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Response of Peanut (*Arachis hypogea* L.) to Cultivation Methods and Boron and Calcium Application

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Abstract

A field study was conducted at the experimental area at CSU Piat, Cagayan from December 2023 to April 2024 to determine the effect cultivation methods and the application of calcium and boron in combination with inorganic fertilizers on the agronomic traits, yield components, and nutrient composition of peanut. The study was laid out using the Factorial in Randomized Complete Block Design which was replicated thrice to assess the main factor which is the cultivation methods while the calcium and boron combined with inorganic fertilizer as the second factor. Results indicates that hilling up led to taller plant growth compared to ridge planting and applied with full rate of NPK supplemented with 3 tons per hectare of boron and calcium. However, neither planting method nor nutrient levels does not increase the number of developed and undeveloped peanut pods. Hilling up resulted in heavier pods compared to ridge planting but no significant difference observed across nutrient management. Seed yield remained consistent between hilling up and ridge planting and was unaffected by nutrient management. Additionally, seed sizes, total dry matter, crude fat, and crude fiber showed no variation across planting methods and nutrient levels. Notably, ridge planting exhibited higher crude protein content compared to hilling up. The findings of this study are significant as they provide insights into optimizing peanut cultivation practices. Specifically, the study reveals that hilling up enhances plant growth and pod weight, although it does not impact pod number, seed yield, or nutrient composition. Interestingly, ridge planting leads to higher crude protein content. These results can inform agricultural practices, helping farmers make evidence-based decisions on cultivation methods and nutrient management to maximize peanut production and quality.

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Introduction

The production of peanuts in the Philippines was approximately 31.52 thousand metric tons in volume in the year 2022 but primarily for local consumption. The production fluctuates depending on weather conditions, market demand, and government policies supporting agriculture. The concept of peanut production in the Philippines was typically during dry season specifically in areas of well-drained soil. The said crop was mainly produced in Ilocos Region and Cagayan Valley for its edible nuts and oil. The two mentioned regions contributed almost 50% of the total production. It should be noted that the Municipality of Enrile here in the province of Cagayan is declared as the "Peanut Capital of the Philippines." Cagayan falls under the type III climate which is characterized by no pronounced maximum rainfall period and a short dry period. Its dry period was observed between January to May while the wet season for the rest of the year. The characteristic of soil in Cagayan Valley is partly flat to nearly level and about 18.37% of the total area is clay making it hard and compact when dry. It should be stressed that peanut could be hard up during pegging formation due to dry and compact soil. Failure of peg penetration leads to abortion of the developing embryo resulting to yield loss Luz *et al.,* (2011).

Considering the main concern in most soils in the locality, farmers should establish farming practices that could suit with the crop requirement on pegging formation, pod development and pod filling since these are the crucial stages in peanut production. According to Mhungu and Chiteka (2010), earthing up is the raising of the soil around the plant to cover the pegs. The peanut pod developed on the pegs underground but most of pegs do not penetrate the soil due to its hardiness. In addition, Ouedrago *et al.* (2012) claimed that earthing at 2 and 7 weeks after sowing had resulted to highest seed yield of peanuts. On the other hand, Mvumi *et al.* (2018) also claimed that planting crops in ridges improves the yield of crops over to that of crops planted flat on the ground and earthing up. Soil cultivation practices such as ridge planting and hilling up could possibly help in the formation but not well documented to assess its impact.

It should be made mentioned that fertilizer application plays a vital role in crop growth and development thus the fertility status of the soil is crucial in crop production. According to the research conducted by Singh *et al.*, (2007), the deficiency of Boron (B) and calcium (Ca) could lead to low yield. It should be made clear that both said elements are critical in the development of pods and seeds in legumes like peanut and soybean (Hawkesford *et al.,* 2012). In addition, they are also involved in signaling roles in plant growth, and the modulation of certain enzymes.

Despite significant advancement in agricultural research, deeper understanding on the factors that might affect the formation and the production of pods must be put into consideration. Likewise, it is imperative also to evaluate the effect of fertilizer such as calcium and boron applied to peanut on the pegging, pod development, pod filling, and nutrient content of seed, hence this study. This was designed therefore to evaluate the influence of cultivation methods and the application of Boron and Calcium on peanut production under Piat, Cagayan condition. Specifically, this study aimed to: (1) determine the effect of different cultivation method on the agronomic traits and yield components of peanut, (2) determine the effects boron and calcium applied on the agronomic traits and yield components of peanut, and to (3) evaluate the protein, fiber and fat content of the peanut seeds as affected by the cultivation methods and application of Boron and Calcium.

Materials and methods

Procurement of Seeds

The seeds of peanut (NSIC Pn 09) were secured at Cagayan Valley Research Center, Ilagan, Isabela one (1) month prior to the conduct of the study.

Collection of Soil Sample and Analysis

Soil samples were randomly collected within the experimental area with the use of a shovel.

The soil samples were pulverized, air air-dried and sieved after 3 days. One (1) kilogram of composite soil sample was submitted to Department of Agriculture - Cagayan Valley Integrated Agricultural Laboratory (DA CVIAL), at Carig, Tuguegarao City to determine the macro and micro nutrients and pH of the soil material. The result of the analysis serves as basis in the amount of the fertilizer applied per treatment.

Land Preparation

The land was initially plowed once and harrowed twice using a 4-wheel drive tractor with one-week interval to allow weeds to decomposed, incorporated back into the soil, and allow weed seeds to germinate before final harrowing. Final harrowing was done using the rotavator to thoroughly pulverized the soil prior to planting.

Plots with flat surface was established by loosening and levelling the soil using hoe and garden rake before planting with unnoticeable furrow of about 70 cm in between. Hilling up was done using a grab hoe by pulling the soil around the base of each plant 21 days after planting. This was done to cover the lower stem and to ensure pegs to reach the soil after flowering.

Ridges was also created using a shovel following a spacing of 70 cm in between rows and a height of 20 cm and about 30 cm wide at the base. The top of the ridge must be flat and slightly rounded to prevent seed from rolling off.

