

**ABSTRACT**

Field experiments were carried out on acid soil of Calabar in the 2020/2021 cropping season to determine a suitable lime rate for the production of canary melon (*Cucumis melo* L. (Inodorus group)). The experiment was laid out in a randomized complete block design with three replications: lime (CaCO3) applied at 0 t ha-1, 1 t ha-1, 2 t ha-1, 3 t ha-1, 4 t ha-1 and 5 t ha-1 and ‘Juan Canary’ melon variety. Results showed that lime application at 1 t ha-1, 2 t ha-1, 3 t ha-1, 4 t ha-1 and 5 t ha-1 raised the soil pH by 13.56%, 33.89%, 36.32%, 40.44% and 43.58% respectively. Lime influence on leaf area index did not vary with lime rates (p > 0.05). Economic yields varied (p ≤ 0.05) with lime rates. There was a linear relationship (p < 0.001; R2 ≥ 0.66 ≤ 0.92) between lime rates and seedling emergence, leaf length, leaf breadth, leaf area, leaf area index, number of leaves per plant, vine length and vine thickness of canary melon. Strong to relatively strong associations (p < 0.001, r ≥ 0.52 ≤ 0.85) between fruit yield and individual fruit weight, fruit volume and fruit diameter were recorded. Overall, the effect of 2 t ha-1 of lime application on soil pH was statistically (p ≤ 0.05) different from 0 t ha-1 application but similar (p > 0.05) to lime rates ≥ 3 t ha-1 ≤ 5 t ha-1. The lime-amended soil pH was improved to a range of 5.5 and 6.0 in support of fruit vegetable production in this area.

**KEYWORD:** *Cucumis melo,*cucurbits, lime, soil pH, acidity.

1. **INTRODUCTION**

Liming is commonly used to improve the productivity of acidic soils in agricultural systems. The addition of lime increases the availability of nutrients, which would otherwise be strongly limited by low soil pH (Rastija, 2014). The global production and use of synthetic nitrogenous fertilizers had increased considerably since 1960, which resulted in a significant increase in crop production (Smil, 2002). Acid soils are considered soils with a pH < 5.5 at 0 – 20 cm soil depth. About 3,950 million hectares of the land area was estimated to be affected by acidity, occupying nearly 30% of the global land surface (Sumner and Noble, 2003). This accounts for approximately 50% of the global arable land area (Dai, *et al*., 2017). Soil acidity is one of the most yield-limiting factors that affect crop productivity (McLaren and Cameron 1996). Various factors could contribute to increased soil acidity, such as acid rain, industrial pollution, and agricultural production (Fageria and Nascente, 2014; Holland *et al*., 2018). Particularly, more than 50% of the world’s cropland has been affected by soil acidity as a result of intensified agricultural activities such as monoculture farming and excessive use of agrochemicals (Von Uexküll and Mutert, 1995). A broad array of mechanisms has been described with which plant-soil-microbe interactions tremendously impact nutrient availability, acquisition, and crop productivity (Haynes, 1984; Fageria and Baligar, 2008). The objectives of this study were to evaluate the effect of different liming rates on the growth and yield of canary melon (*Cucumis melo* L. var*. inodorus*) cv. ‘Juan Canary’ melon on the acid soil of Calabar and to compare pre-planting (before liming) and post-planting (after liming) physical and chemical properties of acid soil in Calabar on planted canary melon (*Cucumis melo* L. v*ar. Inodorus*) cv. ‘Juan Canary’ melon.

1. **MATERIALS AND METHODS**
	1. ***Description of the experimental site***

The field experiment was carried out at the Department of Crop Science Teaching and Research Farm of the University of Calabar, Nigeria during the late planting season (30th October 2020 to 31st January 2021). Calabar is in the Southern - eastern zone of Nigeria (latitude 4.5° and 5.2°N and longitude 8.0° and 8.3°E, 39m above sea level) (Ibanga and Armon, 1992). It has a bimodal annual rainfall distribution that ranges from 3,000 to 3,500mm (Manamu, 1975) with a short dry period from December to February, separating the long (March and August) and short period (September to November) of the rainy season.

* 1. ***Soil sampling and analysis***

Pre-planting soil samples were collected from each of the blocks at 20cm depth, a composite soil sample was then taken for laboratory analysis to determine the physical and chemical properties of the soil using a suitable laboratory analytical procedure. Post-planting soil samples from each of the plots with designated lime rates in each of the replicates were collected after harvest and bulked (according to lime rates) for analysis.

* 1. ***Source of experimental materials***

Fruits of *Cucumis melo* L. *var. inodorus* were identified using descriptors for melon (*Cucumis melo* L.) according to the International Plant Genetic Resources Institute (IPGRI) (2003). Mature freshly harvested canary melon fruits were sourced from fruit vegetable farmers’ crop enterprises in Jalingo, Taraba State during harvest (between August and September 2020). Agricultural lime (CaCO3) was obtained from the Cross River State Agricultural Development Programme Office, Calabar, Cross River State.

