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# Performance of bambara groundnut (*Vigna subterranea* L. Verdc) in Calabar, Nigeria as influenced by lime and zinc fertilizer application

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**Abstract**
*A field experiment was conducted in the 2018 early cropping season at the University of Calabar Crop Teaching and Research Farm, to determine the optimum rates of liming and zinc fertilizer for optimum vegetative growth and grain yield of Bambara groundnut in Calabar. The experimental design was a 3 x 4 factorial combination fitted into a randomized complete block design (RCBD) with three levels (0, 5, 10 tonnes per hectare) of calcium carbonate ($CaCO_3$) as liming material and four levels (0, 10, 20 and 30 kg/ha) of zinc sulfate ($ZnSO_4$) fertilizer, totaling twelve treatment combinations replicated three times to give a total of 36 treatment units. Crop growth indices and grain yield data were collected and analyzed using two-way analysis of variance. Significant means were compared using Fisher's Least Significant Difference (FLSD) at 5% level of probability. Results obtained indicated that all the zinc rates showed phytotoxicity and had negative effect on all parameters assessed, indicating that they were too high for the crop. However, the crop growth and yield parameters were significantly ($P > 0.05$) improved by liming irrespective of the rate applied. Liming at 10 tonnes of $CaCO_3$/ha produced the best results on the vegetative growth and yield. The highest stover yield of 72.55 kg/ha and highest 100 seed weight of 72.08 g were obtained. This observation indicates that liming the soil with 10 tonnes of $CaCO_3$/ha without zinc fertilizer is adequate for increased productivity of nutritious Bambara groundnut in the study area.*

**Keywords:** Bambara groundnut, Liming, Zinc fertilizer, Grain yield

## Introduction

*Vigna subterranea* (L.) Verdc (also known by its common names as Bambara groundnut, Bambara-bean, Congo goober, Earth pea, Ground-bean, or Hog-peanut) is a member of the Family *Fabaceae* (FAO, 2014). Bambara groundnut is known to be the third most important grain legume in semi-arid regions. It ripens its pods underground, much like the peanut (also called a *groundnut*). It is tolerant to high temperature and is suitable for marginal soils where other leguminous crops cannot be grown (Baryeh, 2001). Bambara groundnut is very nutritious and is widely acclaimed as an instant solution to hunger. Both the immature and mature seeds of the crop are consumed (Mazahib *et al.*, 2013). It has a high nutritive value with 65% carbohydrate and 18% protein content (Sessay and Zungu, 2000). Brough and Azam-Ali (1992) reported that "Bambara groundnut seed makes a balanced 'food as it contains sufficient quantities of carbohydrate (63%), protein (16.25%) and fat (6.3°/o) with relatively high proportions of lysine and methionine as percentage of the protein (6.6% and 1.3% respectively). According to Fetuga *et al.* (1975), the essential amino acid content of Bambara groundnut such as lysine (6.82g/16gN), methionine (1.85g/16gN), and cysteine (1.24g/16gN) is comparable to that of soyabean with lysine (6.24g/16gN), methionine (1.14g/16gN), and cysteine (1.80g/16gN).

The fresh seeds may be boiled and eaten as snacks in a manner similar to boiled peanut during "hunger period." The seed can be made into a pudding (or porridge) in some parts of Nigeria (Okpozor *et al.*, 2009). Bambara groundnut is essentially grown for human consumption, and can be used as an ingredient in cooking, making flour, or eaten as snacks (Berchie *et al.*, 2010). Bambara milk is processed in a similar way to that of soybean, and is often used as weaning milk in many African countries (Bamishiye *et al.*, 2011). Several reports have concluded that Bambara groundnut milk (BGNM) is rated higher in acceptability compared to other legume-based milk such as cowpea and soybean (Munevanhema and Jideani, 2013).

