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Full Length Research Paper

Effect of calcium and phosphorus fertilizer on the growth and yield of groundnut (*Arachis hypogaea L.*)

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Two experiments were conducted at the CSIR-Crops Research Institute (CSIR-CRI), Kumasi in Ghana during the major and minor seasons of 2009 to study the effects of calcium and phosphorus fertilization on the growth and seed yield of groundnut (*Arachis hypogaea* L.). A 2x2x3 factorial design was used. The factors studied were two varieties of groundnut, two rates of phosphorus (0 and 40 kg P_2O_5 ha^{-1}) and three levels of calcium (0, 100 and 200 kg Ca ha^{-1}) were applied. Pod and seed yields were generally higher in the major season. Dry spell in the minor season affected the results. Application of calcium fertilizer had a positive effect on the number of filled pods, shelling percentage and 100 seed weight. Application of 100 kg Ca ha^{-1} significantly ($P \leq 0.05$) out-yielded the control in number of filled pods, shelling percentage and 100 seed weight which invariably resulted in higher pod and seed yields. The results also show that phosphorus fertilization significantly ($P \leq 0.05$) influenced vegetative growth and biomass of the two groundnut varieties. Positive relationship was observed between number of filled pods and shelling percentage (r^2=0.97). The results indicated that calcium and phosphorus fertilization are vital for the growth and seed yield of groundnut.

Keywords: *Arachis hypogaea*, calcium, phosphorus, growth, seed yield.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the most important food legume in Ghana in terms of consumption and area under production. It contains 42- 52% oil and 22-30% protein on a dry seed basis and is a rich source of minerals like phosphorus, calcium, magnesium and potassium (Savage and Keenan, 1994). Besides being a source of income for farmers, groundnut provides an inexpensive source of high quality dietary protein and oil in the diets of many Ghanaians (Asibuo et al., 2008). Despite the importance of this crop, its yields remain low below 1.0 t ha^{-1}, which is far less than the potential yield of 2-3 t ha^{-1}. This has affected groundnut production, the income and welfare of groundnut growers. It is not very clear whether this problem of low yields is as a result of declining soil fertility or changes in climatic condition.

Calcium is a soil nutrient deficient in Ghanaian soils. Calcium deficiency leads to high percentage of aborted seeds (empty pods or "pops") and improperly filled pods (Ntare et al., 2008). It also leads to aborted or shriveled fruit, including darkened plumules and production of pods without seed (Singh and Oswalt, 1995). To get good yields of quality groundnut pods, an adequate amount of Ca should be present in the soil from early flowering of crop production onwards. Phosphorus, an essential nutrient for crop growth and yield with good quality is deficient in most Ghanaian soils. Although legumes can fix their own nitrogen, they often need phosphorus and potassium for good seed formation (Asiedu et al., 2000). Phosphorus also promotes root growth, enhances nutrient and water use efficiency and increases yield. The requirement of phosphorus in nodulating legumes is higher compared to non-nodulating crops. Due to the important role played by phosphorus in the physiological processes of plants, application of phosphorus to soil deficient in the nutrient leads to increase groundnut yield. Hence, appropriate Ca combination with P fertilization may reveal the causes of empty pods, low yields and seed quality of groundnut in Ghana. Oyster shell, a

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Table 1. The initial physical and chemical properties of the experimental soil in 2009

Soil Depth	**0-15 cm**	**15-30 cm**
% Organic C	0.94	0.53
% Organic matter	1.62	0.92
Total nitrogen	0.20	0.19
Exchangeable cations (Cmol kg^{-1})		
K	0.29	0.17
Na	0.51	0.23
Ca	3.13	2.60
Mg	3.80	3.07
Al	1.30	0.57
H	0.73	0.63
Available P (mg kg^{-1})	**17.14**	**7.82**
pH	5.25	4.96
% Sand	82.0	75.3
% Clay	10.7	19.3
% Silt	7.3	5.3

natural source of calcium can be used to correct Ca deficiencies and raise pH in acidic soils. No study has been conducted on the effect of Ca from oyster shell and P and their interaction on the growth and yield of groundnut. The main objective of this study was to determine the effect of Ca and P fertilization on the growth and yield (pod and seed) of two groundnut genotypes in the major and minor raining seasons in the semi-deciduous forest zone of Ghana.