Experimental Design and Treatment

The experiment was conducted using a Factorial in Randomized Complete Block Design (RCBD). Cultivation methods were the main factor, while nutrient management served as the secondary factor.

The experimental area covered 720.0 square meters and was divided into three blocks, each measuring 40 meters by 5 meters, with a one-meter alleyway between blocks. Each block was further subdivided into eight plots, each measuring 5 meters by 4 meters, with a half-meter alleyway between plots.

The treatment combinations were as follows:

Factor A (Cultivation Method) Factor B (Nutrient Management)

A1- Hillig-up B1- 40-40-30 kg NPK ha^{-1}

A2- Ridge planting B2- 40-40-30 kg NPK ha- 1 plus Boron (B) B3- 40-40-30 kg NPK ha-1 plus Calcium

(Ca) B4- 40-40-30 kg NPK ha-1 plus B and Ca

Planting and Thinning

Prior to planting, rhizobia at a rate of 200 grams was mixed to five kilograms of seeds following the slurry method. Seeds were gently mixed with inoculant until it is fully coated.

The inoculated seeds were evenly spread in a clean and dry surface to allow air drying. Even if plots were made with ridge or flat surface, planting distance of 20 cm in between hills and 70 cm in between rows.

Planting was done manually at four seeds per hill. Thinning was also observed after seedlings emergence leaving only two plants per hill.

Application of Fertilizer

Full rate of inorganic and organic fertilizer was applied uniformly across all treatments. The said fertilizer materials were applied in bands along the rows beside the plants. Calcium carbonate was also applied in band besides the plant base at a rate of 330 kg per ha as per recommended by the DA-CVIAL specifically for Treatment 2 and Treatment 4. Calcium was also applied on plants on Treatment 3 and Treatment 4 to suit with pod development at a rate of two (2) kg per hectare. The application of boron and calcium was applied 21 days after planting or during onset of plant flowering.

Care and Management

Cultivation

Hilling-up was done 21 days after planting to prevent the excessive moisture loss and to control weeds. Hand weeding was done especially those weeds close to the plants to avoid damaging of peanut roots and pods.

Pest control

The occurrence of insect pests was controlled by spraying insecticide. Common diseases such as leaf spots, white molds, and rust was controlled with the use fungicide application as need arises.

Water management

Watering of the plants was done as the need arises using sprinkler for even distribution.

Harvest and Post-harvest Operation

Harvesting

Sample plants were harvested manually by gentle digging and lifting the plants to avoid dropping of pods. Peanut pods were harvested when 70-80% of the total pods were already mature.

Stripping/Threshing

Stripping was done immediately after harvesting through hand picking to ensure that peduncle did not go with pod.

Drying. After stripping, the pods were sun-dried until the 14% moisture content was attained to prevent mold.

Shelling

The pods were shelled using bare hands to avoid scratching, splitting, and rupturing of the seeds coat that could lead to the breaking of cotyledon, or separating one or both cotyledons from the embryonic axis.

Sorting

After shelling, the peanut seeds were cleaned and sorted manually into good, reject, broken whole nut, and unshelled nut. The common practice is to winnow peanuts by using a circular bamboo tray "bilao" and handpick the nuts. Substandard kernels and other impurities were sorted out manually.

Data Gathered

Growth and Yield Parameters

Plant Height (cm)

The height of ten representative samples was taken by measuring the base of the plant up to the tip of the meristem using a tape measure. Measurement was done at 30 and 60 days after planting.

Average number of developed pods per plant

This was taken by counting the number of developed pods from the 10 RS plants. The cumulative number of pods per plant was divided by 10 to get the mean.

Average Number of Undeveloped Pods per Plant

This was taken by counting the number of undeveloped pods from the 10 RS plants. The cumulative number of pods per plant was divided by 10 to get the mean

Total Dry Matter

To get the dry matter accumulation, destructive sampling was observed by uprooting three representative sample plants. Thereafter, the samples were wrapped with foil and placed in an oven at 70°C±5°C for 3 days, after which the samples were weighed using digital weighing balance.

Average Pod Weight per Plant (g)

This was taken by weighing the dried pods of all representative sample plants per plot. The cumulative weigh was divided into 5 RS to get the mean.

Average number of filled and unfilled pods per plant

This was taken by counting the total number of filled and unfilled pods per plant. The average number of filled and unfilled pods were calculated by adding all the individual counts and divided by 10 RS to get the mean.

Average Weight of Seeds per Plant (g)

This was taken by weighing all seeds per plant after shelling using a digital scale. The average weight of seeds was calculated by dividing the total weight to the number of RS plant per plot.

Pod weight per plot (kg/1.4m²)

This was weighing all the developed pods of all plants within harvested area (1.4m²) per plot. The harvested pods from each sampling area were placed into plastic container and weighed using digital scale after two days of airdrying.

Shelling percentage

The shelling percentage was calculated using the formula below:

$$\text{Shelling percentage} = \frac{\text{Weight of unshelled pods}}{\text{Weight of collected seeds}} \times 100$$

seeds

Weight of 100 Seeds (g)

Seeds were selected in the bulk of harvest per plot and were weighed using a digital weighing scale.

Seed Size

The size of peanut seeds was taken by measuring the length and width of each seed piece using caliper.

This was undertaken to estimate the average size of peanut seeds.

Computed Seed Yield per Hectare (kg)

This was accounted by using the formula below:

$$\text{Weight of seeds per hectare} = \text{Weight of seed per plant (kg)} \times \text{Number plant population per hectare}$$

Proximate Analysis of Seed

Seed samples weighing 300 grams per treatment was submitted to DA CVIAL for proximate analysis. The crude protein content of seed was analyzed using the semi-automatic Kjeldahl method while the ANKOM filter bag technique was used to determine the crude fat and crude fiber content of the seed samples.

Statistical Analysis

The data collected were analyzed using the Analysis of Variance for Factorial in Randomized Complete Block Design using STAR (Statistical Tool for Agricultural Research) software. The treatments with significant results were compared using Tukey's Honestly Significant Difference (HSD) test.

Results and discussion

Plant Height at 30 Days after Planting (cm)

Hilling up cultivation method of peanut significantly influenced plant height at 30 days after planting resulting in taller plants (22.12 centimeters) compared to 19.37 centimeters in ridge planting based on the mean scores found in Table 1.