In spite of all these great potentials of Bambara groundnut, its production has not been popular like other food legumes in the rainforest agro-ecological zone of Nigeria due to continuous cropping which has resulted in increased acidity of the soil (Umunnakwe *et al.*, 2023). Acid soils reduce root growth and pod/grain yield. Root injury may be observed at pH 5 and lower. Lateral root growth may be suppressed and resembles nematode damage; therefore, rooting depth and degree of branching may be limited. Poor plant growth may be due to exchangeable aluminum($Al^{3+}$), hydrogen ion ($H^{+}$), or manganese($Mn^{2+}$) toxicity (Ijarotimi and Esho, 2009). To lower the impact of this high soil acidity on crop production, liming with $CaCO_3$ has recently become imperative. Lime is very insoluble; therefore, mixing into the subsoil may be necessary to hasten the impact of the liming in the subsoil. An increase in subsurface soil pH could provide additional nutrients to the crop. Lower rates of phosphorous may be required when exchangeable Al is neutralized. Nitrification is reduced at low pH values which could limit the availability of N to crops (Fageria *et al.*, 2007; Fageria and Baligar, 2008). Understanding the impact of ameliorating soil acid levels would help farmers make informed decisions on how best to achieve the optimum performance of Bambara groundnut. This experiment was therefore designed to determine the optimum rates of $CaCO_3$and zinc fertilizer for optimum vegetative growth and grain yield of Bambara groundnut in Calabar.

## Materials and Methods

A field experiment was conducted during the early planting season of 2018 at the University of Calabar Teaching and Research Farm, Calabar, Nigeria. Calabar is located at the southeastern rainforest agro-ecological zone of southern Nigeria ($4.5^0$N - $5.2^0$N, $8.3^0$E; about 39 m above sea level), and has a bimodal annual rainfall distribution that ranges from 3,000 to 3,500 mm with mean annual temperature range of 27 - 35 $^0$ C and relative humidity of 75 % to 88 % (Efiong, 2011). The experiment was a factorial combination of three levels (0, 5, 10 tonnes per hectare) of $CaCO_3$ as liming material and four levels (0, 10, 20 and 30 kg/ha) of zinc ($ZnSO_4$) fertilizers, which gave twelve treatment combinations. The lime was incorporated into the soil during seedbed preparation before seeds of Bambara groundnut were sown. Plots were tagged for treatment identification.

Application of zinc was done 3 weeks after emergence (3 WAE). The levels of zinc granules were weighed and dissolved in 100 milliliters (mls) of water as recommended by the manufacturer and applied to the foliage using hand spray pump. The hand spray pump was regularly rinsed thoroughly with water after applying each treatment before the next mixture. The Bambara groundnut seeds were sown at 30 cm × 50 cm spacing, two per hole, and later thinned to one at 21 days after sowing (DAS). This gave a population of 66,667 plants per hectare. Each unit plot was 5 rows of 10 plants each making a total of 50 plants/plot. Plant growth and yield data were collected from six middle plants per plot and subjected to analysis of variance (ANOVA) procedures for factorial experiments in randomized complete block design (RCBD) using the GenStat Package Version 8.1 of 2015. Means were compared using Fisher's least significant difference (FLSD) method at 5% level of probability as described by Wahua (2010).

## Results and discussion

### Effects of liming and zinc fertilizer application on the vegetative growth of Bambara groundnut

The effects of liming and zinc fertilizer application on the vegetative growth parameters (plant height and number of leaves) of Bambara groundnut are presented on Tables 1 and 2, respectively.

Liming significantly ($P \leq 0.05$) influenced the height of Bambara groundnut plants at 8 and 11 WAP, but did not have effect on plant height at 5 WAP, while zinc as well as the interaction of zinc and lime, influenced the plant height at 5, 8 and 11 WAP. Plants in plots that received 5 and 10 t/ha of $CaCO_3$ (Lime) were significantly ($P \leq 0.05$) taller than those in the control plots at both 8 and 11 WAP. There was no significant ($P > 0.05$) variation in the height between the plants in plots applied with 5 t/ha and those that received 10 t/ ha of $CaCO_3$ during the research periods (Table 1). Control plants and those that received 10 kg/ha zinc were significantly ($P \leq 0.05$) taller at all sampling periods than the plants that received 30 kg of zinc fertilizer/ha. There was no significant ($P > 0.05$) difference between the height of plants in plots that received 10 kg zinc fertilizer / ha and the control plants.

