KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

KUMASI - GHANA

EFFECT OF CALCIUM AND PHOSPHORUS
QUALITY OF TWO GROUNDNUT (*Arachis hypogaea* L.) VARIETIES
FERTILIZATION ON THE GROWTH, YIELD AND SEED

A THESIS SUBMITTED TO THE DEPARTMENT OF HORTICULTURE, FACULTY OF AGRICULTURE, COLLEGE OF AGRICULTURE AND NATURAL RESOURCES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF M. Sc DEGREE IN SEED SCIENCE AND TECHNOLOGY

BY

ERNEST GIBRIL KAMARA

JUNE 2010

CERTIFICATION

I hereby declare that except for references to other peoples work which have been duly cited this work is the result of the original work of Ernest Gibril Kamara and that this work has neither in whole nor in part been published by another person or presented for the award of degree elsewhere.

Ernest Gibril Kamara	……………………	…………………
STUDENT	SIGNATURE	DATE
Dr. N. S. Olympio	………………….	…………………
SUPERVISOR	SIGNATURE	DATE
Dr. James Yaw Asibuo	……………………	………………..
CO- SUPERVISOR	SIGNATURE	DATE
Mr. P.Y. Adjei	……………………	…………………
HEAD OF DEPT.	SIGNATURE	DATE

DEDICATION

This work is dedicated to my late grandmother Ya Adama Koroma and late dad Pa Abu Kamara, both of whom could not live long to reap the fruits of their labour.

ACKNOWLEDGEMENTS

I owe a debt of gratitude to my supervisor, Dr. Mrs. N.S. Olympio of the Department of Horticulture, College of Agriculture, Kwame Nkrumah University of Science and Technology and to my co- supervisor, Dr. James Yaw Asibuo of CSIR-Crops Research Institute, not only for being outstanding, but also for instilling in me the passion to pursue this academic research. I greatly appreciate their constructive criticisms, guidance and support at every phase of this project.

I am grateful to the former Deputy-Director General, Dr. A. Jalloh and Director of Njala Agricultural Research Centre, Dr. Fomba of the Sierra Leone Agricultural Research Institute for granting me study leave to undertake my study. I also wish to express my special gratitude to Alliance for a Green Revolution in Africa (AGRA) for granting me scholarship and funding this project. I should also like to acknowledge Dr. Robert Asuboah of Grains and Legumes Development Board for making all facilities readily available to me to conduct seed quality tests.

I am grateful for the unwavering support rendered by Mr. Joseph Donkor, chief technician, Miss. Felicia Ampofo and Mr. James Fordjour, supervisors in the Legume and oilseeds improvement division at CSIR-Crops Research Institute for their assistance during the field data collection. I would also not forget the contribution of Mr. Paul Manu for taking care of the groundnut fields in both seasons.

I owe many thanks to a number of persons who have been particularly helpful to me in my life. These include Mr. and Mrs. Fornah, Mr. M. J. Tucker, Amad K. Smart, N.D. Mansaray, Festus Massaquoi and Alusine Samura.

I wish to thank Mrs. Adelaide Agyeman for analyzing my data, Acquah and Favour for their assistance in the seed quality tests. Special thanks to David, Morro, Smart, Eric, Ebenezer and Emmanuel for motivating and encouraging me during my study.

I am indebted to Dr. Richard Akromah, Bole, Mrs. Felicia Quaye and Gifty for their kindness and support which has helped to make me feel at home throughout my stay in Kumasi.

I am also grateful to my brothers Hassan, John and sisters Fatmata and Salamatu for giving me the much needed moral and material support towards my course work. My highest appreciation and deepest gratitude are extended to Amie and Angela for giving me inspiration and encouragement to complete this work.

Finally, I give God the glory for the great opportunity.

ABSTRACT

Two experiments were conducted on a sandy loam soil 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 seed yield and quality of groundnut (*Arachis hypogaea L.)*. A 2x2x3 factorial experiment laid in a randomized complete block design with three replications was used in this study. The factors studied were two groundnut varieties (Shitaochi and Nkosour), two phosphorus rates (0 and 40 kg P_2O_5 ha^{-1}) and three levels of calcium (0, 100 and 200kg Ca ha^{-1}).

In the major season, the improved variety Nkosour out-yielded Shitaochi, the local variety in pod and seed yield whilst in the minor season the converse was obtained. In both seasons, the application of Ca fertilizer had a positive effect on the number of filled pods, shelling percentage and 100 seed weight. The application of 100 kg Ca ha^{-1} which was similar to 200 kg Ca ha^{-1}, significantly ($P \leq 0.05$) out-yielded the control in the number of filled pods, shelling percent and 100 seed weight and seed yield in both seasons. Calcium application also increased the calcium content, germinability, vigour and the oil content of the seeds.

The application of phosphorus significantly ($P \leq 0.05$) influenced vegetative growth and dry weight of the two groundnut varieties. It also increased the protein content of the seed in both seasons. The two varieties responded positively to calcium and phosphorus fertilization. The findings from of the major and minor seasons indicate that the application of 100 kg ha^{-1} as oyster shell powder has the potential to increase seed and pod yields of groundnut.

Table of Contents

List of Tables

List of Figures

CHAPTER ONE

1.0 Introduction

Groundnut (*Arachis hypogaea* L.) is a self-pollinating, annual herbaceous legume. The centre of origin for *Arachis* spp is thought to be in the Mato Grosso region of Brazil or northeastern Paraguay (Gregory *et* al., 1980). *Arachis hypogaea*, the most widely cultivated species of the genus *Arachis*, probably originated in the region of south Bolivia or northern Argentina (Hammons, 1982) and was subsequently taken to Africa, Europe and Asia.

Groundnut is the thirteenth most important food crop of the world and it is the world's fourth most important source of edible oil and the third most important source of vegetable protein (Taru *et al.*, 2008). It has a tremendous potential to mitigating the protein nutrition in poverty ridden countries of the world. Being a leguminous crop, it can fix atmospheric nitrogen in soils through root nodule bacteria and thus improves soil fertility.

Groundnut is the most important food legume in Ghana in terms of consumption and area under production (Frimpong *et al.*, 2004) and is featured prominently in the cropping systems of the Savanna and Forest-Savanna transitional agro-ecological zones. Its production in Ghana has nearly tripled in the last decade (168,200mt in 1995 to 420,000 mt in 2005) primarily due to increase in the area under cultivation which increased from 184,400 ha in 1995 to 450,00 ha in 2005 (FAO, 2006). Average yields however continue to remain below 1.0mt/ha which is far below the potential yield of 2-3 mt/ha. Besides 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).

Although groundnut is the most widely cultivated legume and a major cash crop in Northern Ghana, it is faced with major challenges including diseases and pests' occurrence, erratic rainfall distribution pattern, poor quality seed and poor soils (Tsigbey *et al*., 2003). This has resulted in low yields of groundnut which can be ascribed to the emerging problem of empty pods (pops) prevalent countrywide.

Declining soil fertility, particularly calcium and phosphorus deficiency, has been implicated as possible cause of the low yield problem in groundnut. Calcium is one of the less mobile nutrients in plants. In groundnut, there is little translocation from the main plant body into the forming pods (Zharare *et al*., 1998). Gascho and Davis (1994) also stated that groundnut is unique in one aspect of its nutrition: the seed develops via nutrients it gathers directly from the soil rather than those translocated from roots to shoots and back to the seeds. This unique aspect has guided the applications of nutrients, especially calcium, for greatest yield, quality and seed germination. Calcium must be added to slightly acidic soils to correct pH and improve the quality of the seed (Ntare *et al*., 2008). Calcium deficiency leads to a 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 groundnut, adequate amounts of calcium should be present in the soil from the early flowering stage up to pod filling.