MATERIALS AND METHODS

Two field experiments were conducted at the Crops Research Institute at Fumesua during the major and minor raining seasons in 2009. The soil type was sandy loam with low organic matter, cation exchange capacity and calcium, moderate nitrogen and phosphorus. The soil was acidic in nature with pH range of 4.96 to 5.25 (Table 1).

Total rainfall in the major and minor raining season was 993.3 and 215.3 mm, respectively. Air temperate varied from 21.1-31.4°C in the major raining season to 22-32°C in the minor raining season. Relative humidity was between 86 and 91% in the major raining season and 77 and 89% in the minor raining season. The experimental areas were ploughed to a depth of about 20 cm and harrowed. Two varieties of groundnut, Nkosour an improved variety and Shitaochi, a local check were planted at a spacing of 30 cm x 15 cm (between row and plants respectively) on plots 12 m^2 (5 m x 2.4 m), giving a plant population of 222,000 plants per hectare. Planting was done on 5th May, 2009 in the major raining season and 20th September, 2009 in the minor season. A 2x2x3 factorial experiment laid in randomized complete block design was used in the study. Two levels of phosphorus (0 and 40 kg ha^{-1} P_2O_5 as triple superphosphate) and three levels of calcium (0, 100 and 200 kg ha^{-1} Ca as oyster shells) and two groundnut varieties (Nkosour and Shitaochi) were used. Phosphorus fertilizer as triple superphosphate was applied at sowing and oyster shell powder at 40 days after planting during peak flowering and beginning of pegging.

Emerged seedlings were counted two weeks after planting. Five plants were taken from each plot to measure the yield attributes. Plant height was measured with a meter rule and means expressed in centimeter, number of leaves and number of branches were recorded from each plot and mean number expressed as per unit basis. Dry weight was determined from the penultimate rows of the lot for destructive sampling at 4, 6, 8 and 10 weeks after planting. Plants were oven-dried at 80ºC for 48 h and the dry weights measured using an electronic weighing scale (Doran, scales Inc.). Relative growth rate was calculated using the following formula:

$$RGR = \frac{\ln W2 - \ln W1}{T2 - T1}$$

where the earlier dry mass of previous sampling was represented by W1 and the dry mass of the sample that followed was represented by W2. The corresponding time of sampling was represented by T1 and T2, respectively. At harvest, five plants in the middle rows were taken randomly to determine the yield components as follows: Number of empty pod, number of filled pods and 100 seed weight. Plants from the two middle rows were used to calculate the pod and seed yield using the formular:

Table 2. Mean percentage field emergence, days to 50% flowering and days to maturity of the two groundnut genotypes.

Variety	Percent field emergence		Days to 50% flowering		Days to maturity	
	Major	Minor	Major	Minor	Major	Minor
Nkosour	70.22b	84.33	27A	30A	109A	113A
Shitaochi	89.78a	85.83	25 B	25B	92B	89B
Mean	81.2	84.8	26	27	100	101
LSD (0.05)	2.9	NS	0.2	0.5	1.9	3.5
CV (%)	5.3	5.1	1.2	5.1	2.8	1.3

[a, b] Different letters in the same row indicate highly significant differences ($p<0.01$). [A, B] Different letters in the same row indicate significant differences ($p<0.05$)

Table 3. The effect of phosphorus fertilization on plant height and leaf number.

Phosphorus level	Major season		Minor season	
	Plant height (cm)	Leaf number	Plant height (cm)	Leaf number
0	37.1a	105A	27.2	80
40	42.3b	125B	27.3	67
Mean	39.7	115	27.3	73.4
LSD (0.05)	4.9	14.7	NS	NS
CV (%)	17.8	18.5	13.3	22

$$\text{Pod yield (kg ha}^{-1}) = \frac{\text{pod yield (kg)}}{\text{Harvested area (m}^2)} \times 10000 \text{ m}^2$$

$$\text{Seed yield (kg ha}^{-1}) = \frac{\text{seed yield (kg)}}{\text{Harvested area (m}^2)} \times 10000 \text{ m}^2$$

Data collected were subjected to analysis of variance (ANOVA) using Genstat Release version 7.2DE.