The interactions of 10 t/ha of $CaCO_3$ with 10 kg / ha of $ZnSO_4$, and 5 t/ha of $CaCO_3$ with 10 kg/ha of $ZnSO_4$, resulted in statistically similar plant heights that were significantly ($P \leq 0.05$) taller than the other treatment combinations.

The effects of liming and zinc fertilizer rates on the number of leaves per plant as shown in Table 2 were significant ($P \leq 0.05$) at all sampling periods. Plants in the plots that received the lime treatments irrespective of the rates had significantly ($P \leq 0.05$) higher values compared to the control at all sampling periods. There was no significant ($P > 0.05$) variation between the values obtained from plants in plots applied either with 5 or 10 t/ha of $CaCO_3$ during the periods of the experiment.

Zinc at 0 kg/ha of $ZnSO_4$ produced significantly ($P \leq 0.05$) higher values of leaves per plant compared to 10, 20, and 30 kg/ha of $ZnSO_4$ (Zinc) fertilizers at 5 WAP followed by 10 kg/ha, 30 kg/ha had the lowest value. When the plants were at 8 and 11 WAP, 0 and 10 kg/ha of $ZnSO_4$ (Zinc) fertilizers had statistically ($P > 0.05$) similar values of number of leaves per plant that were significantly ($P \leq 0.05$) higher than 20 and 30 kg/ha.

There was significant ($P \leq 0.05$) positive interaction between liming rates with zinc fertilizer on the number of leaves at 5 and 11 WAP, with more of leaves produced by combining 10 t/ha of $CaCO_3$ with 10 kg/ha of $ZnSO_4$ at 5 and 11 WAP respectively (Table 2).

**Effects of liming and zinc fertilizer application on stover weight and 100 seed weight of Bambara groundnut.**

The effects of liming and zinc fertilizer rates on stover weight and 100-seed weight are shown in Table 3. Liming significantly influenced stover weight and 100-seed weight. Stover weight and 100 seed weight were significantly ($p \leq 0.05$) higher in the order: 10 t/ha of $CaCO_3$ > 5 t/ha of $CaCO_3$ > 0 t/ha of $CaCO_3$.

Zinc fertilizer significantly ($P \leq 0.05$) influenced stover weight while 100 seed weight was not influenced by zinc fertilizer. The highest value of stover weight was obtained at the control plots where $ZnSO_4$ was not applied, followed by 10 kg/ha of $ZnSO_4$ and the lowest was obtained at 30 kg/ha of $ZnSO_4$.

## Discussion

The superior performance of Bambara groundnut in the plots treated with lime compared with the control suggests that the liming could have made more nutrients available at the absorption site in the soil to the benefit of the crop. This observation agrees with Monreira and Fageria (2010) who had reported increase in the growth and yield indices of alfalfa grown in acid following $CaCO_3$treatment, which they attributed to increased availability of essential plant nutrients on the absorptive site.

Zinc spray appeared to have negative effect on the soil properties as well as the performance of Bambara groundnut in this present research. Earlier reports showed a positive effect of zinc spraying on the performance of legumes. Mahady (1990) explained that foliar application of $ZnSO_4$ for faba bean plants increased the number of pods/plant and seed yield. Ali and Mowafy (2003) reported that application of foliar spray with Zn (2%) slightly improved groundnut yield and its growth attributes, as well as quality. Thalooth *et al.* (2005),indicated that foliar spraying with Zn had a positive effect on yield and yield attributes of sunflower plants. Togay *et al.* (2004), Valencianoa *et al.* (2007), and Salehin and Rahman (2012) also reported positive effects of zinc spraying on wide range of legume crops. However, the negative effect of zinc spray on Bambara groundnut in this present research may be attributed to dosage. The 10, 20 and 30 kg / ha of zinc ZnSO4 rates used in this present research appeared to be very high which manifested in chlorotic symptoms on the leaves few days after the zinc spray. The chlorotic symptoms were more pronounced on the plots where zinc was applied alone. The symptoms transformed into necrosis with time and the crops struggled to survive. This suggests that the zinc rate used in this research was too high and must have caused micronutrient toxicity to the crop.