Phosphorus is another important nutrient for legumes in particular (Poehlman, 1991). It is a key constituent of adenosine triphosphate (ATP) in plants (Sankar *et al.*, 1984) and also plays various roles in seed formation. Absorption and reduction of nitrate is an energy consuming process and the energy is supplied by ATP. 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 (Ikisan, 2000). Due to the important roles played by phosphorus in the physiological processes of plants, application of phosphorus to soils deficient in the nutrient tends to increase groundnut yield. However, phosphorus a major nutrient is deficient in most Ghanaian soils (Owusu-Bennoah, 1997). Thus calcium in combination with phosphorus fertilization may improve the yield levels and seed quality of groundnut in Ghana. The present study was therefore undertaken to determine the response of two groundnut genotypes to calcium and phosphorus levels and their effect on pod yield, seed and nutritional quality.

The specific objectives were:

1. To determine the effect of calcium and phosphorus fertilization on the yield and quality of groundnut seed,
2. To determine the effects of genotype and growing season on the nutritional quality of groundnut seed.
3. To identify an appropriate calcium rate for increased pod filling and groundnut yield.

CHAPTER TWO

2.0 Literature Review

2.1 Origin and geographical distribution

The cultivated groundnut (*Arachis hypogaea* L.) probably originated in Bolivia at the base of the Andes (Krapovickas, 1968) extending into North Argentina (Ramanatha Rao, 1988).

Groundnut is believed to have originated from Latin America and was introduced into West Africa by Portuguese traders in the 16^{th} century (Hogendons, 1978; Purseglove, 1988). The origin of this crop dates back to 350 BC (Hammons, 1994). The author reported that, the first probable domestication of groundnut took place in the Valley of the Panama and Paraguay River systems in the grain Chaco area of South America and then moved to North America from Africa through slave trade. Weiss (2000) also reported that cultivated groundnut originated from South America.

Africa is now regarded as a secondary centre of diversity. Groundnuts are grown in most tropical, sub-tropical and temperate countries between latitudes 40^{0}N and 40^{0}S in Africa, Asia, North and South America (Cummins, 1986). According to the author it is an ancient crop of the new world and was grown in Mexico, Central America and South America in Pre-Columbian times. Domesticated groundnut had already evolved into several types before it was introduced into the old world by Spanish and Portuguese explorers. Further two-seeded types originating from Brazil were brought to West Africa, and three-seeded types originating from Peru were taken from the West Coast of South America to the Philippines, from where they spread to Japan, China, Indonesia, Malaysia, India, Madagascar and Eastern Africa. In the late 1700s Spanish groundnut types were introduced into Europe from Brazil.

2.2 Climatic and soil requirements of the crop

Groundnut is essentially a tropical plant and requires a long and warm growing season (Weiss, 2000). The favourable climate for groundnut is a well-distributed rainfall of at least

500mm during the growing season, and with abundance of sunshine and relatively warm temperature. Williams *et al*. (1975) reported that the optimum temperature for vegetative growth of groundnut plants were in the range of 25-30^{0}C while the optimum temperature for reproductive growth is lower (20-25^{0}C). Weiss (2000) also reported that temperature in the range of 25 to 30^{0}C is optimum for plant development.

Heat and/or drought induced stresses are the major environmental factors limiting pod yields in the Semi- Arid tropics (ICRISAT, 1994). The optimum day and night temperature for vegetative and reproductive growth and development in groundnut ranges from 25/25^{0}C to 30/26^{0}C and from 25/25^{0}C to 26/22^{0}C, respectively (Wood, 1968; Cox, 1979).

Groundnut productivity is low in the semi-arid tropics mainly due to drought caused by low and erratic rainfall (Nigam *et al*., 2001). Misari *et al*. (1988) reported that groundnut requires 500-1600 mm of rainfall, which may last for 70-100 days of rainy season in the Sudan savannah. Further it requires well-drained light coloured loosed friable sandy loam soil, optimum moisture in pod zone and mean daily temperature of about 30^{0}C. The authors added that rainfall should be well distributed during the flowering and pegging of the crop. The total amount required for pre-sowing is 150mm and for flowering and pod development an evenly distributed rainfall of 400-500 mm is required although crop can be produced on as little as 300 to 400 mm of rainfall. Groundnut cannot withstand frost, long and severe drought or water stagnation. However, the crop does best in sandy loam and loamy soils and in black soils with good drainage. Heavy and sticky clays are not suitable for groundnut cultivation because the pod development is hampered in these soils (Larinde, 1999). Ikisan (2000) indicated that nodulation and nitrogen fixation show rapid decline under drought conditions and that prolonged desiccation leads to nodule loss with partial inability to further form nodules.

Once established, groundnut is drought tolerant, and to some extent tolerates flooding. Rainfall of 500 to 1000 mm will allow commercial production. The productivity of groundnut is higher in soils with high fertility and pH between 6.5-7.0 (Singh and Oswalt, 1995).

At harvest, traits such as seed weight is the sum of development and responses to stresses over the growing season and particularly during the reproductive phase of growth (Teng *et al.*, 2008).

2.3 Area, Production and Productivity of groundnut

Groundnut is one of the most popular and universal crops cultivated in more than 100 countries in six continents (Nwokolo, 1996). Its cultivation is mostly confined to the tropical countries and warm temperate regions ranging from 40^{o}N to 40^{o}S. Major groundnut producing countries are China (40.1%), India (16.4%), Nigeria (8.2%), USA (5.9%) and Indonesia. It is the chief crop rotation component in many sub-Saharan countries in the world (Gbehounou and Adango, 2003). Based on production, the world average groundnut production was 1690kg/ha in 2006 (FAOSTAT, 2008). Groundnut is currently grown on nearly 22.2milliom hectares with actual production of 35mt and average yield of 1554kg/ha (ICRISAT, 2009). According to FAOSTAT (2008) groundnut yields in Africa was much lower (980 kg/ha) than the world average. Researchers associate these lower yields to abiotic, biotic and socioeconomic factors (Caliskan *et al.*, 2005; Pande *et al.*, 2003; Upadhyaya *et al.*, 2006). Production is concentrated in Asia and Africa where the crop is grown mostly by small holder farmers under rain fed conditions with limited inputs.

Although groundnut is grown in all agro-ecological zones of Ghana, about 85% of the area under groundnut cultivation and the bulk of groundnut production is from the Guinea Savanna and Sudan savanna zones (Atuahene - Amankwa *et al*., 1988). The annual rainfall in these two production areas ranges from 990mm to 1070mm and the rains usually start in May and continue through October.

2.4 Economic importance and uses

Groundnut is the sixth most important oilseed crop in the world (Ntare *et al*., 2008). Most of the world production of groundnut is crushed for oil that is used mainly for cooking. The cake after oil extraction is rich in protein and minerals, which is used in food preparation and feed for livestock. The seeds or kernels are eaten raw, boiled or roasted, made into confectionery and snack foods, and are used in soups or made into sauces. The haulm is used as fodder especially in the drier Savanna zones (Marfo *et al*., 1999). NPC (1990) stated that groundnut is used for making margarine, candy, salted groundnut, crackers/cookies, salad oils and soaps.