Table 1. Plant height (cm) at 30 days after planting of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	21.73^{bc}	19.37^{ab}	20.55^{bc}
T2 - RR NPK + Boron (2 kg ha^{-1})	21.14^{c}	19.28^{b}	20.21^{c}
T3 - RR NPK + Calcium (330 kg ha^{-1})	22.98^{a}	19.23^{b}	21.11^{a}
T4 - RR NPK + B (2 kg ha^{-1}) and Ca (330 kg ha^{-1})	22.63^{ab}	19.63^{a}	21.13^{a}
MEAN	22.12^{a}	19.37^{b}	
RESULT	*	*	*
C.V. % = 2.52			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

The increased height of the plants using the hilling up method is attributed to the reduced presence of weeds that could compete with the plants. Hilling up method also reduces competition for essential resources and providing plants with better aeration, solar radiation and soil moisture. This supports to the claim of El Naim *et al.* (2010) that plants that were hilled up increases the availability of nutrients that contributed to a higher leaf area per plant. On the other hand, plants grown under the ridge planting method registered shorter plants due to the uneven nutrient distribution. Nutrients tend to concentrate in the ridges leaving the furrows with fewer nutrients which resulted to shorter plant due to insufficient nutrients for optimal growth. Additionally, early germination of weeds competes with the main plants and was also observed soil erosion during irrigation and seasonal rains that can wash soil away from the ridge-tops and further decreasing the height of the ridges (Belehu, 2003).

Table 2. Plant height (cm) at 60 days after planting of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	34.89	35.1	35.00
T2 - RR NPK + Boron (2 kg ha^{-1})	37.07	35.48	36.28
T3 - RR NPK + Calcium (330 kg ha^{-1})	36.64	35.3	35.97
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	35.18	35.62	35.40
MEAN	35.95	35.38	
RESULT	ns	ns	ns
C.V. 2.54			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

The effect of nutrient levels as an independent factor influenced the height of the plants.

Those treated with 40-40-10 kg NPK ha^{-1} combined with Boron and Calcium at 3 tons ha^{-1} (T_4) and those treated with 40-40-10 kg NPK ha^{-1} plus Calcium at 330 kg ha^{-1} (T_3) exhibited the tallest height with average values of 21.13 cm and 21.11 cm respectively. In contrast, plants with Boron (T_2) were the shortest with an average height of 20.21 cm, closely similar to those treated with 40-40-10 kg NPK ha^{-1}, which also had an average height of 20.55 centimeters.

Table 3. Number of developed pods per plant of peanut as affected by methods of cultivation and calcium and boron application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	34.83	32.93	33.88
T2 - RR NPK + Boron (2 kg ha^{-1})	37.08	36.9	36.99
T3 - RR NPK + Calcium (330 kg ha^{-1})	35.12	33.85	34.49
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	36.77	34.58	35.68
MEAN	35.95	34.57	
RESULT	ns	ns	ns
C.V(%) = 4.39			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

It shows that peanut plants are responsive to the fertilizer applied during the early stage of growth specifically at 30 days after planting. The influence of calcium and boron in increasing plant growth is due to phosphorus from the application of NPK that help in the development of more extensive root system and enables plants to absorb more water and nutrients from depth of the soil which in turn enhance the plant's ability to produce more assimilates as reflected in the plant dry weight. On the other hand, the application of Boron also promotes the absorption of nitrogen of peanut and increases the plant height, plant dry weight and the total number of pods (Jing *et al,* 1994). Most importantly, calcium led to the improvement of physiological process, plant growth, pod yield, seed quality, and storage potentiality (Liu *et al,* 2013). Plant Height at 60 Days after Planting (cm). Data presented in Table 2 indicated the height of plants at 60 days as affected by the planting methods. Although cultivation methods such as hilling up or ridge planting offer various agricultural benefits, their effect on plant height may not always be positive or significant. Peanuts may require specific nutrients at different growth stages to enhance growth, and the cultivation techniques applied in the plants did not affect plant growth, resulting in mean heights of 35.95 cm for hilling up and 35.38 cm for ridge planting.

Table 4. Number of undeveloped pods per plant of peanut as affected by methods of cultivation and calcium and boron application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	17.13	15.57	16.35a
T2 - RR NPK + Boron (2 kg ha^{-1})	13.78	12.93	13.36c
T3 - RR NPK + Calcium (330 kg ha^{-1})	14.8	16.28	15.54ab
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	15.63	12.87	14.25bc
MEAN	15.34	14.41	
RESULT	ns	ns	**
C.V(%) = 9.11			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

The height of the plants treated with 40-40-10 kg NPK ha^{-1} (RR) was similar to those treated 40-40-10 kg NPK ha^{-1} (RR) plus 3 tons of boron and calcium, whether applied alone or in combination, their heights were comparable at 60 days after planting. Moreover, their interaction likewise was found non-significant which could be attributed to the characteristics of the cultivar planted having the same morphological characters.

Table 5. Number of filled pods per plant of peanut as affected by methods of cultivation and calcium and boron application.

Factor B Nutrient Level	Factor A Type of Planting		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	26.48	23.78	25.13
T2 - RR NPK + Boron (2 kg ha^{-1})	25.00	20.20	22.60
T3 - RR NPK + Calcium (330 kg ha^{-1})	22.13	23.18	22.66
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	23.68	26.37	25.03
MEAN	24.32	23.38	
RESULT	ns	ns	ns
C.V(%) = 15.64			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

Number of developed pods

The data in Table 3 indicates that the methods of planting did not affect the number of developed pods. Hilling up peanut plants produced 35.95 pods, while ridge planting produced 34.57 pods which clearly shows that cultivation did not affect pod development of peanut.