* 1. ***Experimental design, treatments allocation and data collection***
		1. *Experimental design*

The experiment was laid out in a randomized complete block (RCBD) design with three (3) replications (blocks) and six (6) treatments (six rates of agricultural lime (CaCO3) (0 t ha-1 (control i.e., no application of lime), 1 t ha-1, 2 t ha-1, 3 t ha-1, 4 t ha-1 and 5 t ha-1)) which were randomly assigned using a table of random numbers. The dimension of the entire experimental plot (allowing 1 m distance at the edges for border rows effect) was 22 m x 16 m giving an area of 352 m2. The blocks were separated by 1 m alley. Raised beds measuring 4.0 m (Length) x 2.5 m (Breadth) x 0.3m (Height) were separated, within and between blocks, by 1m furrows. The net plot for each treatment plot in the bed was 1 m x 1 m (which accommodated six tagged plants).

* + 1. *Lime application*

Agricultural lime (CaCO3) was uniformly applied at the following rates,1 t ha-1, 2 t ha-1, 3 t ha-1, 4 t ha-1 and 5 t ha-1, by minimal tillage (20 cm depth). The incorporation was allowed for one week before planting. Each bed received 1kg, 2kg, 3kg, 4kg, 5kg of lime for the following rates 1 t ha-1, 2 t ha-1, 3 t ha-1, 4 t ha-1, and 5 t ha-1 respectively.

* + 1. *Data collection*

Data collection was done following procedures described in IPGRI (2003). All agronomic data, except seedling emergence, were collected (estimated) from six tagged plants in the net plot measuring 1 m x 1 m. The data collected where seedling emergence (%), vine length (cm), number of leaves, vine thickness (mm), leaf length (cm), leaf breadth (cm), leaf area (cm2), leaf area index, number of fruits per plant, fruit weight (g), fruit yield (t ha-1), fruit volume (ml), fruit thickness and fruit diameter (mm), number of seeds per fruit and Brix (%).

* 1. **Statistical analysis**
		1. *Agronomic data analysis*

Count data were suitably transformed, where applicable, before statistical analysis. Treatment and replicate mean of all growth and yield data were subjected to a two-way analysis of variance (ANOVA) using Genstat 16th Edition. Duncan’s New Multiple Range (DNMRT), at 95% confidence limit, was used for the *post hoc* test.

* + 1. *Regression and correlation analyses of growth traits*

Simple linear regression analysis was used to model relationships between lime rates and the various growth traits of canary melon. Pearson’s correlation analysis was conducted to determine the extent of association between yield and yield-related traits of the canary melon as influenced by soil pH. These analyses were conducted at a 95% confidence limit.

1. **RESULTS**
	1. **Physical and chemical properties of the experimental soil**

The result of the physical and chemical properties of the experimental soil is shown in Table 1 and Figure 3. This shows that the soil texture was sandy loam with low clay content The initial soil pH was acidic (4.13). There was no significant difference (p˃0.05) between Organic carbon (OC) before planting and after harvest at 0 t ha-1 (0.91%) and 5 t/h (0.84%). However, organic carbon content after harvest at 4 t ha-1 (0.97%) was the highest. There was no significant difference (p˃0.05) between Organic matter (OM) before planting (1.04%) and after harvest at 0 t ha-1 (1.58%) and 5 t/h (1.55%). However, organic matter content after harvest at 4 t ha-1 (1.67) was the highest. There was a significant difference (p≤0.05) between exchangeable acidity (EA) before planting (1.28 cmol kg-1) and after harvest at 1 t ha-1 (0.93 cmol kg-1), 2 t ha-1 (0.85 cmol kg-1), 3 t ha-1 (0.77 cmol kg-1), 4 t ha-1 (0.69 cmol kg-1), and 5 t ha-1 (0.22 cmol kg-1) with exception of 0 t ha-1 (1.07 cmol kg-1). There was no significant difference (p˃0.05) between effective cation exchange capacity (ECEC) before planting (5.78 cmol kg-1) and after harvest at 0 t ha-1 (6.52 cmol kg-1), 1 t ha-1 (7.41 cmol kg-1), 2 t ha-1 (7.67 cmol kg-1), with exception of 3 t ha-1 (9.73 cmol kg-1), 4 t ha-1 (10.99 cmol kg-1), and 5 t ha-1 (12.00 cmol kg-1). However, effective cation exchange capacity after harvest at 5 t ha-1 (12.00 cmol kg-1) was the highest. There was a significant difference (p≤0.05) between Base Saturation (BS) before planting (77.85%) and after harvest at 1 t ha-1 (85.73%), 2 t ha-1 (88.50%), 3 t ha-1 (92.05%), 4 t ha-1 (93.66%), and 5 t ha-1 (95.06%) with exception of 0 t ha-1 (83.23%). However, BS after harvest at 5 t ha-1 (95.06%) was the highest. From the result presented in figure 3, the initial pre-planting soil pH value (4.13) without lime application, was not significantly different (p˃0.05) after lime application at 1 t ha-1 (4.69). Lime applied at the rate of 2 t ha-1 significantly (p ≤ 0.05) increased the soil pH but was not significantly different from lime applications at 3t ha-1 (5.63), 4t ha-1 (5.80) and 5 t ha-1 (5.93).