Groundnut is an important crop for resource-poor farmers in West Africa, crucial for their economic prosperity and nutritional welfare. Improvements in groundnut productivity and output are also crucial because of its potential to regain and increase export earnings. Groundnut is the principal source of dietary protein, oil/fat, and vitamins such as thiamine, riboflavin and niacin. Groundnut paste is an important source of calories for small children, particularly those being weaned. These children simply cannot obtain the calories they require from high-bulk cereal grains, and depend on groundnut for energy as well as vitamins. Groundnut cake and haulms (straw, stems) are used as livestock feed, helping to maintain livestock productivity. The crop also contributes up to 60 kg/ha nitrogen to the soil, benefiting crops subsequently planted in the same field. Being a legume with root nodules, groundnut enriches soil by fixing nitrogen without draining the non-renewable energies and without upsetting the agro-ecological balance (Reddy and Kaul, 1986). It serves not only as an important and cheap source of protein in the diets of many Ghanaians but it is also a critical component in our cropping systems. This is because of the substantial quantities of nitrogen the crop fixes for succeeding cereal crops (NAES, 1994). Groundnut is grown in all agro ecologies in Ghana from the dry savanna regions to the moist areas and eaten with boiled maize to reduce the impact of hunger during the lean season when most food stuffs are in short supply (Asibuo *et al*., 2008).

Groundnut plays a key role in the agriculture-dependent economies of West Africa. Improvements in groundnut productivity and output will improve the sustainability of farming systems. It will impact on rural employment, trade, and purchasing power for resource-poor smallholder families, strengthen the economic position of women, and improve household nutrition. Groundnut shell is used as fuel for manufacturing coarse boards and cork substitutes.

2.5 Seed Quality of groundnut

Uniform stands of healthy, vigorous seedlings are essential if growers are to achieve the yield and quality needed for profitable groundnut production. Thus, seed quality is critical to growers. According to Perry (1981), several major factors influence the vigour and viability of seed lots which included genotype, nutrition and growth conditions of the mother plant, physiological maturity of seed at harvest, physical handling of the seed during processing, seed moisture content and temperature during storage. Spears *et al*. (2002) stated that peanut quality can be separated into five related components: germination, vigour, genetic purity, crop purity and health. Of these components, germination and vigour have the greatest impact on seedling emergence and survival. Rapid and uniform germination is as important for better crop production as is the total germination. In order to get a successful stand establishment high quality seeds with maximum germination and vigour, must reach farmers.

AOSA (2002) defines germination as an indication of a seed's ability to produce a normal plant under favourable conditions. To a peanut grower, germination percentage is the value printed on the seed tag and represents the maximum germination rate of the seed lot if seeds are planted with optimal temperature and soil moisture. However, field conditions are rarely optimal and the germination rate may at times over estimate field emergence and seedling survival (AOSA, 2002). It is unusual for peanut seed lots to have different seedling emergence and survival rates. Those differences in field performance are often attributed to the physiological quality component known as seed vigour (Spears *et al*., 2002). Seed vigor is defined as those properties of seeds that determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions (AOSA, 2002). The first count of the standard germination test is considered to be a measure of seed vigor. Its suitability for predicting field emergence of soybean was discussed by Tekrony and Egli (1977). Generally, vigour tests have proven to be more useful as predictors of field emergence than the standard germination test. When planted in fields with stressed environmental conditions, especially cool, wet conditions, a high vigor seed lot can withstand the stress during germination and early seedling development longer than a low vigor seed lot (Spears *et al*., 2002). Thus, emergence is generally higher and seedling growth is more rapid. Vigor tests are used extensively in the seed industry to provide a sensitive, consistent, fast, simple and economic method that can be used to predict the seed performance in the field environment (McDonald, 1980). Copeland and McDonald, 2001 also reported that a change of seed chemical composition is one of the factors that may influence the seed germination and vigor. Nautiyal (2009) reported that both medium and higher seed- weight groups of Virginia and Spanish groundnuts are efficient in utilization of reserve food material and that lower seed weight group was found to be insufficient in the supply of reserve food material stored in the cotyledons to establish vigorous seedlings. Seed quality of peanut is influenced by seed calcium concentration (Ca), which is known to be affected by seed size and soil Ca fertility during seed production.

El Tinay *et al*. (1989) reported that moisture content of groundnut seeds was not affected by biological, chemical or organic fertilizers but rather by relative humidity of the surrounding atmosphere at the time of harvest and during storage.

The seed coat of some groundnuts may prevent germination by preventing water uptake or gas exchange, mechanically restraining the growth of the embryo, chemically inhibiting germination or acting as a barrier to photoreception (Hull, 1973).

2.6 Chemical composition of groundnut

Groundnut is an important oil seed crop and food grain legume. It contains about 50% oil, 25-30% protein, 20% carbohydrate and 5 % fibre and ash which make a substantial contribution to human nutrition (Fageria *et al*., 1997). Earlier report by Savage and Keennan (1994) reveal that groundnut contains 42 to 52% oil and 22 to 30% protein on a dry seed basis and is a rich source of minerals (phosphorus, calcium, magnesium and potassium). Reddy (1988) also indicated that the seed of groundnut contains 25-32% protein and the cake, the residue after oil extraction, 46-60% protein. Results of studies conducted by Asibuo *et al*. (2008) showed that the oil content range from 33.6 to 54.96% and that Virginia cultivars which belong to the subspecies *hypogaea* had higher oil content (49.7%) than the Spanish and Valencia market types, which belong to subspecies fastigiata (47.3%). They observed that the mean protein content of subspecies *fastigiata* was however higher (25.69%) than subspecies hypogaea (22.78%). This conforms to previous composition studies in groundnut by Dwivedi *et al*. (1993), who also reported higher oil content on Virginia varieties than Spanish types.

Ranjit *et al*. (2007) reported that the oil content of groundnut differed significantly with the application of different levels of lime and that the lime level of 100% LR recorded higher oil content (48.5%) compared to other lime levels. The application of different levels of phosphorus influenced oil content and yield significantly. The results of Elshiekh and Mohamedzein (1998) showed that mycorrhizal inoculation and/or superphosphate significantly increased both oil and protein content of groundnut seeds. Gobarah *et al*. (2006) also stated that application of 60kgP_2O_5/fad with foliar spraying with 1.00g/L zinc resulted in the highest yields of seed, oil and protein. Khalil and Chughatal, (1982) found the following ranges: 92-200 mg Ca, 10- 343 mg Mg, 1.4-33.3 mg Na, 1150-1450 mg K per 100g in groundnut seeds.

2.7 Effect of phosphorus fertilization on growth and yield of groundnut

Phosphorus plays an important role in crop maturation, root development, photosynthesis, nitrogen fixation and other vital processes. As a major nutrient and in order of importance, phosphorus is second to nitrogen (Gervey, 1987).

Effect of phosphorus on root development is well established. In groundnut cultivation, smallholder farmers apply little or no phosphorus fertilizer. Sharma and Yaday (1997) reported that phosphorus plays a beneficial role in legume growth by promoting extensive root development and thereby ensuring a good yield. Balasubramanian *et al.* (1980)

observed in a fertility study that phosphorus application results in better nodulation and seed yield. Application of nitrogen and phosphorus fertilizers enhanced root development which improved the supply of other nutrients and water to the growing parts of the plants, resulting in an increased photosynthetic area and hence more dry matter accumulation (Prihar and Tripathi, 1989).

Imbalance in plant nutrition is one of the major constraints altering maximum crop yield under rain fed conditions. Islam and Noor (1982) reported that plants grown without P fertilizer had the lowest pod yield. Hossain *et al*. (2007) found that the application of nitrogen in combination with phosphorus significantly influenced nitrogen and phosphorus uptake by leaf, stem, seed, as well as the number of mature pods per plant, 100 seed weight and pod yield. Plants that received 60 kg N and P/ha had higher uptake of nitrogen, phosphorus and better morphological characters that eventually resulted in greater pod yield. The results also revealed that a good yield of (2417kg/ha) of groundnut could be harvested at 40-60 kg NP/ha. Rhodes (1983) reported that phosphorus application improved nodulation and seed yield of cowpea. El-Dsouky and Attia (1999) also attributed increased number and weight of nodules, nitrogen activity and groundnut yield to phosphorus fertilization.