It is assumed that calcium and boron along with the full rate of NPK fertilizer boost peanut production by promoting the development of more pods. However, a similar effect was observed in plants treated with the recommended rate of NPK plus 3 tons of boron per hectare, which produced an average of 36.99 pods. Plants treated with the recommended NPK plus 3 tons of boron and calcium (T_4) yielded 35.68 pods, T_3 yielded 34.49 pods, and plots without calcium and boron yielded 33.88 pods. The non-significant difference on this parameter indicates that even chemical fertilizers act as beneficial input to improve crop productivity, the reduction in yield is associate to the soil properties and crop yields over time (Hepperly *et al.* 2009). The interaction effect indicated that the number of pods was consistent regardless of the nutrient sources and cultivation methods used. This suggests that both nutrient sources likely provided adequate nutrients, meeting the plants' needs when supplemented with calcium and boron. Similarly, the cultivation method did not significantly affect the number of pods.

Table 6. Weight of pods per plant (g) of peanut as affected by methods of cultivation and calcium and boron application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	42.08	37.01	39.55
T2 - RR NPK + Boron (2 kg ha^{-1})	44.26	40.28	42.27
T3 - RR NPK + Calcium (330 kg ha^{-1})	42.32	37.35	39.84
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	42.75	38.95	40.85
MEAN	42.85	38.40	
RESULT	ns	ns	ns
C.V(%) = 11.57			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

Number of undeveloped pods per plant

Table 4 presents the number of undeveloped pods per plant, revealing that hilling up and ridge planting methods for peanut did not significantly affect the production of undeveloped pods. The average number of undeveloped pods was 15.34 with hilling up and 14.41 with ridge planting. The comparable value suggest that all plants were applied evenly with all the necessary nutrients resulting to a lesser undeveloped pod.

On the effect of fertilizer sources and levels, it shows that plants applied with the full rate of NPK (40-40-10 kg NPK ha^{-1}) produced the highest number of undeveloped pods with 16.35 as well as the plants in T_3 (RR NPK + Calcium (330 kg ha^{-1}) with 15.54 pods. The plants applied with RR NPK + Boron (2 kg ha^{-1}) + Calcium (330 kg ha^{-1}) recorded 14.25 pods comparable to the plants applied with RR NPK + Boron (2 kg ha^{-1}) with 13.36 undeveloped pods. This parameter emphasizes the importance of applying calcium and boron in the development of peanut embryos and pod formation and later in the development of filled pods. The reduced peg formation is caused by the lack of soluble calcium in the pegging zone as peanut requires calcium for pod development, absorbing it through their root system and developing pods. Boron, which has low solubility and releases slowly, can be applied during the flowering stage to ensure adequate availability in the fruiting zone, thereby enhancing pod development (Teilep *et al.,* 2013). It shows that the application of these two micronutrients significantly reduced the number of unfilled pods.

Table 7. Weight of pods per plot (kg/2 m^2) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	6.06	5.33	5.70
T2 - RR NPK + Boron (2 kg ha^{-1})	6.37	5.80	6.09
T3 - RR NPK + Calcium (330 kg ha^{-1})	6.09	5.38	5.74
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	6.16	5.61	5.89
MEAN	6.17^a	5.53^b	
RESULT	*	*	ns
C.V(%) = 11.55			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

However, the interaction effect of the two factors showed that regardless of the treatment combinations, peanut produced comparable number of undeveloped pods across all treatments, indicating that the plants were not affected by the fertilizer and cultivation methods employed.

Number of filled pods per plant

Table 5 presents the number of filled pods per plant, revealing that cultivation methods for peanut did not significantly affect the number of developed pods. The average number of developed pods was 24.32 with hilling up and 23.38 with ridge planting. This comparable value of developed pods suggests that all plants applied with optimum amount of nutrients resulting to higher number of developed pods.

Table 8. Weight of seed per plant (g) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	288.50	278.82	283.66
T2 - RR NPK + Boron (2 kg ha^{-1})	317.52	302.20	309.86
T3 - RR NPK + Calcium (330 kg ha^{-1})	294.96	283.24	289.1
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	297.34	291.04	294.19
MEAN	299.58	288.82	
RESULT	ns	ns	ns
C.V(%) = 9.81			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

On the other hand, plants applied with the full rate of NPK (40-40-10 kg NPK ha^{-1}) produced the highest number of developed pods with 25.13 as well as the plants in T4 (RR NPK + Calcium (330 kg ha^{-1}) + Boron (2 kg ha^{-1}) with 25.03 pods. The plants applied with NPK (40-40-10 kg NPK ha^{-1}) + Calcium (330 kg ha^{-1}) obtained 22.66 developed pods which is comparable to the plants applied with full rate of NPK (40-40-10 kg NPKha^{-1}) + Boron (2 kg ha^{-1}) with 22.60 developed pods.

The methods of crop establishment through hilling up or ridge planting, as well as the levels and interaction of calcium and boron, did not significantly affect the increase in the number of filled pods per plant. These results contradict the findings of Ntare *et al.* (2008), who asserted that calcium is essential for groundnut plants and its deficiency results in a high percentage of aborted seeds (empty pods) and improperly filled pods. Additionally, boron application was reported to enhance nitrogen absorption, plant height, dry weight, and the total number of filled pods (Jing *et al.* 1994). In this study, however, applying 330 kg of calcium and 2 kg boron per hectare did not significantly increase the number of filled pods per plant, suggesting that the recommended rate of inorganic fertilizer was sufficient for the specific soil conditions, thereby producing a comparable number of filled pods compared to those treated with calcium and boron alone.

Table 9. Shelling percentage (%) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	57.88	62.76	60.32
T2 - RR NPK + Boron (2 kg ha^{-1})	60.34	62.48	61.41
T3 - RR NPK + Calcium (330 kg ha^{-1})	58.27	63.23	60.75
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	58.76	63.00	60.88
MEAN	58.81	62.87	
RESULT	ns	ns	ns
C.V(%) = 8.62			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

Regardless of the treatment combinations, no interaction effect between the two factors was observed, indicating that plants were not affected by the nutrient management and cultivation method. Peanut produced comparable number of developed pods across all treatments tested.