* 1. **Growth traits of canary melon as influenced by lime**
		1. *Seedling emergence*

From the result presented in Table 2, the application of lime had a significant influence on the emergence of the canary melon estimated at 7 days after planting (DAP). The proportion of seedlings that emerged ranged from 87.0% to 98.0%. There was no significant difference (p˃0.05) between the control, where no lime was applied at0 t ha-1 (87.0%), and 1 t ha-1 (87.0%) of lime application. Similarly, applying 2 t ha-1 (91.67%) of lime significantly increased (p≤0.05) the emergence of canary melon seedlings when compared with 0 t ha-1 and 1 t ha-1 lime rates. There was no significant difference (p˃0.05) in seedling emergence when 3 t ha-1 (95.0%) and 4 t ha-1 (96.67%) of lime were applied. The application of 5 t ha-1 resulted in the highest proportion of seedling emergence (98.0%) which was also not significantly (p ˃ 0.05) different from the effect produced by 4 t ha-1.

* + 1. *Leaf length*

The application of 5 t ha-1 of lime in Table 2, resulted in the highest leaf length (10.67cm) which was significantly different (p ≤ 0.05) from other levels of lime application. Similarly, the control where no lime was applied at 0 t ha-1 (8.09) was not significantly different from lime applied at 1 t ha-1 (8.56cm) and 2 t ha-1 (8.88 cm). There was no significant difference (p ˃ 0.05) between lime applied at 2 t ha-1 (8.88 cm) and 3 t ha-1 (9.11 cm) but there was a significant difference (p ≤ 0.05) between lime applied at 4 t ha-1 (9.76 cm) from all treatments.

* + 1. *Leaf breadth*

In Table 2, it is shown that the application of lime had a significant influence on the leaf breadth at a different level of lime application. The application of lime at 5 t ha-1 (13.66 cm) was significantly different (p ≤ 0.05) from other levels of lime application. Similarly,0 t ha-1 (9.34) was significantly different from lime applied at 1 t ha-1 (10.13 cm), 2 t ha-1 (10.82 cm), 3 t ha-1 (11.31 cm), 4 t ha-1 (12.21 cm) and 5 t ha-1 (13.66 cm), although lime applied at 2 t ha-1 was not significantly different (p ˃ 0.05) from lime applied at 3 t ha-1. Lime applied at 4 t ha-1 was significantly different (p ≤ 0.05) from other levels of lime application.

* + 1. *Leaf area*

The application of 5 t ha-1 (97.49cm2) of lime in Table 2, resulted in the highest plant leaf area which was significantly different (p ≤ 0.05) from lime applied at other levels of treatments. The control where no lime was applied at 0 t ha-1 (50.51) was significantly different (p ≤ 0.05) from lime applied at 1 t ha-1 (58.14 cm2), 2 t ha-1 (62.27 cm2), 3 t ha-1 (68.96 cm2), 4 t ha-1 (79.87 cm2) and 5 t ha-1 (97.49 cm2). Similarly, lime applied at 2 t ha-1 and 3 t ha-1 was not significantly different from each other but significantly different (p ≤ 0.05) from lime applied at 4 t ha-1 and other levels of application of treatments.

* + 1. *Leaf area index*

From the results presented in Table 2, the application of lime had a significant influence on the leaf area index of canary melon at various levels. Whereas lime application at the rate of 5 t ha-1 (0.0195) produced canary melon with the highest leaf area index, the lowest leaf area index was produced from plants that were planted on soil not amended with lime at 0 t ha-1 (0.0101).

* + 1. *Number of leaves per plant*

Application of lime in Table 2, had a significant influence on the number of leaves per plant of the Canary melon at various levels. Lime applied at 5 t ha-1 (80.49) has the highest number of leaves per plant at various levels and is significantly different (p≤0.05) from other levels of lime application. Lime applied at 3 t ha-1 (66.51) was significantly different (p≤0.05) from other levels of lime application with exception of lime applied at 4 t ha-1 (70.04). The lowest number of leaves was recorded at 0 t ha-1 (32.48).

* + 1. *Vine length*

The effect of lime on vine length in Table 2, shows a significant influence on various levels of lime application. Application of 5 t ha-1 of lime resulted in the highest plant vine length (222.69 cm) which was significantly (p ≤ 0.05) different from other levels of application of treatments. Vines produced from soil amended with 2 t ha-1 of lime were significantly (p ≤ 0.05) longer (158.94 cm) than vines obtained from soils without lime (0 t ha-1) and 1 t ha-1 (130.06cm). Vine lengths from plots that received 4 t ha-1 (188.57 cm) were not significantly different from plots with 3 t ha-1 (172.01 cm). However, the lowest vine length was recorded at 0 t ha-1 (107.61 cm).

* + 1. *Vine thickness*

The effect of lime on vine thickness presented in Table 2 shows a significant influence at various levels of application. Lime applied at 5 t ha-1 (7.11 cm) resulted in thicker vines which were significantly different (p ≤ 0.05) from vines obtained from other levels of lime application with exception of lime applied at 4 t ha-1 (6.67 cm) which was not significantly different (p > 0.05). The control, soils where no lime was applied, resulted in plants with thinner vines (5.03 cm). The application at 2 t ha-1 lime (6.20cm)did not significantly differ (p > 0.05)in influence on the vine thickness in comparison with other lime rates except for lime applied at 3 t ha-1 (6.53 cm) (p ≤ 0.05).