Nasr-Alla *et al*. (1998) reported that increasing the rate of P and K as a single or combined application increased the number of branches per plant, yield of pods per plant and per hectare of groundnut. El- Habbasha *et al*. (2005) reported that increasing P levels increased each of leaves, and stem weight/plant, number of pods and seeds/plant, 100 seed weight, seed and oil yields, oil percentage, seed protein content as well as NPK contents.

Deshmukh *et al.* (1993) found that the application of Phosphorus fertilizer to groundnut increased protein content. Bhatol *et al.* (1994) also found that nitrogen fertilizer decreased the oil of groundnut while phosphorus fertilizers increased it.

Gobarah *et al*. (2006) also reported that increasing rate of phosphorus from 30 to 60 kg P_2O_5/ha significantly increased vegetative growth, yield and its components as well as seed quality; protein content and NPK percentages, while oil percentage did not reach an appreciable level by increasing the phosphorus rate.

2.8 Effect of calcium on growth and yield of groundnut

Among the secondary nutrients, calcium deficiency causes groundnut pegs and pods to abort and reduce yield, (Meena *et al*., 2007). Skelton and Shear (1971) stated that calcium is poorly translocated via the phloem of the gynophores and must be absorbed by the developing pod. Cox *et al*. (1982) concluded that calcium deficiency is the most common nutrient limiting groundnut yield on acid, coarse-textured soils in the USA. Gascho and Davis (1994) also stated that for groundnut production in acid soils, Ca is the essential element most commonly deficient. While the most important consequence of Ca deficiency for groundnut productivity occurs in the reproductive stages of development, some indication of Ca deficiency may be evident in the vegetative growth (Gascho and Davis, 1994). Walker *et al.* (1976) found that application of gypsum to soils low in calcium increased the percentage of oil in all peanut cultivars while nitrogen content was reduced. Megdoff and Bartlett (1980) reported that adsorption of a basic cation like calcium ion on the exchange complex will increase the availability of nutrients due to cation exchange. Davidson *et al*. (1983) reported that application of gypsum to groundnuts grown in Georgia increased germination and reduced aflatoxin content by 40%. Duangpatra (1987) found that seeds with high calcium and phosphorus content were high in germination percentage and seed vigour while seeds with high potassium were low in seed germination and vigor. Rahman (2006) observed that calcium significantly influenced plant height and that longest plants were obtained from the 150 kg/ha Ca whilst the shortest plants were from the control plot. The author also noted that calcium fertilization influenced the number of branches per plant significantly with the highest number of branches produced by the 150kg/ha Ca treatment. Rahman (2006) also found that calcium significantly affected all the yield attributes and quality up to 150 kg/ha and then declined. There was an increasing trend in qualitative characteristics like percentage of oil and protein content of groundnut with the increase in the level of calcium from 0-100 kg/ha. The study also showed that calcium had a positive effect on the number of mature pods per plant and shelling percentage (Rahman, 2006).

Murata (2003) reported that increasing Ca application rates increased the pH of the soil thereby eliciting positive effects on the growth and productivity of groundnut.

According to Bharati (2009) in groundnut planting it is recommended that the pegging zone be kept moist; this facilitates the uptake of calcium by pods and essential for seed development. The results of Gajanan *et al*. (1991) and Zhang and Zao (1995) revealed that when calcium was deficient, application of calcium gave small seed increase. Similar results were also obtained by Rahman (2006). Velasquez and Ramirez (1985) reported that calcium has a positive effect on shell of fruits and it increased weight of kernels.

The most readily available index of calcium deficiency is provided by the shelling percentage. Hartmond *et al*. (1993) reported a positive correlation between the percentage of locules that filled and shelling percentage; confirming the value of shelling percentage as an index of calcium deficiency.

CHAPTER THREE

3.0 Materials and Methods

3.1.0 Description of study area

Two field experiments were carried out at the Research fields of CSIR-Crops Research Institute at Fumesua ($01^{o}36'W$; $06^{o}43'N$) during the major and minor rainy seasons of 2009. Fumesua is in the semi-deciduous forest zone with elevation of 186m above sea level (ASL) and has a bimodal rainfall distribution.

In the semi-deciduous forest zone, the major rainy season starts in late March and ends in mid-July. There is a short dry spell from mid-July to mid-September followed by the minor rainy season from mid-September to mid-November. The mean annual rainfall is 1500mm. The mean minimum and maximum temperatures are $21^{o}C$ and $31^{o}C$ respectively. The mean annual relative humidity is about 60% at noon and 95% in the morning. The soil at the experimental site at Fumesua is ferric Acrisol (FAO/UNESCO legend, 1986).

3.1.1 Cropping history of study area

Both experiments were conducted in plots that had previously been planted to cowpea.

3.2 Soil sampling and analysis

Soil samples were collected from two depths (0-15cm and 15-30cm) for both experiments. Each sample comprised a composite of three sub-samples taken at random points per replication. Samples were air-dried, ground passed through a 2 mm sieve and stored in polythene bags for analysis.

Soil samples were analysed by standard laboratory procedures. Soil pH (1:2 soil/ water ratio was measured with a pH meter. Available phosphorus was determined using the Bray-1 method (Bray and Kurtz, 1945), organic carbon by the Walkey-Black wet dichromate method (Walkley and Black, 1934) and total nitrogen by the Kjeldahl digestion method (Bremner and Mulvaney, 1982). Exchangeable cations (Ca, Mg, K and Na) were estimated by spectrophotometry (Black, 1965).

3.3 Experimental design and Cultural practices

The experimental areas were ploughed to a depth of about 20cm 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 (row and hill) on plots 12 m^2(5m x 2.4m) giving a plant population of 222,000 plants per hectare. Planting was done on the 5th May, 2009 in the major rainy season and 20th September, 2009 in the minor season. A 2x2x3 factorial experiment laid in a randomized complete block design with three replications was used in the study. Two levels of phosphorus (0 and 40kg /ha P_2O_5) in the form of Triple Superphosphate and three levels of calcium (0, 100 and 200 kg/ha Ca) in the form of oyster shells were investigated. Phosphorus fertilizer was applied at sowing and oyster shell powder 40days after planting during peak flowering and onset of pegging. Weeds were controlled by hand hoeing at 3 and 6 weeks after planting and thereafter as and when necessary.

3.4 Data Collection

3.4.1 Crop growth parameters

Vegetative growth was assessed by measuring the following parameters:

Field emergence/germination percentage- Field emergence was assessed by counting the number of plant stands 2 weeks after planting in the two middle rows.

Days to 50% flowering- This was determined visually by counting the number of days when 50% of the plants from the experimental units had opened flowers.

Days to maturity-This was recorded when about 80% of the pods were mature. In each plot, 2-3 plants were uprooted and the number of matured pods indicated by the blackening of the internal shell wall with brownish yellow kernel testa according to Williams and Drexler (1981).

Number of branches per plant – The number of branches produced by the plants was determined by counting the number of branches on five tagged plants in the two middle rows at 1, 2 and 3 months after planting (MAP) and the mean expressed on per unit basis.

Number of leaves per plant- Determined by counting the number of leaves on 5 tagged plants in the two middle rows at 1, 2 and 3 MAP and mean recorded.