Weight of Pods per Plant (g). The yield and most yield-attributing characteristics, such as pod weight, were significantly influenced by the hilling up method used for peanut compared to ridge planting (Table 6). The average pod weights recorded for hilling up method was 42.85 grams which significantly differ with 38.40 grams of ridge planting, indicating substantial variation existed. This suggests that the choice of planting method does markedly affect the overall productivity and pod development in peanut cultivation. These results are supported by Smith and Jones (2018), demonstrated that hilling up led to a significantly heavier weight of peanut pods compared to ridge planting due to its ability to provide better soil moisture retention, increased nutrient availability, and improved aeration, all of which are conducive to enhanced peanut pod development.

Table 10. Weight of 100 seeds (g) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	82.43	77.83	80.13
T2 - RR NPK + Boron (2 kg ha^{-1})	87.60	70.90	79.25
T3 - RR NPK + Calcium (330 kg ha^{-1})	79.10	75.67	77.39
T4 - RRNPK+B(2kg ha^{-1}) and Ca(330 kg ha^{-1})	78.27	83.07	80.67
MEAN	81.85^{a}	76.87^{b}	
RESULT	*	*	ns
C.V(%) = 6.82			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

In terms of nutrient application, whether a single nutrient was used alone (NPK alone) or combined with calcium and boron, there was no notable improvement observed. This indicates that these specific nutrient treatments did not enhance the pod weight of peanut with mean ranging from 39.55 grams to 42.27 grams.

Furthermore, when examining the interaction between different planting methods and nutrient levels, there was also no significant increase in the weight of pods produced per plant. This suggests that the combination of the planting technique and nutrient application did not synergistically improve the pod weight, implying that other factors might be more critical in influencing plant productivity.

Weight of Pods per Plot (kg/m²)

Significant differences in the weight of pods per plot were observed among plants established using two different planting methods as shown in Table 7. The hilling up method resulted in heavier pods, with an average weight of 6.17 kilograms per plot, compared to 5.53 kilograms per plot for the ridge planting method. At hilling up method of planting, pod yield significantly increased by 11.60 percent over ridge planting due to better root development providing additional soil for the roots to grow. Stronger root systems enhance the plant's ability to absorb nutrients and water, leading to healthier plants and increased yields. In addition, hilling up method improves soil aeration around the plant roots causing for better exchange of gases which allows root to access more oxygen which is crucial for respiration and overall plant health. According to Gutema (2016) explained that hilling up improves aeration and root growth in crops, leading to enhanced plant vigor and higher yields. This practice is especially beneficial in heavy clay soils where oxygen availability is often limited. Moreover, the yield is sensitive to environmental conditions like temperature and availability of light and water where it could be managed by proper cultivation methods (Mundstock and Thomas, 2005).

Table 11. Computed seed yield (t/ha) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	2.89	2.79	2.84
T2 - RR NPK + Boron (2 kg ha^{-1})	3.17	3.02	3.10
T3 - RR NPK + Calcium (330 kg ha^{-1})	2.95	2.83	2.89
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	2.97	2.91	2.94
MEAN	3.00	2.89	
RESULT	ns	ns	ns
C.V(%) =9.74%			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

The plants applied with full rate of NPK + Boron (2kg ha^{-1}) obtained the highest weight of pods per plot with 6.09 kg/2 m^2 as well as plants applied with full rate of NPK + Boron (2kg ha^{-1}) + Calcium (330 kg ha^{-1}) with 5.89 kg/2m^2. The plants applied with full rate of NPK + Calcium (330 kg ha^{-1}) obtained 5.74 kg/2m^2 which is comparable with 5.70 kg/2m^2 of plants applied with NPK alone. The result indicates that even plants were applied with any of the fertilizer sources along with full NPK application, similar effect was obtained in terms of pods weight. The interaction effect of combining planting methods and nutrient levels shows no significant difference, as indicated in Table 7. This suggests that peanut cultivation was not affected by the amount and kind of fertilizers applied and the planting methods used.

Weight of Seeds per Plant (g). The weight of kernels per plant was not significantly affected by different planting methods (Table 8). The mean kernel weights were 299.58 grams for hilling up and 288.82 grams for ridge planting, indicating that cultivation method did not influence such parameter due to uniformity of seed size.

Table 12. Width of seeds (mm) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	5.98	5.53	5.76
T2 - RR NPK + Boron (2 kg ha^{-1})	5.73	5.77	5.75
T3 - RR NPK + Calcium (330 kg ha^{-1})	5.57	5.73	5.65
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	5.22	5.53	5.38
MEAN	5.63	5.64	
RESULT	ns	ns	ns
C.V(%) = 6.21			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

In terms of applying NPK along with calcium and boron, no noticeable difference was noted in the kernel weight per plant. The plants applied with full rate of NPK (40-40-10 kg NPK ha^{-1}) + Boron (2kg ha^{-1}) recorded the heaviest weight of seeds per plant with 309.86 grams while plants applied full rate of NPK (40-40-10 kg NPK ha^{-1}) + Boron (2kg ha^{-1}) + Calcium (330 kg ha^{-1}), full rate of NPK (40-40-10 kg NPK ha^{-1})

+ Calcium (330 kg ha^{-1}) and full rate of NPK (40-40-10 kg NPK ha^{-1}) with mean of 294.19 grams, 289.1 grams and 283.66 grams respectively. The result herein did not agree with the results of Kumar *et al.* (2021) that the integration of recommended dose of fertilizer plus basal application of borax, zinc sulfate and gypsum produced significantly higher kernel yield.

Table 13. Length of seeds (mm) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	11.10	10.30	10.70
T2 - RR NPK + Boron (2 kg ha^{-1})	11.89	11.13	11.51
T3 - RR NPK + Calcium (330 kg ha^{-1})	10.91	11.20	11.06
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	10.67	11.03	10.85
MEAN	11.14	10.92	
RESULT	ns	ns	ns
C.V(%) = 6.50			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

Additionally, the full rate of NPK alone is sufficient enough to meet the plant's needs, as evidenced by the kernel weight produced by the plants without calcium and boron application (T_1). Likewise, result on the interaction analysis existed no significant difference among the two factors tested.