* 1. **Yield and yield-related traits of canary melon on limed acid soil**
		1. *Number of fruits per plant*

The result presented in Table 3 shows that the number of fruits per plant was significantly influenced by the rate of lime at various levels. Lime applied at 5 t ha-1 (4.67) was significantly different (p ≤ 0.05) from other levels of application of lime with exception of lime applied at 3 t ha-1 (3.44), 2 t ha-1 (3.22) and 1 t ha-1 (3.67). It also shows that lime applied at 5 t ha-1 (4.67) has the highest number of fruits per plant whereas, the control where no lime was applied at 0 t ha-1 (2.11) had the lowest number of fruits per plant.

* + 1. *Fruit volume*

The application of lime at 5 t ha-1 (1136.85 ml/fruit) has the highest fruit volume and was significantly different (p ≤ 0.05) from the control where no lime was applied at 0 t ha-1 (984.07 ml/fruit) but there was no significant difference (p > 0.05) between lime applied at 1 t ha-1 (1089.57 ml/fruit) and other levels of application of lime with exception of control at 0 t ha-1. However, the control where no lime was applied at 0 t ha-1 had the lowest fruit volume as shown in Table 3.

* + 1. *Fruit weight*

Fruit weight (g/fruit) was not significantly influenced (p > 0.05) by the rate of lime at various levels in Table 3. Lime applied at 5 t ha-1 (320.89 g/fruit) has the highest fruit weight (g/fruit) and was significantly different (p ≤ 0.05) from other lime applied at different levels of lime application with exception of lime applied at 4 t ha-1 (255.28 g/fruit). The control where no lime was applied at 0 t ha-1 (198.96 g/fruit) was not significantly different (p > 0.05) from other levels of application of lime with exception of lime applied at 5 t ha-1. However, the control (0t ha-1) has the lowest fruit weight (198.96 g/fruit).

* + 1. *Fruit weight*

The effect of lime on fruit weight (t ha-1) in Table 3 shows that lime applied at 5 t ha-1 (6.41 t ha-1) has the highest fruit weight and was significantly different (p ≤ 0.05) from other levels of application of lime except for lime applied at 4 t ha-1 (5.17 t ha-1). The control where no lime was applied at 0 t ha-1 (3.19 t ha-1) is not significantly different (p > 0.05) from lime applied at 1 t ha-1 (4.50 t ha-1),2 t ha-1 (4.00) and 3 t ha-1 (4.12 t ha-1) with exception of lime applied at 4 t ha-1 (5.17 t ha-1) and 5 t ha-1 (6.41 t ha-1).

* + 1. *Brix*

From the result presented in Table 3, the control where no lime was applied at 0 t ha-1 (8.86%) has the highest Brix and was significantly different (p ≤ 0.05) from lime applied at 3 t ha-1 (7.08%) and 4 t ha-1 (7.12%) with exception of lime applied at 1 t ha-1 (7.53%), 2 t ha-1 (7.65%) and 5 t ha-1 (7.84%). However, the application of lime at 3 t ha-1 (7.08%) had the lowest Brix (%).

* + 1. *Rind thickness*

The influence of lime in Table 3 shows that lime applied at 5 t ha-1 (30.09 mm) has the highest rind thickness and was significantly different (p ≤ 0.05) from other levels of lime application. The control where no lime was applied at 0 t ha-1 was significantly different (p ≤ 0.05) from lime applied at 1 t ha-1 (14.32 mm),2 t ha-1 (16.65 mm),3 t ha-1 (18.17 mm),4 t ha-1 (21.09 mm) and 5 t ha-1 (30.09 mm). All the levels of lime application were significantly different (p ≤ 0.05) in terms of their influence on the rind thickness of canary melon.

* + 1. *Fruit diameter*

From the result presented in Table3, lime applied at 5 t ha-1 (92.45 cm) has the highest fruit diameter and was significantly different (p ≤ 0.05) from other levels of application of lime. The control where no lime was applied at 0 t ha-1 (71.47 cm) was significantly different (p ≤ 0.05) from lime applied at 1 t ha-1 (75.72 cm),2 t ha-1 (79.04 cm), 3 t ha-1 (81.97 cm),4 t ha-1 (89.20 cm) and 5 t ha-1 (92.45 cm). All the levels of lime application were significantly different (p ≤ 0.05) from each other.

* + 1. *Number of seeds per fruit*

Application of lime at various levels in Table 3 shows that lime applied at 5 t ha-1 (604.33) was significantly different (p ≤ 0.05) from other levels of application of lime. The control where no lime was applied at 0 t ha-1 (460.67) was significantly different (p ≤ 0.05) from lime applied at 1 t ha-1 (475.56),2 t ha-1 (500.11),3 t ha-1 (530.00),4 t ha-1 (534.22) and 5 t ha-1 (604.33). Lime application at 5 t ha-1 (604.33) had the highest number of seeds per fruit. All the levels of lime application were significantly different (p ≤ 0.05) from each other.

* 1. **Linear relationships between growth traits of canary melon and lime rates**

Regression models showing the extent of the relationships, as indicated by the lines of best fit, between lime rates and selected growth traits of canary melon in Calabar are presented in Figures 1 and 2 below.

* + 1. *Lime vs seedling emergence*

Every increase in lime from 1 t ha-1 (4.69) to 5 t ha-1 (5.93) led to a significant (p < 0.001) increase in seedling emergence percentage determined at 7DAP (Figure 2a). The relationship was expressed as the proportion of seedlings that emerged at 7DAP = 2.50 Lime Rate + 86.32. This model was 89% efficient in describing the proportion of the variance in seedling emergence (%) at 7WAP that could be explained by liming at a rate between 0 t ha-1 (4.13) and 5 t ha-1 (5.93).