RESULTS

The results of the study show that the two varieties differed significantly ($P<0.001$) in percentage field emergence during the major (wet) season but not in the minor season (Table 2). Shitaochi had the highest percent field emergence (89.77%) whilst Nkosour had the lowest (70.22%) in the major season. There were significant ($p<0.05$) differences between the two varieties in days to fifty percent flowering and days to maturity. Phosphorus application significantly ($p<0.05$) increased plant height and leaf number (Table 3). The mean plant height in the major season was 45% higher than the minor season. Also the number of leaves in the major season was 36.7% more than the minor season. Application of phosphorus fertilizer generally increased total dry weight in both seasons. The highest relative growth rate of 0.12 gg^{-1} day was achieved through phosphorus application between the 6 and 8 weeks after planting in both seasons (Figure 1). Calcium application had a positive effect on the number of filled pods per plant and significantly ($p \leq 0.05$) affected the two groundnut genotypes during both seasons. The highest number of filled pods was obtained in the treatment with 100 kg Ca ha^{-1} in the major season (Table 4) and was 33.5% more than the unfertilized treatment. Increasing the rate of calcium from 100 kg ha^{-1} to 200 kg ha^{-1} did not bring significant ($p<0.5$) increase in number of filled pods. The number of filled pods was generally higher in the major season than the minor season. The ratio of filled to unfilled pods was 3.8:1 in the major season and 0.7:1 in the minor season.

Calcium application also significantly ($p \leq 0.001$) influenced seed and pod yield in both seasons. The treatments with 100 kg Ca ha^{-1} gave the highest seed yield (2065 kg ha^{-1}) and were significantly ($p\leq0.05$) different from the control but not significantly different from the 200 kg Ca ha^{-1} (Table 5). Calcium application increased seed yield by 49% in the major season whilst an increase of 26% was obtained in the minor season. Calcium application also significantly ($p \leq 0.001$) influenced shelling percent, seed and pod yields in both seasons (Table 5). Application of 100 kg Ca ha^{-1} resulted in about 50% higher seed yield than the control in the major season.

DISCUSSION

Generally, the results show that percentage field emergence was higher in the minor season than the major season. This may be due to the fact that fresh pods

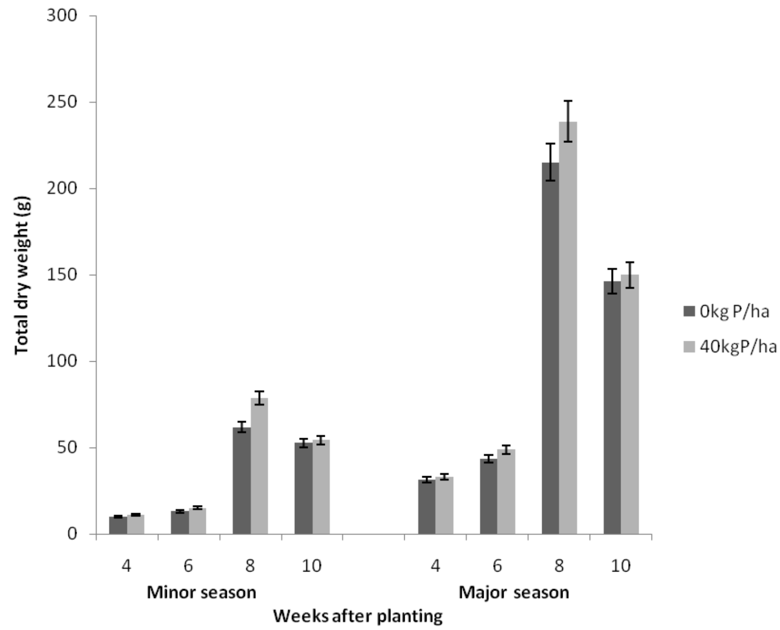

Figure 1. Total dry weight as affected by phosphorus fertilization at different weeks after planting in the major and minor seasons.

Table 4. The effect of calcium fertilization on filled pods, unfilled pods and 100 seed weight of the two groundnut varieties.