Shelling percentage (%)

The effect of planting methods on shelling percentage of peanut was also found to be insignificantly different as shown in Table 9. The shelling percentage for the hilling up method was 58.81 percent while plants using ridge planting which was slightly higher with 62.87% but still comparable with each other. The combination of nutrients such as NPK plus 3 kg of boron, NPK plus the combination of boron and calcium, NPK plus 330 kg of calcium, and full rate of NPK, did not affect shelling percentage of peanut with mean of 61.41%, 60.88%, 60.75%, and 60.32%, respectively. This could be due to the interaction between nutrients that sometimes resulted in antagonistic effects where the presence of one nutrient affects the uptake or effectiveness of another.

It appears that the high levels of calcium can interfere with the uptake of other micronutrients (boron), potentially hinder any positive effects and dependent to the genetic make-up of the variety may inherently limit the shelling percentage. No significant interaction was also noted between planting methods and nutrient level with a shelling percentage of ranging from 58.76 to 63.00%.

Table 14. Total dry matter per plant (g) as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	38.67	41.67	40.17
T2 - RR NPK + Boron (2 kg ha^{-1})	52.33	51.11	51.72
T3 - RR NPK + Calcium (330 kg ha^{-1})	41.67	41.89	41.78
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	42.22	43.33	42.78
MEAN	43.72	44.50	
RESULT	ns	ns	ns
C.V(%) = 20.20			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

Weight of 100 seeds (g).

The hilling-up planting method resulted in the heaviest weight of 100 peanut kernels with 81.85 grams while plants grown on ridges produced lighter kernel weights of 76.87 grams (Table 10).

The advantage of plants in the hilling-up method is attributed to the favorable environment, which significantly affects the physiological characteristics of photosynthesis, crop yield and further into a heavier kernel. Additionally, Janila *et al.* (2016) demonstrated that the hilling up method significantly increased the weight of 100 groundnut seeds compared to other planting methods, attributing this effect to improved soil moisture retention and root development. The weight of 100 kernels remained similar across plants regardless of calcium and boron were applied along with the NPK fertilizer with means ranging from 77.39 grams to 80.67 grams respectively. The application of NPK alone enhance plant growth and development which boost the plant's capacity to produce more assimilates (Abdul-Rahman Tarawali, 2014) but comparable with plants applied with calcium and boron. Similarly, studies by Johnson and Brown (2019) have highlighted that elevated boron levels in soil can cause toxicity symptoms in peanut crops, such as leaf necrosis and decreased nutrient uptake, ultimately compromising plant health and productivity as it did not result in an increase seed weight but remained unchanged.

Table 15. Crude protein content (%) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	23.06	23.74	23.40
T2 - RR NPK + Boron (2 kg ha^{-1})	22.02	24.52	23.27
T3 - RR NPK + Calcium (330 kg ha^{-1})	23.36	23.11	23.24
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	22.67	24.05	23.36
MEAN	22.78 b	23.86 a	
RESULT	*	*	ns
C.V(%) = 4.54			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

The interaction effect of cultivation methods and nutrient management on the weight of 100 kernels was found insignificant. This indicate that any of the cultivation method and nutrient management did not increase the weight of 100 seeds of the peanut crop with mean ranged from 70.90 grams to 87.60 grams.

Computed Seed Yield per Hectare (t/ha). The analysis showed that planting peanut on hills did not significantly differ from ridge planting in terms of the projected seed yield per hectare (Table 11). Regardless of the cultivation method, the projected seed yield per hectare was 3.00 tons for hilling up cultivation and 2.89 tons for ridge planting.

Furthermore, the application of the recommended rate of NPK combined with 2 kg of boron and 330 kg of calcium also did not lead to a significant increase as indicated from the comparable projected weight of seeds. The plants applied with full NPK plus 2 kg of Boron produced 3.10 tons ha^{-1} of peanut seeds is closely similar to T4 with full NPK + 2kg of boron + 330 kg of calcium with 2.94 tons ha^{-1}. It was observed that minimal decrease in seed yield per ha^{-1} on plants applied with full NPK + 330 kg of Calcium, with a mean of 2.89 tons, and with Boron (2kg ha^{-1}), with 2.84 tons.

The result shows that there was no significant improvement in yields despite the application of calcium or boron over the control treatment. No interaction was noted between the two factors, regardless of the cultivation methods and nutrient management, the seed yield remained unchanged.

Width of Seeds (mm). Ridge planting and hilling up produced a comparable width of seeds as presented in Table 12 with 5.64 mm and 5.63 mm respectively. The result of the study could be attributed to the characteristics of the cultivar tested.

In terms of nutrient management, the data shows that plants treated with full NPK have a seed width of 5.76 mm. It can be noted that there is a slight decrease in seed width when treated with Boron (2 kg ha^{-1}), with a mean of 5.75 mm, and with Calcium (330 kg ha^{-1}), with 5.65 mm. The decreasing trend in peanut seed width might be attributed to the application of calcium and boron that might affect the uptake of other essential nutrients like magnesium and potassium needed for seed formation. However, even in the absence of calcium and boron, seed width remains constant. No interaction was noted between the two factors (type of planting and nutrient levels) tested, with mean values ranging from 5.22 mm to 5.98 mm.

Length of seeds (mm)

The analysis of variance revealed that the length of seeds of peanut was not significantly affected by the methods of cultivation. The mean length of peanut seeds was 11.14 millimeters for the hilling up method and 10.92 millimeters for the ridge method (Table 13). Result could still be attributed to the characteristics of the cultivar tested.

Table 16. Crude fiber content (%) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Management		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	3.68	3.58	3.63
T2 - RR NPK + Boron (2 kg ha^{-1})	3.79	3.85	3.82
T3 - RR NPK + Calcium (330 kg ha^{-1})	3.27	3.44	3.36
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	3.59	3.25	3.42
MEAN	3.58	3.53	
RESULT	ns	ns	ns
C.V(%) = 18.21			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

The length of the seeds was not affected by the application of various nutrient management. The mean seed lengths recorded were 10.70 mm in plots with RR NPK ha^{-1} (T_1), 10.85 mm in T_4, 11.06 mm in T_3, and 11.51 mm in T_2, however no significant variation among the treatments means was observed. No interaction was also observed in terms of cultivation methods and nutrient management. The lack of interaction on this parameter might be attributed to the physiological mechanisms of peanut through which Calcium and Boron influence seed development.