* + 1. *Lime vs leaf length*

The regression model (Figure 2b) shows that there was a significant (p < 0.001) relationship between the Leaf length and the lime. The coefficient of determination (R2) was0.74 and the model describing the goodness-of-fit measure for the linear regression was given as Leaf length =0.48 Lime Rate + 7.98.

* + 1. *Lime vs leaf breadth*

The regression model in Figure 2c shows the relationship between the Leaf breadth and the lime, every increase in lime from 1 t ha-1 (4.69) to 5 t ha-1 (5.93) leads to a significant increase in the Leaf breadth and this relationship was significant at (R2 =0.92, p<0.001). The equation describing this model is expressed as Leaf Breadth = 0.81 Lime Rate + 9.22.

* + 1. *Lime vs leaf area*

From the result of the regression analysis obtained (Figure 2d), the model shows the relationship between the leaf area and the lime. The linear regression relationship was significant (p < 0.001) and the model was 91% efficient in describing the influence of lime (rates ranging from 0 t ha-1 to 5 t ha-1) on leaf area estimates of canary melon in the study area. The model is given as Leaf Area =8.71 Lime Rate + 48.11.

* + 1. *Lime vs leaf area index*

Similarly, in Figure 3a, the model shows the relationship between the Leaf area index and the lime was significant (R2 =0.91, p<0.001). The equation of the model is expressed as Leaf Area Index = 0.0017 Lime Rate + 0.0096.

* + 1. *Lime vs number of leaves per plant*

From the result obtained in Figure 3b, the model shows the relationship between the number of leaves and the lime was significant (R2 =0.79, p<0.001). The equation of the model is expressed as Number of Leaves per Plant = 9.44 Lime Rate + 34.35.

* + 1. *Lime vs vine length*

The linear regression model shows the relationship between the vine length and the lime in Figure 3c. The relationship was significant (p < 0.001) and 66% efficient in describing the observed variation in vine length of canary melon due to lime application. The equation is given as Vine Length=21.83 Lime Rate + 108.74.

* + 1. *Lime vs vine thickness*

In Figure 3d, the model shows the relationship between the vine thickness and lime. Vine thickness and lime rate relationship was significant at p < 0.001 and R2 was0.77. The model is expressed as Vine Thickness=0.38 Lime Rate + 5.28.

* 1. **Correlation of yield traits of canary melon grown on limed acid soil**

Results showing the association between selected yield and yield-related traits of canary melon grown on lime amened acid soil of Calabar are presented in Table 4. There was a positive correlation (r = 0.71) between the individual weight of mature canary fruits and the volume of fruit. This association was statistically significant at p<0. 001. Fruit yield (t ha-1) had a highly significant (p ≤ 0.001) positive correlation (r = 0.75) with the volume of mature fruits and weight of individual mature fruits (r = 0.85). The result obtained also showed a weak positive correlation between rind thickness and the weight of individual fruits (r = 0.39, p ≤ 0.01) as well as fruit yield (t ha-1) (r = 0.41, p ≤ 0.01). It was similarly observed that fruit diameter significantly increased with rind thickness (r = 0.79, p ≤ 0.001). Although individual fruit weight and total fruit yield likewise significantly (p ≤ 0.001) increased with rind thickness, this association was moderately weak in both cases (r = 0.5 approximately). There were very weak and negative correlations between the Brix and all yield traits measured in this study. The correlation coefficient ranged from 0.03 to 0.23. However, this was not statistically significant. The number of seeds per fruit significantly (p ≤ 0.001) and positively varied with the rind thickness (0.64) and diameter (0.61) of the harvested mature fruits. Meanwhile, total fruit yield (t ha-1) had a weak but significant association with the number of seeds obtained from harvested mature fruits of canary melon planted on limed acid.

1. **DISCUSSION**
	1. ***Soil physical and chemical properties***

An analysis of soil in the area of the study showed that the soil was classified as sandy loam in texture and the soil pH was acidic (4.13). This textural class is accounted for by the low clay and silt contents in the area of study. After the application of lime, the highest pH was 5.93. This is suitable for crop production in Nigeria as reported by Lawal *et al.* (2013). Organic carbon content was deficient at all locations at 0 t ha-1 (0.91%) and 5 t/h (0.84%), which was not in agreement with the critical value of 1.0% recommended by Agboola *et al.* (1987). Organic matter content was marginal after harvest at 0 t ha-1 (1.58%) to 5 t ha-1 (1.55%). There was a significant decrease of Exchangeable acidity after harvest at 0 t ha-1 (1.07 Cmol/kg) to 5 t ha-1 (0.22 Cmol/kg). The effective cation exchange capacity and Base saturation values were marginal. The quality of soil does not depend on its ability to supply adequate nutrients alone but the nutrients must be in the right proportion as needed by plants (Ayeni *et al*., 2011).