Plant height- Plant height was measured with a metre rule on 5 tagged plants of each plot. Height was measured from ground level to the topmost leaf axil of the main stem and the mean height was expressed in centimetres.

Dry Weight- Dry weight was determined from four plants harvested from the penultimate rows of the plot for destructive sampling at 4, 6, 8 and 10 weeks after planting. Plants were oven dried at 80^0C for 48 hrs and the dry weights were measured using an electronic weighing scale (Doran 7000, Doran scales Inc.). Mean dry weight per plant was recorded in grams.

Relative growth rate (RGR) - This was determined using the formula of Hunt (1978); to provide more informative comparison of relative performance of the plants. The RGR is expressed as:

$$\mathrm{RGR} = \frac{\mathrm{InW2} - \mathrm{InW1}}{\mathrm{T2} - \mathrm{T1}}$$

where W1 represented the dry mass of previous sampling and W2 the dry mass of the sample that followed. The corresponding times of sampling were represented by T1 and T2 respectively.

In = natural log.

3.4.2. Yield components and Yield/ha

Number of filled pods/plant- This was estimated by counting the number of filled pods from the five tagged plants harvested from the two middle rows and the mean recorded. **Number of empty pods**- The number of empty pods was assessed from the five tagged plants from the two middle rows. The pods were plucked and pressed with the fore-finger and the thumb. Those that produced a pop sound were counted as empty (unfilled) or pods without seeds.

100 seed weight – A random 100 dried seed was taken from the harvested bulk and weighed to the nearest 0.1g.

Shelling percentage - This is the ratio of the seed weight to the pod weight expressed as a percentage.

Pod yield (kg /ha) - Plants from the two middle rows were harvested, sun-dried and weighed to record pod yield per plot and then converted into pod yield (kg/ha) by using the formula :

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

Seed yield - The pods from the harvested plants from the two middle rows were shelled and the weight of the seed recorded at 12% moisture content and later converted using the formula:

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

3.5 Seed quality testing and biochemical analysis

3.5.1 Germination and vigor testing

The unshelled pods were sundried and put in paper bags and stored under ambient conditions in the open air in the farm house at CRI, Fumesua. The pods were shelled after three months for the major and one for the minor season trials and seeds were tested for seed quality.

Seed moisture content was measured by moisture meter (Wagtech International moisture tester DMC 500). Seeds were germinated according to the ISTA Rules (2007) for testing seeds. Sun-dried seed with moisture content between 6.8-9.4% moisture content stored in paper bags at ambient temperature for three and one month for the major and minor seasons, respectively, were tested for germination. 100 seeds were used for each of four replications (ISTA, 2007). The seeds were planted on sand in containers (55cmx 42cm) with two replications per container. Sand free of fungi, seeds and weeds was used. For every 1 litre of sand, 160ml of water was added and mixed thoroughly with a hand trowel. The four replications were then placed under optimal germination condition for the period specified in the rules. After 10 days the number of normal seedlings, abnormal seedlings and ungerminated seeds (Dead, fresh seed and hard seeds) were recorded according to ISTA (2007). Normal seedlings are those that show the capacity to develop into normal plants in the field when grown under favourable conditions. Seedlings with secondary infection but parent seed are not the source of infection. Abnormal seedlings- Are those that do not show the potential to develop into normal plants in the field under good soil conditions. These include badly damaged, deformed or decayed seedlings.

Fresh seed – Seeds that absorb water, become swollen but do not germinate. Hard seeds- These are seeds that do not absorb water at all. Hard seededness is a form of dormancy. Dead seeds are that show signs of contamination. Usually, soft, discoloured, frequently mouldy. The final germination percentage was calculated from the total number of normal seedlings from the first and final count. The first count was done after 5 days and the final count was made after 10 days. The first count was also used as a vigor indicator and the second count for determining germination ability. Speed of germination index (SGI) was calculated as described in the AOSA (2002) handbook on vigor as the following formula; SGI = Number of normal seedling (first count)/days to first count + Number of normal seedlings (final count)/ days to final count.

3.5.2 Nutritional Analysis

Oil content was determined by the standard soxhlet extraction procedure (AOAC, 1990) using petroleum ether by Soxhlet apparatus. Crude Protein content was determined using the Kjeldahl method (Bremner and Mulvaney, 1982) by measuring the total nitrogen content with the samples and then converting the figure to a total crude protein value by multiplication with conversion factor of 5.46 (Jones,1931). Available phosphorus was determined by spectrophotometric vanadium phosphomolybdate method (Motsara and

Roy, 2008), Calcium and Mg content of the kernels were determined by EDTA titration method (Motsara and Roy, 2008) and K by flame photometry.

3.6 Data analysis

Data was subjected to analysis of variance (ANOVA) using Genstat Release version 7.2DE. Least significant difference (LSD) test was used to determine difference in means. Regression and correlation analyses were also explored to examine the relationships between parameters.

CHAPTER FOUR

4.0 Results

4.1 Soil analysis of experimental site

The results of the soil analysis at the experimental site are presented in Table 4.1. Percent organic carbon, organic matter, total nitrogen and exchangeable cations (K, Na etc) were higher at the depth of 0-15cm than 15-30cm. The cation exchange capacity (CEC) at 015cm and 15-30 cm were 9.76 and 6.07 respectively. Calcium content ranged from 26% to 33% in the 0-15cm to 15- 30cm soil depth respectively. The pH ranged from 4.96 to 5.25. The topsoil consisted of 82% sand, 10.7% clay and 7.3% silt whilst the subsoil had
75.3% sand, 19.3% clay and 5.3% silt. The soil type was sandy-loam.

Table 4.1: The initial Physical and chemical properties of the experimental soil in 2009

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

4.2 Weather data during the growing periods

The total rainfall distribution for the growing period of 2009 during which the experiments were conducted is shown in Table 4.2. Total rainfall recorded in the major season (993.3mm) was 361.3 % higher than in the minor season (215.3 mm). June recorded the highest rainfall amount (533.7 mm) and highest number of rain days (16) in the major season. The least amount of rainfall (20.2mm) and number of rain days was recorded in August. In the minor season, the highest amount of rainfall (112.6mm) and number of rain days (14) was recorded in October whilst December had the least rainfall amount and number of rain days. Air temperature ranged from 21.1^oC to 31.4^oC in the major season and 22^oC to 32.9^oC in the minor season. Relative humidity recorded was between 86% and 91% in the major season and between 77% and 88.8% in the minor season.

Table 4.2: Temperature (^0C), relative humidity (%), total rainfall (mm) and number of rainy days at Fumesua in 2009.

Month	Temperature (^{o} C)		Relative Humidity (%)	Total rainfall (mm)	Rain days
	Min	Max			
Major season					
May	22.9	31.4	86.0	194.5	10
June	22.2	30.0	91.0	533.7	16
July	21.8	28.3	90.6	244.9	11
August	22.1	27.3	90.4	20.2	5
Total				993.3	42
Minor season					
September	22.0	29.2	88.8	69.7	8
October	22.3	31.1	88.8	112.6	14
November	22.2	31.8	86.6	26.3	6
December	22.2	32.9	77.1	6.7	3
Total				215.3	31

Source: CSIR- FORESTRY RESEARCH INSTITUTE OF GHANA (FORIG).

4.3 Percentage field emergence 2 weeks after planting

The two varieties differed significantly ($P < 0.001$) in percentage field emergence during the major rainy season. The local check, Shitaochi had the highest percent field emergence (89.77%) whereas the improved variety had the lowest (70.22%). The application of phosphorus fertilizer in the form of Triple Superphosphate (TSP) did not significantly affect the field emergence of the two varieties. However, the interaction of variety and phosphorus levels was significant ($P \leq 0.05$). No significant difference was observed between the two varieties in mean percentage field emergence in the minor season. The application of phosphorus fertilizer did not significantly affect the percentage emergence in the minor season.