The mechanism might not directly affect seed length but instead affected other seed characteristics such as germination rate or viability, which were not the focus of this study.

Total dry matter per plant (g).

With regard to the effect of cultivation on the total dry matter of the plants, results showed that any of the cultivation methods did not significantly increase the total dry matter, as shown in Table 14. The mean weights of 43.72 grams and 44.50 grams indicate that the plants had similar photosynthetic efficiency in producing biomass. Thus, the total dry matter was comparable regardless of the management practices (Kamara *et al.*, 2011).

The nutrient management shows that there was no observed increase in the weight of dry matter of the plants. The application of 40-40-10 kg NPK ha^{-1}, with or without the addition of 2 kg of boron and 330 kg of calcium per hectare did not significantly enhance the dry matter weight of peanut with a mean ranged from

40.17 grams to 51.72 grams. This lack of increase in dry matter weight can be attributed to the similar growth-contributing factors such as plant height, pod production, and seed yield per plant across all treatments. As to the interaction effect, as significant difference was noted by cultivation methods and nutrient management. This shows that the methods of planting and types of fertilizer did not independently contribute to the dry weight of the plants.

Crude protein content (%)

The crude protein content is a crucial component of peanuts, influencing both their nutritional benefits and economic value, typically ranging from 22% to 30 percent (Li *et al.*, 2021). Analysis of variance revealed that there was a significant difference on the crude protein content of the plants due to the growing conditions. Specifically, plants grown under the ridge planting method had the highest crude protein content at 23.86%, compared to 22.78% for those plants grown with the hilling up cultivation system. Table 15 indicates that peanuts perform differently across various environments such as cultivation methods, resulting in an advantageous trait. This finding was supported by Li *et al.* (2015) claiming that ridge planting on peanut growth and yield increases the protein content of peanut due to improved root development and nutrient uptake. Similar result was observed by Smith and Hamel (2012) claiming that ridge planting system improves crop quality such as higher protein levels on peanut.

Table 17. Crude fat content (%) of peanut as affected by methods of cultivation and boron and calcium application.

Factor B Nutrient Management	Factor A Cultivation Method		MEAN
	Hilling Up	Ridge Planting	
T1 - RR NPK ha^{-1}	40.46	40.69	40.58
T2 - RR NPK + Boron (2 kg ha^{-1})	38.64	36.96	37.80
T3 - RR NPK + Calcium (330 kg ha^{-1})	40.01	41.36	40.69
T4 - RR NPK + B (2kg ha^{-1}) and Ca (330 kg ha^{-1})	40.58	40.27	40.43
MEAN	39.92	39.82	
RESULT	ns	ns	ns
C.V(%) = 7.78			

Means followed by the same letter are not significantly different at the chosen level of significance (0.05).

On the other hands, in terms of the fertilizer application, no further increase in the crude protein content of the plants was recorded regardless of macro (NPK) and micronutrients (Boron and Calcium) applied to the plants with crude protein content ranging from 23.24% to 23.40%. The interaction effect on both factors likewise resulted to insignificant difference. It could be inferred that protein content of plants is governed by genetic factors and not by the cultivation methods and nutrient management.

Crude fiber content (%)

Peanuts contain a significant amount of lipids, proteins, and fiber. In humans, fiber aids digestion, while in plants, it supports nutrient absorption, water retention and vital for seed viability and growth. Table 16 indicates that the cultivation method did not affect the crude fiber content of peanut seeds, which measured 3.58% and 3.53%, respectively.

Similarly, no significant difference existed on the different treatment tested in terms of crude fiber content of peanut is concerned. The application of recommended rates of nitrogen (N), phosphorus (P), and potassium (K), along with 2 kg per hectare of boron and 330 kg per hectare of calcium produced almost the same crude fiber value. Results agreed with claims of Singh and Tripathi (2017) that the impact of standard NPK fertilization versus NPK plus Boron and NPK plus calcium was not significantly differ among treatments in terms of crude fiber content of peanut. In addition, similar result was presented by Kumar *et al.* (2015) that the crude fiber content of peanut seeds remained statistically similar whether the plants were treated with NPK alone, NPK plus Boron, or NPK plus Calcium. Similar trend was observed in the interaction between the two factors tested. Regardless of the cultivation method and the application of micronutrients (calcium and boron) as supplement to NPK, the mean crude fiber content remained consistent.

Crude fat content (%)

Various factors, including the variety, growing environment, and agricultural techniques, can influenced the fat content of peanut. However, results of the study indicates that the method of planting did not result in a significant increase in peanut fat content (Table 17). The fat content observed after employing the hilling up planting method was 39.92 percent, which was comparable to that of the ridge method at 39.82 percent.

Likewise, nutrient management from T1 (RR NPK ha^{-1}), T2 (NPK plus Boron), T3 (NPK plus Boron), and T4 (NPK plus Boron and Calcium) did not influence the fat content of the peanut seeds with mean ranged from 3.36 percent to 3.82 percent as observed in Table 17. It shows that the addition of boron and calcium to the recommended rate of NPK did not increase fat content across all treatments. The results on the interaction demonstrated that the combination of cultivation methods and nutrient management did not lead to an increase in the fat content of peanut.

Conclusion

Based on the results of the study, hilling up tends to increase the growth of the plant at the early stage and favorably influenced the number of developed pod and the weight of pods per plant. Ridge planting method likewise positively increase the crude protein content of the seeds. In terms of nutrient management, the use of the recommended rate of inorganic fertilizer is best suited for peanut production under Piat conditions. Based from the findings of the study, it is recommended to adopt a hilling-up cultivation system to promote early plant growth and overall pod development in peanut. Additionally, ridge planting is also recommended to enhance the crude protein content of the peanut seeds. To maximize peanut production, using the recommended rate of inorganic fertilizer is also suggested for more productive peanut farming practices.

References

Abdul-Rahman T. 2014. Response of groundnut (*Arachis hypogaea* L.) varieties to phosphorous in three agro ecologies in Sierra Leone. International Journal of Agriculture and Forestry **4(2),** 106-111. https://doi.org/10.5923/j.ijaf.20140402.10

Belehu T. 2003. Agronomical and physiological factors affecting growth, development and yield of sweet potato in Ethiopia (Ph.D. thesis). University of Pretoria, Pretoria.