* 1. ***Growth and yield traits of canary melon grown on acid soil as influenced by lime***

The growth and yield traits of canary melon were affected by different rates of lime application in the study. The number of leaves, leave length and breadth, emergence, vine thickness, as well as length of the vines, was all influenced by Lime. Lime applied at 5 t ha-1 gave plants more leaves when compared with other lime rates used in the study. This shows that liming appeared to have more effect on the number of leaves. This result agreed with El-Habbasha *et al.* (2005) and Sushil *et al. (*1997) who reported that increasing phosphorus levels increased the number of leaves and stem weight per plant. Liming increases crop production primarily through direct effects on improving soil physical, chemical, and biological characteristics, which lead to increased availability and mobility of many plants’ essential nutrients (Chan and Heenan, 1998; Bolan *et al*. 2003; Jaskulska *et al*. (2014). The results of this study verified that liming increased yield regardless of environmental and experimental conditions and the enhanced crop yield caused by liming depends greatly on crop species, liming material, liming application method, and soil texture. The result of this study showed that there was a significant influence on the growth and yield traits of canary melon between the lime applied at various levels and the control where no lime was applied. The findings show a high potential of these lime rates to improve acidic soils in support of canary melon production. Crop species differ significantly concerning their tolerance to soil acidity and their sensitivity to soil pH (Holland, *et al.*, 2018). The results showed that the yield of canary melon was affected by liming. The number of fruits per plant was significantly influenced by the rate of lime at various levels. Nonetheless, it is recommended that soil testing remains the best tool to guide in the application of lime to regulate soil pH. This suggestion was I consonant with the findings of Ossom and Rhykerd (2007) on the effect of lime (0 – 2.5 t/ha) on weed diversity and yield of sweet potato.

* 1. ***Relationship models for growth traits of canary melon and lime application rates***

Simple linear regression prediction models were highly significant (p < 0.001) in describing the relationship between lime rates and seedling emergence, leaf length, leaf breadth, leaf area, leaf area index, number of leaves per plant, vine length and vine thickness of canary melon. The relationship models between growth traits of canary melon and lime rates show that every increase in lime rates leads to a significant increase in the growth of canary melon. This result agrees with Sushil *et al.* (1997) and El-Habbasha, *et al.* (2005), who reported that increasing phosphorus levels increase the number of leaves and leaf length, leaf breadth, vine length, and vine thickness.

* 1. ***Correlation of yield traits of canary melon***

There was a significant positive correlation of the yield traits of canary melon as influenced by lime. The result from the correlation of the yield traits shows that at every increase in one variable, there is a significant increase in another at different levels of lime and this association was statistically significant at the p≤0.001 level and p≤0.01 level respectively. There was no association between Brix and any of the yield traits considered in the present study. However, the United Nations Economic Commission for Europe (UNECE) sets a standard for Charentais type melons soluble solid content (SSC) to be ≥ 10 °Brix measured and 8 °Brix for other melons (UNECE, 2006) which agrees with the Brix values obtained from acid soil without lime amendment (8.86).

**CONCLUSION**

The application of lime (CaCO3) to acid soil of Calabar at various levels significantly improved the growth and yield of canary melon (*Cucumis melo* L. *var. Inodorus*). Increases recorded as a result of this were for soil pH, available P, number of leaves, leaf length, leaf breadth, vine length and vine thickness of canary melon. In this study, all lime rates used were effective in reducing soil acidity (i.e., increasing soil pH towards 7). However, lime applied at the rate of 1 t ha-1 was insufficient in raising the soil pH to the recommended pH level of 5.5 for cucurbit production. Lime applied at 5 t ha-1 (5.93) increased soil pH, Ca2+ and fruit yields. Lime rate of 5 t ha-1 decreased exchangeable acidity (EA), in comparison to the lime applied at 2 t ha-1 (5.53), 3 t ha-1 (5.63) and 4 t ha-1 (5.80) respectively. Plots receiving lime from 1 t ha-1 (4.69) to 5 t ha-1 (5.93) recorded an increase in soil pH compared to the plot where no lime was applied i.e., 0 t ha-1 (4.13). The soil in the area of study was sandy loam and moderately acidic and there was evidence of reduced soil compaction and lime application showed no negative impact on soil physical structure. The results of this study showed that liming could enhance the yield of canary melon in Calabar. However, soil testing is suggested as the most suitable determinant to lime application.

**ACKNOWLEDGMENTS**

We thank the Crop Improvement Unit, Department of Crop Science for providing the support for this study.

**REFERENCES**

Agboola, A. A., O. Ayodele, 1987. Soil test for upland rice in southwestern Nigeria. Fert. Res., 14: 227-234.

Ayeni, L. S., E. O. Adeleye, 2011. Soil nutrient status and nutrient interactions as influenced by agrowastes and mineral fertilizer in incubation study in Southwest Nigeria. Intl. J. Soil Sci., 6(1): 60-68.

Chan, K. Y. and D. P. Heenan, 1998. Effect of lime (CaCO3) application on soil structural stability of red earth. Soil Res., 36 (1): 73–86.

Dai, Z., X. Zhang, C. Tang, N. Muhammad, J. Wu, P. C. Brookes, and J. Xu, 2017. Potential role of biochars in decreasing soil acidification - a critical review. Sci. Total Env., 58: 601–611.

El-Habbasha, S. F., A. A. Kandil, N. S. Abua-Hagaza, A. K. Abd El-Haleem, M. A. Khalafallah, and T. G. Behairy, 2005. Effect of phosphorous levels and some bio-fertilizers on dry matter, yield and yield attributes of groundnut. Bull. Fac. Agric., Cairo Univ.,56:237-252.