Calcium level	Major season				Minor season			
	Branches/plant	Filled pod	Unfilled pod	100 seed weight (g)	Branches/plant	Filled pod	Unfilled pod	100 seed weight (g)
0	8.33[a]	17.3[a]	6.6[a]	31.8	5.5	8.4[a]	13.0	28.0
100	9.35[b]	23.1[b]	4.9[b]	37.2	10.4	5.9[b]	11.9	30.5
200	9.50[b]	21.5[b]	4.8[b]	33.2	10.2	5.8[b]	13.7	29.4
mean	9.1	20.6	5.4	34.1	5.8	9.6	12.9	29.3
LSD (0.05)	0.9	3.2	1.3	NS	NS	1.0	NS	1.2
CV (%)	11.7	18.3	27.8	18.3	18.3	12.7	27.1	8.0

from the major season were harvested, dried and replanted in the minor. The major season seeds were harvested the previous year and may not have the same quality as a result of long months of storage. In both seasons, the percentage emergence of Shitaochi was higher than Nkosour. The difference was significant ($p<0.05$) in the major season.

The differences in days to 50% flowering and days to maturity were due to their contrasting market types. The results are in conformity with those of Nigam et al. (1990) who reported that Virginia groundnut group consists of plants that flower longer and mature later than those of Valencia and Spanish types. The minor season plants took longer time to reach maturing probably due to water deficits during the pod filling stage resulting in delayed maturity and poorly filled pods. Similar findings were reported by Boote et al. (1976) and Wright et al. (1991).

Phosphorus application significantly increased plant height, leaf number in the major season and total dry weight in both seasons whilst application of calcium increased number of branches. Similar results have been reported by Sharma and Yaday (1997) and Rahman (2006). In the minor season, calcium and phosphorus fertilization did not influence vegetative growth probably due to inadequate rainfall.

Application of phosphorus fertilizer generally increased total dry weight in both seasons. The increases in dry weight due to phosphorus application may be due to the fact that phosphorus is known to help in the development of more extensive root system (Sharma and

Table 5. Effect of calcium fertilization on shelling percentage, seed and pod yield (kg ha^{-1}) of groundnut in the major and minor seasons.

Calcium level	Major season			Minor season		
	Shelling %	Seed yield	Pod yield	Shelling %	Seed yield	Pod yield
0	59.1^{A}	1378^{A}	2328^{A}	57.74^{a}	521^{a}	816^{a}
100	67.2^{B}	2065^{B}	3076^{B}	60.25^{ab}	659^{ab}	1080^{b}
200	63.6^{B}	1881^{B}	2972^{B}	63.30^{b}	719^{b}	1041^{b}
Mean	63.3	1775	2792	60.3	633	979
LSD	1.3	224.2	367.6	5.3	91.3	220.6
CV (%)	27.8	14.9	15.6	8.0	15.6	26.6

Yaday, 1997; Gobarah et al., 2006) and thus enables plants absorb more water and nutrients from depth of the soil. This in turn could enhance the plant's ability to produce more assimilates which were reflected in the high biomass. Similar results have been reported in previous studies (Tomar et al., 1990; El- Habbasha et al., 2005; Gobarah et al., 2006).

Applying 100 kg Ca ha^{-1} and 200 kg Ca ha^{-1} did not lead to significant difference in most of the parameters measured, indicating that 100 kg Ca ha^{-1} was enough for the particular soil. The soil used in the current experiment was originally poor in P and Ca, and as such response to 40 P in combination with 100 and 200 Ca applications was high. Application of Ca and P fertilizers increased nutrients available to the crop during the major season. It led to greater utilization of assimilates into the pods and ultimately increased number of filled pods and shelling percentage.

Generally the results of the study show that the seed and pod yields of the major season were higher than those of the minor season with or without fertilizer. The lower yields obtained in the minor season could be attributed to the low rainfall and high temperatures. The total amount of rainfall recorded (215.3 mm) in the minor season was far below the optimum requirement of 500 mm for groundnut production. This is in agreement with the results of Gadgil (2000) who also observed that variation in groundnut yield arises to a large extent from the variation in total rainfall during the growing season. The reduced plant height and number of leaves in the minor season might have resulted in reduced photosynthetic capacity of the two genotypes and invariably led to reduced number of pods per plant, number of filled pods, pod and seed weight.

Results of the two experiments suggest that the use of oyster shell as a source of calcium offers an alternative source of calcium fertilizer for obtaining higher yield in groundnut. From the results, application of phosphorus increased the vegetative growth whilst calcium increased the number of filled pods and hence the seed and pod yield. Application of 40 kg P_2O_5 ha^{-1} in combination with 100 kg Ca ha^{-1} resulted in the highest yield in both seasons. For highest yields, it is recommended that farmers grow their crop in the major season.

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