Table 4.3: The effect of phosphorus fertilization and variety on the percent field emergence of the two groundnut varieties at 2 WAP during the major rainy season (2009)

	Percentage field emergence		
Variety	Phosphorus level (kg/ha)		Mean
	0	40	
Nkosour	69.71	70.72	70.22
Shitaochi	92.66	86.89	89.78
Mean	81.2	78.8	
LSD (0.05)	Variety = 2.93; Phosphorus = 2.93; Variety x Phosphorus = 4.15		
CV (%)	5.3		

4.4 Mean days to flowering and maturity

A significant ($P \leq 0.05$) difference was observed between the two varieties in mean number of days to 50% flowering in the major season (Table 4.4). The improved variety Nkosour took a longer time to produce flowers (27 days) compared to the local check Shitaochi (25 days). The application of phosphorus fertilizer did not affect the number of days to flowering. Nkosour which took more days to produce flowers also took the longest number of days to reach maturity (109.3) compared to Shitaochi which matured much earlier (92 days).

Highly significant ($p < 0.001$) differences were observed between the two varieties with the application of phosphorus in mean number of days to flowering and days to maturity in the minor season. Again the improved variety Nkosour took a longer time to produce 50% flowers (29 days) and matured in 113 days whilst the local check, Shitaochi took shorter time for plants to produce flowers (25days) and matured after 89 days (Table 4.5). Application of phosphorus reduced the number of days to flowering but increased the number of days to maturity in the minor season.

Table 4.4: Mean number of days to flowering and maturity as affected by groundnut variety in the major (wet) season

Variety	Days to flowering	Days to maturity
Nkosour	27.00	109.00
Shitaochi	25.00	92.00
Mean	26.0	100.0
LSD (0.05)	0.22	1.93
CV (%)	1.2	2.8

Table 4.5: Mean number of days to flowering and maturity as affected by groundnut variety in the minor season

Variety	Days to flowering	Days to maturity
Nkosour	30.00	113.00 Shitaochi
25.00	89.00	
Mean	27.00	101
LSD (0.05)	0.49	3.47
CV (%)	2.6	1.3

4.5 Plant Height

In general significant differences were observed in plant height between the varieties at the various months after planting in the major season. The local variety had taller plants of 49.1 cm at 3 months after planting (MAP) whilst the improved variety Nkosour had the shortest plants (30.2 cm) at 3 MAP. The application of phosphorus significantly affected plant height at 1, 2 and 3 months after planting (MAP). In both groundnut varieties, plants with phosphorus application (40 kg ha^{-1} P_2O_5) were significantly taller than those without phosphorus fertilizer (Table.4.7). At 2 and 3 months after planting, phosphorus application increased plant height by 17 and 14 % respectively. The application of calcium did not significantly influence plant height.

Variation in mean plant height due to variety was significant at the different months after planting except at 1 MAP (Table.4.8) in the minor season. The local variety had a higher plant height compared to the improved variety Nkosour at 1, 2 and 3 months after planting. No significant difference was observed in plant height due to the application of phosphorus or calcium in the minor season.

Table 4.6: Mean plant height of the two groundnut varieties at different months after planting in the major season

Variety	Plant height (cm)		
	1 MAP	2MAP	3 MAP
Nkosour	7.19	26.40	30.20
Shitaochi	12.27	45.10	49.10
Mean	9.73	35.70	39.70
LSD (0.05)	0.74	4.65	4.89
CV (%)	11.0	18.8	17.8

Table 4.7: Mean plant height of groundnut varieties as affected by phosphorus fertilization at different months after planting in the major season

Phosphorus Level	Plant height (cm)		
(kg ha^{-1})	1 MAP	2MAP	3 MAP
0	8.89	32.8	37.10
40	10.57	38.70	42.30
Mean	9.73	35.70	39.70
LSD (0.05)	0.74	4.65	4.89
CV (%)	11.0	15.8	17

Table 4.8: Mean plant height as affected variety at different months after planting in the minor season

Variety	Plant height (cm)		
	1 MAP	2 MAP	3 MAP
Nkosour	9.54	15.83	18.97
Shitaochi	13.99	28.23	35.57
Mean	11.76	22.03	27.27
LSD (0.05)	3.69	1.12	2.50
CV (%)	13.8	24.2	13.3

4.6 Number of branches per plant

There was no significant difference between the two groundnut varieties in the number of branches at one month after planting during the major wet season. At 2 months after planting, significant differences were observed among the varieties, phosphorus and calcium levels. Nkosour had a higher mean number of branches per plant (12.3) and Shitaochi had the least (5.8) (Table.4.9). The application of Triple Superphosphate as source of phosphorus fertilizer increased the number of branches by 13% in both varieties at 2 MAP. Calcium fertilization significantly ($P \leq 0.05$) influenced the number of branches per plant for both groundnut varieties. The 200 kg ha^{-1} Ca application had the highest number of branches per plant (9.5) whilst the 0 kg ha^{-1} Ca application produced the least number of branches per plant (8.5). Plants with 100 and 200kg ha^{-1} Ca had significantly higher number of branches than those without Calcium at 2 MAP. However, no significant difference was observed between the 100kg ha^{-1} Ca and 200Kg ha^{-1} Ca at 2 and 3 MAP (Table.4.10).

The results of the minor season show that phosphorus and calcium application did not influence the number of branches. However, significant difference was observed between the groundnut varieties in the number of branches. The improved variety significantly had a higher number of branches than the local variety Shitaochi at the different months after planting (Table 4.11).

Table 4.9: The mean number of branches per plant of the two groundnut varieties at different months after planting in the major season

Variety	Number of branches /plant		
	1 MAP	2 MAP	3 MAP
Nkosour	4.73	12.29	12.29
Shitaochi	4.61	5.83	5.93
Mean	4.67	9.06	9.04
LSD (0.05)	0.73	0.73	0.80
CV (%)	22.5	11.7	12.8

Table 4.10: The effect of calcium on number of branches per plant at 2 months after planting in the major season

Calcium levels ($kg\ ha^{-1}$)	Number of branches/ plant
0	8.33
100	9.35
200	9.50
Mean	9.06
LSD (0.05)	0.89
CV (%)	11.7

Table 4.11: Mean number of branches as influenced by variety at different months after planting in the minor season

Variety	Number of branches		
	1 MAP	2 MAP	3 MAP
Nkosour	5.17	7.36	7.50
Shitaochi	4.19	4.20	4.27
Mean	4.67	5.76	6.46
LSD (0.05)	0.39	0.52	0.34
CV (%)	12.3	13.0	7.5

4.7 Number of leaves per plant

Leaf number significantly ($p \leq 0.05$) differed with variety and phosphorus levels at one, two and three months after planting in the major rainy season (Table 4.12 and 4.13). Number of leaves increased rapidly from 1 MAP to 2 MAP and then declined at 3 MAP in both groundnut varieties. The improved variety Nkosour significantly produced more number of leaves at 1, 2 and 3 MAP than the local check, Shitaochi (Table 4.12). The application of phosphorus significantly increased the leaf numbers in both varieties at one, two and three months after planting (Table 4.13). Similarly in the minor season there was a significant ($p \leq 0.05$) difference in the mean number of leaves between the varieties at the different months after planting (Table 4.14). The improved variety Nkosour had significantly ($P \leq 0.05$) more number of leaves than the local check Shitaochi at 1, 2 and 3 months after planting in the minor season. The highest number of leaves was obtained by Nkosour at 3 MAP (108.5) whilst the local check Shitaochi had 38.2. No significant difference was observed in the number of leaves as a result of calcium or phosphorus application.