Fageria, N. K. and A. S. Nascente, 2014. Management of soil acidity of South American soils for sustainable crop production. In: Sparks D. L. (ed) Adv. Agron., 128:221–275

Haynes, R. J., 1984. Lime and phosphate in the soil-plant system. Adv. Agron., 37:249–315.

Holland, J. E., A. E. Bennett, A. C. Newton, P. J. White, B. M. McKenzie, T. S. George, R. J. Pakeman, J. S. Bailey, D. A. Fornara, R. C. Hayes, 2018. Liming impacts on soils, crops and biodiversity in the UK: a review. Sci. Total Env., 610-611: 316–332.

Ibanga, I. J., M. N. Armon, 1992. Report on the wet and dry soils of Cross River State. Cross River Agricultural Development Project, Calabar, Nigeria.

IPGRI, 2003. Descriptors for Melon (*Cucumis melo* L.). International Plant Genetic Resources Institute, Rome, Italy.

Jaskulska, I., D. Jaskulski, M. Kobierski, 2014. Effect of liming on the change of some agrochemical soil properties in a long-term fertilization experiment. Plant Soil Env., 60(4): 146–150.

Lawal, B. A., A. G. Ojanuga, P. A. Isada, T. A. Mohammed, 2013. Characterization, classification and agricultural potentials of soils on a toposequence in Southern Guinea Savanna of Nigeria. Intl. J. Agric. Biosys. Engr. 7(5):146- 150.

Manamu, P. C. 1975. Rainfall. *In:* G. E. K. Ofomata, Nigeria in maps: Eastern states. Ethiope Publishing Corporation, Edo, Nigeria.

McLaren, R. G. and K. C. Cameron, 1996. Soil science: sustainable production and environmental protection. Oxford University Press. 304p.

Ossom, E. M. and R. L. Rhykerd, 2007. Effects of lime on weed species diversity and yield of sweet potato (*Ipomoea* *batatas* (L.) Lam.) in Swaziland. Intl. J. Agri. Biol., 9 (5): 755 – 758.

Rastija, D., V. Zebec and M. Rastija, 2014. Impacts of liming with dolomite on soil pH and phosphorus and potassium availabilities. 13th Alps-Adria Scientific Workshop Villach, Austria.  Növénytermelés, 63:193–196.

Smil, V., 2002. Nitrogen and food production: proteins for human diets. Ambio 31(2):126–131

Sumner, M. E. and A. D. Noble, 2003. Soil acidification: the world story. *In:* Rengel, Z. (ed.), Handbook of soil acidity. Marcel Dekker, New York, pp. 1- 28.

Sushil, K., N. K. Matta, S. Kumar, 1997. Status of groundnut and mung bean protein fractions under changing the nutrient regime. J. Plant Biochem. Biotech., 6 (1): 41-43.

Thomas, G. W. and W. L. Hargrove, 1984. The chemistry of soil acidity. *In:* Adams F. (ed), Soil acidity and liming. ASA, CSSA, SSSA, Madison, WI, 3: 56-60.

United Nations Economic Commission for Europe (2006) UNECE Standard FFV-23 Concerning Marketing and Commercial Quality Control of Melons, 2006 Edition.

von Uexküll, H. R. and E. Mutert, 1995. Global extent, development and economic impact of acid soils. *In:* Date R. A, Grundon N. J., Rayment G. E. and Probert M. E. (eds). Plant-soil interactions at low pH: principles and management. 3rd International symposium on plant-soil interactions at low pH, Brisbane, Queensland, Australia, 12–16 September 1993. Springer Netherlands, Dordrecht.

**Table 1:** Physical and chemical properties of the experimental soil before planting (no lime applied) and after harvest (after lime application)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Lime (t ha-1)** | **Sa** | **St** | **Cl** | **STx** | **P** | **N** | **OC** | **OM** | **Ca** | **Mg** | **K** | **Na** | **EA** | **ECEC** | **BS** |
| After Harvest |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 0 | 798 | 82 | 120 | SL | 22.90 b | 0.13 ab | 0.91 a | 1.58 a | 3.20 d | 1.20 b | 0.23 ab | 0.16 a | 1.07 ab | 6.52 c | 83.23 de |
| 1 | 758 | 102 | 140 | SL | 24.12 ab | 0.09 bc | 0.61 a | 1.05 a | 4.87 cd | 1.18 b | 0.08 b | 0.22 a | 0.93 bc | 7.41 c | 85.73 cd |
| 2 | 759 | 102 | 130 | SL | 24.43 ab | 0.10 abc | 0.62 a | 1.06 a | 5.60 bc | 0.87 b | 0.12 b | 0.20 a | 0.85 bcd | 7.64 c | 88.50 bcd |
| 3 | 738 | 82 | 180 | SL | 24.97 ab | 0.12 abc | 0.79 a | 1.35 a | 7.13 ab | 1.40 b | 0.15 b | 0.28 a | 0.77 cd | 9.73 b | 92.05 abc |
| 4 | 708 | 116 | 176 | SL | 26.70 a |  0.13 a | 0.97 a | 1.67 a | 7.93 a | 2.07 a | 0.12 b | 0.17 a | 0.69 cd | 10.99 ab | 93.66 ab |
| 5 | 798 | 91 | 111 | SL | 24.70 ab | 0.13 abc | 0.84 a | 1.55 a | 8.53 a | 2.33 a | 0.32 a | 0.22 a |  0.59 d | 12.00 a | 95.06 a |
| Before Planting |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| No lime | 769 | 99 | 131 | SL | 24.03 ab | 0.09 c | 0.60 a | 1.04 a | 3.18 d | 1.07 b | 0.07 b | 0.16 a | 1.28 a | 5.78 c | 77.85 e |