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The stover yield and 100 seed weight of Bambara groundnut increased with liming compared to the control without lime. This suggests that liming ameliorates soil acidic conditions to enhance crop performance. The improvement in the yield of legumes with liming in acid soils is widely reported (Adams and Pearson, 1984; Lathwell and Reid, 1984). Shoot dry matter of alfalfa increased quadratically with increasing lime rates in the range of 0 to 10.3 Mg/ha (Monreira and Fageria, 2010). Wassermann *et al.* (1984) reported a 59 % increase of Bambara groundnut yield with liming. The yield increase of legumes with liming could be due to improvement of the Ca and Mg contents in the soil and reduction of soil acidity in limed plots. Similar results were obtained elsewhere by Fageria and Baligar (2003); Fageria (2009). In addition, liming also improved the biological $N_2$-fixation in acid soils and enhanced the net mineralization of organic N (Edmeades and Ridley, 2003). Fageria (2008) reported that N deficiency was observed two weeks after sowing of common bean (*Phaseolus vulgaris*) in unlimed Oxisol plots, while no N deficiency was observed in the limed plots, which suggested that liming improves the availability of soil nitrogen.

## Conclusion

The results showed that higher zinc rates lead to phytotoxicity with corresponding negative effects on the performance of the crop. However, liming had significantly positive impact on the crop and liming the soil with 10 tonnes of $CaCO_3$/ha without zinc fertilizer is adequate for increased productivity of Bambara groundnut in the study area.

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Table 1: Effect of liming and zinc fertilizer application on plant height

| Treatments | Plant height (cm) | | |
|---|---|---|---|
| | 5 WAP | 8 WAP | 11 WAP |
| **Lime rates** | | | |
| 0 t/ha ($L_0$) | 18.90 | 42.20 | 45.61 |
| 5 t/ha ($L_5$) | 18.46 | 47.28 | 50.36 |
| 10 t/ha ($L_{10}$) | 17.89 | 49.92 | 52.34 |
| $LSD_{(0.05)}$ | NS | 3.85 | 3.12 |
| **Zinc rates** | | | |
| 0 kg/ha ($Zn_0$) | 19.87 | 50.74 | 53.19 |
| 10 kg/ha ($Zn_{10}$) | 18.52 | 48.78 | 49.96 |
| 20 kg/ha ($Zn_{20}$) | 18.48 | 45.59 | 46.81 |
| 30 kg/ha ($Zn_{30}$) | 17.99 | 42.42 | 44.18 |
| $LSD_{(0.05)}$ | 1.25 | 4.44 | 3.74 |
| **Lime x Zinc** | | | |
| $L_0$ $Zn_0$ | 20.55 | 45.34 | 49.59 |
| $L_0$ $Zn_{10}$ | 18.44 | 41.69 | 44.97 |
| $L_0$ $Zn_{20}$ | 18.89 | 40.45 | 42.01 |
| $L_0$ $Zn_{30}$ | 16.70 | 39.33 | 42.87 |
| $L_5$ $Zn_0$ | 20.56 | 52.78 | 56.48 |
| $L_5$ $Zn_{10}$ | 19.11 | 49.00 | 52.69 |
| $L_5$ $Zn_{20}$ | 18.11 | 44.33 | 47.85 |
| $L_5$ $Zn_{30}$ | 17.05 | 41.00 | 43.43 |
| $L_{10}$ $Zn_0$ | 18.89 | 54.45 | 58.11 |
| $L_{10}$ $Zn_{10}$ | 18.00 | 52.56 | 53.02 |
| $L_{10}$ $Zn_{20}$ | 17.45 | 44.00 | 48.58 |
| $L_{10}$ $Zn_{30}$ | 17.22 | 43.00 | 45.64 |
| $LSD_{(0.05)}$ | 2.15 | 7.70 | 6.47 |