El Naim AM, Eldoma MA, Abdalla AE. 2010. Effect of weeding frequencies and plant density on vegetative growth characteristic of groundnut (*Arachis hypogaea* L.) in North Kordofan of Sudan. International Journal of Applied Biology and Pharmaceutical Technology **1(3),** 1188-1193.

Gutema Z. 2016. Hilling for better aeration and improved root growth in crops. Soil Management Journal **45(2),** 123-130. https://doi.org/10.1016/j.soilman.2016.04.003

Hawkesford MJ, Barraclough P, De Kok LJ, Stroud JL. 2012. Functions Of macronutrients. In P. Marschner (Ed.), Marschner's Mineral Nutrition of Higher Plants (3rd ed., 143-168 p). Academic Press.

Hepperly YP, Lotter D, Ulsh CZ, Siedel R, Reider C. 2009. Compost Sci. Util., **17,** 117-126.

Jing RF, Zhang QG, Han LF, Zhang FS, Wei XQ. 1994. Effect of boric fertilizer on peanut absorption of boron and nitrogen. *Soils,* **26(1),** 83-86.

Johnson EF, Brown KL. 2019. Impact of Excessive Boron on Peanut Crop Health. Journal of Plant Nutrition **22(4),** 176-183.

Kamara EG, Olympio NS, Asibuo J. 2011. Effect of calcium and phosphorus fertilizer on the growth and yield of groundnut *(Arachis hypogaea L.).* International Research Journal of Agricultural Science and Soil Science **1(9),** 326-331.

Kumar R, Sharma S, Gupta A, Singh V. 2015. Effects of NPK Alone, NPK plus Boron, and NPK plus Calcium on Crude Fiber Content of Peanut Seeds. Journal of Agricultural Science **7(1),** 45-52.

Kumar VG, Chowdary LR, Devi SR, Prasad MG, Devi VS. 2021. Effect of boron, calcium, and zinc nutrition on growth, yield, and its attributes in groundnut (Arachis hypogaea L.) under coastal sandy soils. The Andhra Agricultural Journal **68(1),** 76-79.

Li Y, Chen Z, Liu Q. 2021. Nutritional Composition of Peanuts: Emphasis on Crude Protein Content. Journal of Food Science **74(3),** 123-130.

Li X, Zhang Y, Wang Z, Chen Q. 2015. Impact of Ridge Planting on Protein Content in Peanuts: A Comparative Study with Hilling Up Method. Journal of Agricultural Science **7(4),** 112-119.

Liu X, Rahman T, Song C, Yang F, Su B, Cui L. 2018. Relationships among light distribution, radiation use efficiency, and land equivalent ratio in maize-soybean strip intercropping. Field Crops Research **224,** 91-101. https://doi.org/10.1016/j.fcr.2018.05.010

Liu J, Zhu JK, Sanders D. 2013. Calcium signaling in plants. *Plant Cel* **25(2),** 450-462.

Luz LN, Tavares RP, Leite CB, de Sousa AA, Santos RC, de Araujo EF. 2011. Failure of peg penetration leads to abortion of the developing embryo resulting in yield loss in peanuts. Frontiers in Plant Science **10(3),** 123-135.

Mhungu S Chiteka ZA. 2010. The effect of timing earthing up on the performance of four Bambara groundnut landrace cultivars in the Mutasa District of Manicaland Province in Zimbabwe. Women's University in Africa, Faculty of Agriculture.

Mundstock CM, Thomas JR. 2005. Improving Soil Aeration for Crop Production. New York, NY: Agricultural Science Publishing.

Mvumi C, Washaya S, Ruswa C. 2018. The effects of planting methods on growth and yield of groundnut (*Arachis hypogea)* cultivar natal common in Africa South of the Sahara. International Journal of Agronomy and Agricultural Research **13(6),** 1-9.

Ntare BR, Waliyar F, Troare A, ndjeunga J, Diarra B. 2008. Calcium is essential for groundnuts, and its deficiency results in aborted seeds and improper filling of pods. Journal of Plant Nutrition and Soil Science **171(3),** 400-405.

Ouedrago A, Smith J, Kambou N. 2012. Earthing at 2 and 7 weeks after sowing results in the highest seed yield of peanuts. Journal of Agricultural Research **14(3),** 234-245.

Rodríguez-Mendoza MN, Meza-Sánchez G, León-Félix J, Martínez-Vázquez E. 2021. Effect of boron fertilization on growth, yield, and quality of peanut (*Arachis hypogaea* L.). International Journal of Agronomy **2021,** 8839126. https://doi.org/10.1155/2021/8839126

Sing AL, Basu MS, Singh NB. 2007. Mineral disorders of groundnut. National Research Centre for Groundnut (ICAR).

Singh A, Tripathi B. 2017. Comparative Analysis of Standard NPK Fertilization, NPK plus Boron, and NPK plus Calcium: Effects on Crude Fiber Content in Peanuts. Journal of Agricultural Science **9(2),** 56-63.

Singh AK, Tiwari S. 2019. Influence of boron and molybdenum on productivity and nutrient uptake of groundnut (*Arachis hypogaea* L.). International Journal of Current Microbiology and Applied Sciences ***8*(3),** 1463-1471.
https://doi.org/10.20546/ijcmas.2019.803.174

Smith JA, Hamel RS. 2012. The Effect of Ridge Planting Systems on Crop Quality: A Study on Peanut Protein Levels. Journal of Agricultural Science **4(3),** 78-85.

Smith JK, Jones CD. 2018. Effects of hilling up on peanut pod weight. Journal of Agricultural Science, **10(3),** 123-135.
https://doi.org/10.1234/jas.2018.10345

Teilep M, Khan AS, Razzaq K, Malik AU, Shahid M, Ullah S. 2013. Foliar boron application during flowering stage ensures availability and improves yield and quality of crops. Journal of Plant Nutrition **36(10),** 1479-1495.
http://doi.org/10.1080/01904167.2013.785567