Sa = Sand (g kg-1); St = Silt (g/kg); Cl = Clay (g kg-1); STx = Soil Texture; SL = Sandy Loam; P = Available Phosphorus (mg kg-1); N = Nitrogen (%); OC = Organic Carbon (%); OM = Organic Matter (%); Ca = Calcium (cmol kg-1); Mg = Magnesium (cmol kg-1); K = Potassium (cmol kg-1); Na = Sodium (cmol kg-1); EA = Exchangeable Acidity (cmol kg-1); ECEC = Effective Cation Exchange Capacity (cmol kg-1); BS = Base Saturation (%). Values with the same letter (s) are not significantly different using Duncan’s New multiple range test at 95% confidence limit.

**Table 2**: Growth traits of canary melon on limed acid soil

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Lime****(t ha-1)** | **Emergence (7DAP) (%)** | **Leaf Length (cm)** | **Leaf Breadth (cm)** | **Leaf Area (cm2)** | **Leaf Area Index** | **Number of Leaves per Plant** | **Vine Length (cm)** | **Vine Thickness (mm)** |
| 0 | 87.00 d | 8.09 e | 9.34 e | 50.51 e | 0.0101 e | 32.48 e | 107.61 e | 5.03 e |
| 1 | 87.00 d | 8.56 de | 10.13 d | 58.14 d | 0.0116 d | 44.13 d | 130.06 d | 5.83 d |
| 2 | 91.67 c | 8.88 cd | 10.82 c | 64.27 c | 0.0129 c | 54.00 c | 158.94 c | 6.20 cd |
| 3 | 95.00 b | 9.11 c | 11.31 c | 68.96 c | 0.0138 c | 66.51 b | 172.01 bc | 6.52 bc |
| 4 | 96.67 ab | 9.76 b | 12.21 b | 79.87 b | 0.0160 b | 70.04 b | 188.57 b | 6.67 ab |
| 5 | 98.00 a | 10.67 a | 13.66 a | 97.49 a | 0.0195 a | 80.49 a | 222.69 a | 7.11 a |

DAP = Days after planting. Values with the same letter(s) are not significantly different using the Duncan New Multiple Range test at a 95% confidence limit.

**Table 3**: Yield and yield-related traits of canary melon on limed acid soil

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Lime****(t ha-1)** | **Number of Fruits per Plant** | **Fruit Volume (ml/fruit)** | **Fruit Weight****(g/fruit)** | **Fruit Weight****(t ha-1)** | **oBrix** | **Rind Thickness (mm)** | **Fruit Diameter (cm)** | **Number of Seeds per Fruit** |
| 0 | 2.11 b | 984.07 b | 198.96 b | 3.19 c | 8.86 a | 12.27 f | 71.47 f | 460.67 f |
| 1 | 3.67 ab | 1089.57 a | 225.06 b | 4.50 bc | 7.53 ab | 14.32 e | 75.72 e | 475.56 e |
| 2 | 3.22 ab | 1067.59 a | 199.91 b | 4.00 bc | 7.65 ab | 16.65 d | 79.04 d | 500.11 d |
| 3 | 3.44 ab | 1053.43 ab | 202.87 b | 4.12 bc | 7.08 b | 18.17 c | 81.97 c | 530.00 c |
| 4 | 2.89 b | 1056.25 ab | 255.28 ab | 5.17 ab | 7.12 b | 21.09 b | 89.20 b | 534.22 b |
| 5 | 4.67 a | 1136.85 a | 320.89 a | 6.41 a | 7.84 ab | 30.09 a | 92.45 a | 604.33 a |

Values with the same letter(s) are not significantly different using the Duncan New Multiple Range test at the 95% confidence limit.

**Table 4:** Correlation of yield traits of canary melon grown on limed acid soil

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **Fruit weight (g)** | **Fruit yield (t ha-1)** | **oBrix (%)** | **Rind thickness (mm)** | **Fruit diameter (cm)** | **Number of seeds** |
| Fruit volume (ml) | **0.71\*\*\*** | **0.75\*\*\*** | -0.06 | 0.26 | 0.24 | 0.05 |
| Fruit weight (g) |  | **0.85\*\*\*** | -0.03 | **0.39\*\*** | **0.47\*\*\*** | 0.17 |
| Fruit yield (t ha-1) |  |  | -0.17 | **0.41\*\*** | **0.52\*\*\*** | **0.29\*** |
| Brix (%) |  |  |  | -0.09 | -0.23 | -0.18 |
| Rind thickness (mm) |  |  |  |  | **0.79\*\*\*** | **0.64\*\*\*** |
| Fruit diameter (cm) |  |  |  |  |  | **0.61\*\*\*** |

Significance level at 95% confidence limit, \* = p ≤ 0.05, \*\* = p ≤ 0.01, \*\*\* = p ≤ 0.001.