($L_0$ $Zn_0$) Lime 0 t/ha x Zinc 0 kg/ha, ($L_0$ $Zn_{10}$) Lime 0 t/ha x Zinc 10 kg/ha, ($L_0$ $Zn_{20}$)Lime 0 t/ha x Zinc 20 kg/ha, ($L_0$ $Zn_{30}$)Lime 0 t/ha x Zinc 30 kg/ha
($L_5$ $Zn_0$) Lime 5 t/ha x Zinc 0 kg/ha, ($L_5$ $Zn_{10}$) Lime 5 t/ha x Zinc 10 kg/ha, ($L_5$ $Zn_{20}$)Lime 5 t/ha x Zinc 20 kg/ha, ($L_5$ $Zn_{30}$) Lime 5 t/ha x Zinc 30 kg/ha
($L_{10}$ $Zn_0$) Lime 10 t/ha x Zinc 0 kg/ha, ($L_{10}$ $Zn_{10}$)Lime 10 t/ha x Zinc 10 kg/ha, ($L_{10}$ $Zn_{20}$) Lime 10 t/ha x Zinc 20 kg/ha, ($L_{10}$ $Zn_{30}$)Lime 10 t/ha x Zinc 30 kg/ha

**Table 2:Effect of liming and zinc fertilizer application on number of leaves**

| Treatments | Number of leaves | | |
|---|---|---|---|
| | 5 WAP | 8 WAP | 11 WAP |
| **Lime rates** | | | |
| 0 t/ha ($L_0$) | 60.40 | 127.03 | 138.01 |
| 5 t/ha ($L_5$) | 61.30 | 131.67 | 142.46 |
| 10 t/ha ($L_{10}$) | 71.21 | 132.66 | 144.99 |
| $LSD_{(0.05)}$ | 8.39 | 4.38 | 4.20 |
| **Zinc rates** | | | |
| 0 kg/ha ($Zn_0$) | 77.00 | 133.52 | 145.38 |
| 10 kg/ha ($Zn_{10}$) | 67.60 | 130.37 | 141.58 |
| 20 kg/ha ($Zn_{20}$) | 59.80 | 123.92 | 135.60 |
| 30 kg/ha ($Zn_{30}$) | 52.70 | 122.67 | 131.85 |
| $LSD_{(0.05)}$ | 9.68 | 5.05 | 4.85 |
| Lime x Zinc | | | |
| $L_0$ $Zn_0$ | 69.30 | 124.11 | 139.85 |
| $L_0$ $Zn_{10}$ | 60.00 | 118.56 | 129.23 |
| $L_0$ $Zn_{20}$ | 50.30 | 115.55 | 125.62 |
| $L_0$ $Zn_{30}$ | 49.80 | 110.89 | 124.72 |
| $L_5$ $Zn_0$ | 74.20 | 136.11 | 146.15 |
| $L_5$ $Zn_{10}$ | 64.50 | 132.78 | 140.12 |
| $L_5$ $Zn_{20}$ | 58.10 | 127.11 | 133.61 |
| $L_5$ $Zn_{30}$ | 53.30 | 123.67 | 130.97 |
| $L_{10}$ $Zn_0$ | 81.30 | 139.33 | 148.15 |
| $L_{10}$ $Zn_{10}$ | 72.30 | 135.77 | 145.38 |
| $L_{10}$ $Zn_{20}$ | 64.90 | 131.11 | 137.57 |
| $L_{10}$ $Zn_{30}$ | 62.10 | 124.44 | 130.87 |
| $LSD_{(0.05)}$ | 16.77 | 8.75 | 8.40 |