Table 4.12: Effect of variety on number of leaves in the major season

Variety	Leaf number		
	1 MAP	2 MAP	3 MAP
Nkosour	55.04	213.70	173.60
Shitaochi	33.74	62.90	55.90
Mean	44.39	140.80	114.80
LSD (0.05)	2.91	18.07	14.60
CV (%)	9.50	18.60	18.50

Table 4.13: Number of leaves of two varieties as affected by phosphorus fertilization in the major season

Phosphorus Level ($kg\ ha^{-1}$)	Leaf number		
	1 MAP	2MAP	3 MAP
0	42.76	127.70	105.00
40	46.53	153.90	124.50
Mean	44.39	140.80	114.80
LSD (0.05)	2.91	18.07	14.66
CV (%)	9.5	18.6	18.5

Table 4.14: Effect of variety on the number of leaves in the minor season

Variety	Leaf number		
	1 MAP	2 MAP	3 MAP
Nkosour	36.86	105.50	108.50
Shitaochi	29.47	43.70	38.2
Mean	33.16	74.60	73.35
LSD (0.05)	3.80	7.98	13.75
CV (%)	16.60	15.50	27.1

4.8 Mean dry weight and relative growth rate

Dry weight of the two varieties generally increased with time up to 8 weeks after planting and then declined in the major season (Table 4.15). The mean total dry weight of Nkosour was significantly higher than Shitaochi in all the weeks after planting. The dry weight was affected by calcium and phosphorus fertilization after 4 weeks after planting. Application of 40kg P ha^{-1} increased dry weight of groundnut by 10% at 8 weeks after planting (Fig. 4.1). Application of 100kgCa ha^{-1} and 200kg Ca ha^{-1} had significantly ($P \leq 0.05$) higher dry weight than the control at 6, 8 and 10 WAP (Table 4.16). The relative growth rate of Shitaochi (0.03gg^{-1} day) at 4 to 6 WAP was higher than Nkosour (0.02gg^{-1} day).

.

Table 4.15: Total dry weight as affected by variety at different weeks after planting in the major season

Variety	Dry weight (g)			
	4 WAP	6 WAP	8 WAP	10 WAP
Nkosour	36.44	48.97	234.8	156.9
Shitaochi	28.11	43.79	218.9	148.1
Mean	32.28	46.38	226.8	139.3
LSD (0.05)	2.98	2.96	13.48	12.62
CV (%)	13.4	9.2	8.6	12.3

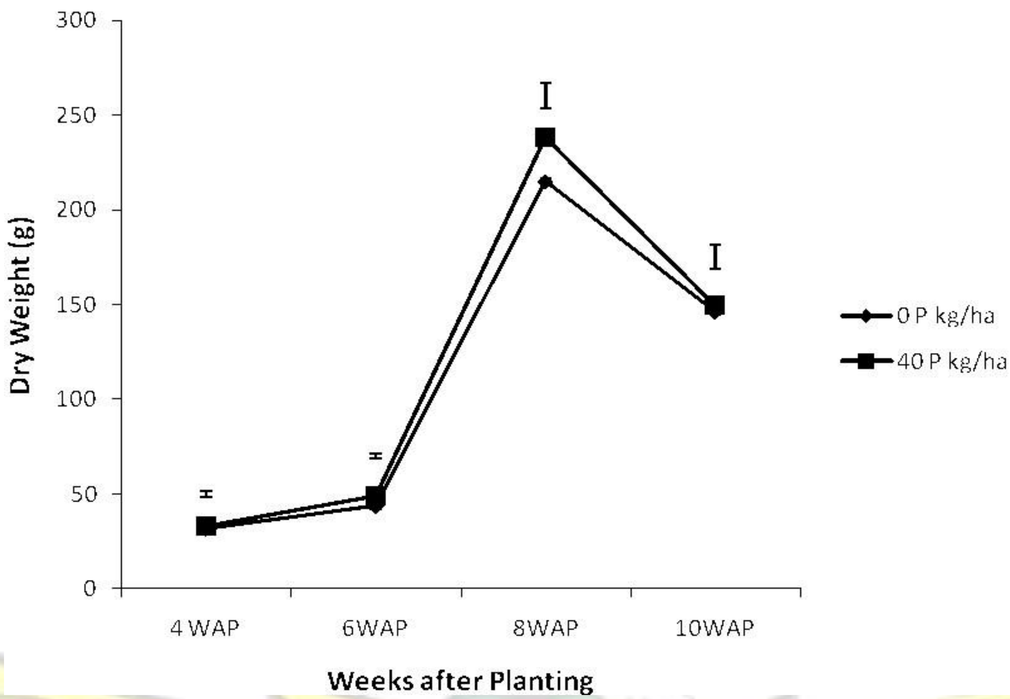


Fig 4.1: Effect of phosphorus application on the dry weight in the major season

Table 4.16: Effect of calcium on dry weight (g) of groundnut at different months after planting

Calcium levels (kg ha^{-1})	Weeks after planting			
	4 WAP	6WAP	8WAP	10 WAP
0	30.42	44.20	213.2	144.00
100	34.42	49.12	234.80	146.20
200	32.00	45.80	232.60	154.10
Mean	32.28	46.37	226.87	148.10
LSD (0.05)	3.62	3.65	16.51	15.45

CV (%)	13.4	9.2	6.8	12.3

Generally mean dry weight increased at different weeks after planting. At 4 and 6 WAP there was no significant difference in total dry weight between the two varieties in the minor season. There was a rapid growth rate from 6 to 8 WAP with Nkosour having a relative growth rate of 0.13 gg^{-1} day resulting in a significant difference between the two varieties. Shitaochi had a lower relative growth rate of 0.09 gg^{-1} day. From the 4 to 6 WAP, Nkosour had a relative growth rate of 0.03 gg^{-1} day whilst Shitaochi had a relative growth rate of 0.02 gg^{-1} day. Phosphorus application significantly ($P \leq 0.05$) influenced total dry weight at 6 and 8 WAP (Table 4.17). There was however, no significant difference in mean dry weight from application of calcium to the varieties.

Table 4.17: Effect of phosphorus on dry weight of groundnut genotypes in the minor season

Phosphorus levels (kg/ha)	Weeks after planting			
	4 WAP	6WAP	8WAP	10 WAP
0	10.04	13.11	61.80	52.70
40	10.96	15.11	78.90	54.30
Mean	10.50	14.11	70.30	53.50
LSD (0.05)	0 .75	1.31	12.65	7.54
CV (%)	10.3	13.5	26.0	20.4

4. 9 Number of pegs per plant

There were highly significant (P < 0.001) differences in mean number of pegs per plant during the major season independently between the two groundnut varieties and at the two phosphorus levels (P < 0.001). The improved variety had 46% more pegs per plant than the local check. The reproductive number viz; the number of filled pods and pegs per plant was higher in Nkosour (46.98) than Shitaochi (30.18). The application of phosphorus significantly increased the number of pegs by 52.4%. No significant difference was observed due to calcium application.