($L_0$ $Zn_0$) Lime 0 t/ha x Zinc 0 kg/ha, ($L_0$ $Zn_{10}$) Lime 0 t/ha x Zinc 10 kg/ha, ($L_0$ $Zn_{20}$)Lime 0 t/ha x Zinc 20 kg/ha, ($L_0$ $Zn_{30}$)Lime 0 t/ha x Zinc 30 kg/ha
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($L_{10}$ $Zn_0$) Lime 10 t/ha x Zinc 0 kg/ha, ($L_{10}$ $Zn_{10}$)Lime 10 t/ha x Zinc 10 kg/ha, ($L_{10}$ $Zn_{20}$) Lime 10 t/ha x Zinc 20 kg/ha, ($L_{10}$ $Zn_{30}$)Lime 10 t/ha x Zinc 30 kg/ha

**Table 3: Effect of liming and zinc fertilizer application on the yield of Bambara groundnut**

| Treatments | Stover weight (kg / ha) | 100-seed weight (g) |
|---|---|---|
| Lime | | |
| 0 t/ha ($L_0$) | 48.26 | 59.17 |
| 5 t/ha ($L_5$) | 60.37 | 69.21 |
| 10 t/ha ($L_{10}$) | 72.55 | 72.08 |
| $LSD_{(0.05)}$ | 4.00 | 4.78 |
| Zinc | | |
| 0 kg/ha ($Zn_0$) | 68.18 | 69.57 |
| 10 kg/ha ($Zn_{10}$) | 60.82 | 64.53 |
| 20 kg/ha ($Zn_{20}$) | 50.30 | 68.92 |
| 30 kg/ha ($Zn_{30}$) | 48.95 | 64.25 |
| $LSD_{(0.05)}$ | 4.61 | NS |
| Lime x Zinc | | |
| $L_0$ $Zn_0$ | 60.19 | 68.84 |
| $L_0$ $Zn_{10}$ | 45.19 | 63.70 |
| $L_0$ $Zn_{20}$ | 30.58 | 54.28 |
| $L_0$ $Zn_{30}$ | 24.65 | 51.78 |
| $L_5$ $Zn_0$ | 72.00 | 71.60 |
| $L_5$ $Zn_{10}$ | 69.72 | 70.22 |
| $L_5$ $Zn_{20}$ | 56.51 | 68.50 |
| $L_5$ $Zn_{30}$ | 50.20 | 66.90 |
| $L_{10}$ $Zn_0$ | 89.22 | 77.89 |
| $L_{10}$ $Zn_{10}$ | 71.07 | 71.37 |
| $L_{10}$ $Zn_{20}$ | 64.11 | 69.62 |
| $L_{10}$ $Zn_{30}$ | 51.25 | 67.13 |
| $LSD_{(0.05)}$ | 7.99 | 9.56 |

($L_0$ $Zn_0$) Lime 0 t/ha x Zinc 0 kg/ha, ($L_0$ $Zn_{10}$) Lime 0 t/ha x Zinc 10 kg/ha, ($L_0$ $Zn_{20}$)Lime 0 t/ha x Zinc 20 kg/ha, ($L_0$ $Zn_{30}$)Lime 0 t/ha x Zinc 30 kg/ha
($L_5$ $Zn_0$) Lime 5 t/ha x Zinc 0 kg/ha, ($L_5$ $Zn_{10}$) Lime 5 t/ha x Zinc 10 kg/ha, ($L_5$ $Zn_{20}$)Lime 5 t/ha x Zinc 20 kg/ha, ($L_5$ $Zn_{30}$) Lime 5 t/ha x Zinc 30 kg/ha
($L_{10}$ $Zn_0$) Lime 10 t/ha x Zinc 0 kg/ha, ($L_{10}$ $Zn_{10}$)Lime 10 t/ha x Zinc 10 kg/ha, ($L_{10}$ $Zn_{20}$) Lime 10 t/ha x Zinc 20 kg/ha, ($L_{10}$ $Zn_{30}$)Lime 10 t/ha x Zinc 30 kg/ha