Table 4.18: The influence of variety on number of filled pods, unfilled pods and number of pegs per plant during the major season

Variety	Filled pod/plant	Unfilled pods	Number of pegs/plant
Nkosour	23.62	5.71	23.36
Shitaochi	17.67	5.18	12.51
Mean	20.65	5.44	17.94
LSD (0.05)	2.61	1.05	3.27
CV (%)	18.3	27.8	26.4

4.10 Number of filled and Unfilled pods per plant

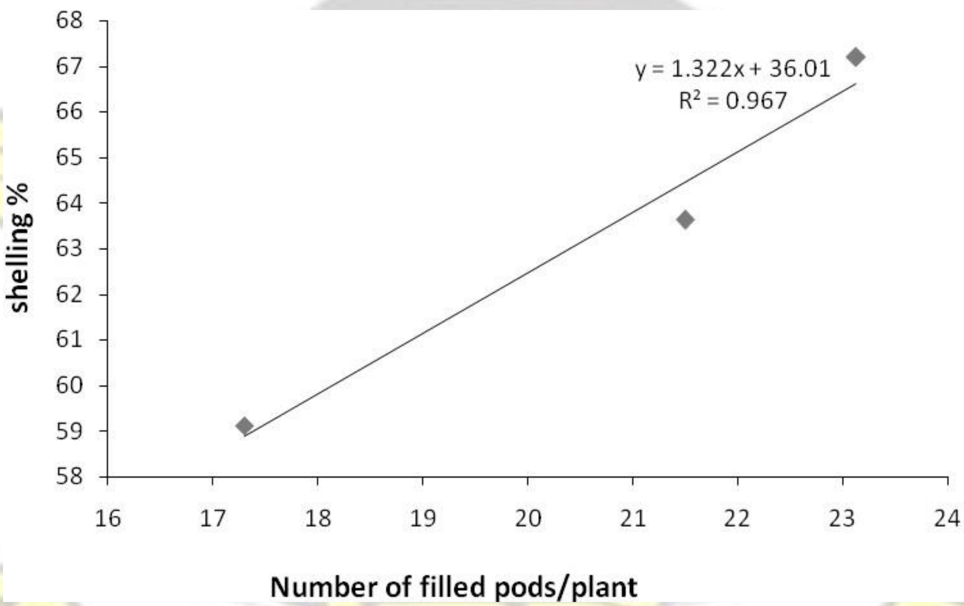
The two varieties differed significantly ($P \leq 0.05$) with respect to the number of filled pods/plant, during the major season (Table 4.19). No significant difference was observed between the varieties with respect to number of unfilled pods/plant. Application of phosphorus increased number of filled pods from 19.03 to 22.26 (17%).

Table 4.19: Effect of phosphorus fertilization (kg ha^{-1}) on number of filled and unfilled pods of the two groundnut varieties during the major wet season

P level	Filled pods/plant	Unfilled pods
0	19.03	4.96
40	22.26	5.93
Mean	20.65	5.44
LSD (0.05)	2.61	1.05
CV (%)	18.3	27.8

Calcium application had a positive effect on the number of filled pods per plant during the major season. The highest number of filled pods was obtained with 100kg Ca ha^{-1} in the major season which was similar to application with 200kg Ca ha^{-1}. The lowest number of filled pods was obtained with 0 kg Ca ha^{-1}. Calcium also significantly affected the percentage of filled pods. There was a positive relationship (R^2= 0.967) between the number of filled pods and the shelling percentage (Fig.4.2).

The results also show that the application of calcium significantly reduced the number of unfilled pods by 34% and 37% in the 100 and 200kg Ca ha^{-1} respectively



.

Fig.4.2: Relationship between number of filled pods and shelling percent

Variety significantly ($p \leq 0.05$) influenced the number of filled pods per plant in the minor season (Table 4.21). The local check Shitaochi had 14.9 % greater number of filled pods than the improved variety in the minor season. Conversely it had significantly ($p \leq 0.05$) less number of unfilled pods than the improved variety. The application of phosphorus fertilizer significantly affected the number of filled pods. The 40kg P ha^{-1} fertilizer application produced more filled pods (10.71) than the control (Table 4.21).

Calcium application had a positive effect on number of filled pods per plant in the minor season. There was a significant ($p \leq 0.05$) difference between the 100 and 200kg Ca ha^{-1} applications and the control. The highest percent of filled pods/plant was obtained with 100Kg Ca ha^{-1} which was similar to application with 200kgCa ha^{-1}. The lowest percent number of filled pods was obtained in the treatment with 0 kg Ca ha^{-1}(Fig.4.3).

Table 4.20: Effect of groundnut variety on number of filled and unfilled pods in the minor season.

Variety	Filled pods	Unfilled pods
Nkosour	8.99	14.56
Shitaochi	10.33	11.17
Mean	9.64	12.86
LSD (0.05)	0.85	2.41
CV (%)	12.7	27.1

Table 4.21: Number of filled and unfilled pod as affected by phosphorus fertilization in the minor season

Phosphorus level	Filled pods	Unfilled pods
0	8.58	12.94
40	10.71	12.78
Mean	9.64	12.86
LSD (0.05)	0.85	2.41
CV (%)	12.7	27.1

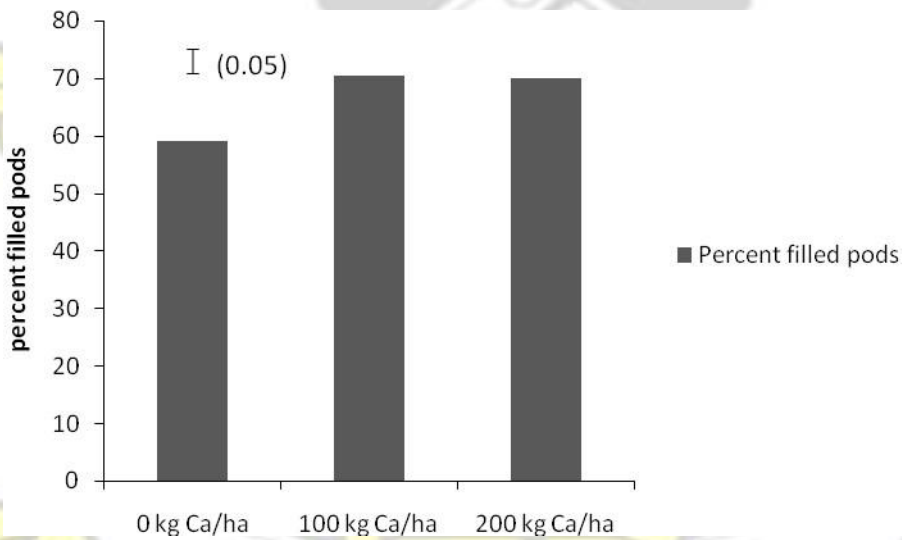


Fig. 4.3: Effect of calcium on percent filled pods on groundnut

4.11 100 seed weight and shelling percentage

No significant difference was observed between the groundnut varieties in 100 seed weight. Phosphorus fertilization exhibited a significant effect on 100 seed weight ($P \leq 0.05$). The control (without phosphorus fertilizer) had a mean 100 seed weight of 31.3g whilst the fertilized treatments had a mean 100 seed weight of 36.8, an increase of 17.6% over the control (Table 4.22). Phosphorus application also produced significantly higher 100 seed weight (30.44g) and shelling percentage whilst the control had the least 100 seed weight (28.12g) and shelling percentage in the minor season (Table 4.23).

The 100 and 200 kg Ca ha^{-1} applications significantly ($P \leq 0.05$) had higher 100 seed weight than the control. The application of 100 kg Ca ha^{-1} produced the highest 100 seed weight (37.2 g) whilst the control had the least (31.3g). Calcium application significantly ($P < 0.001$) affected the shelling percentage of groundnut in the major season (Table 4.24). The highest shelling percentage was obtained with 100 kg Ca ha^{-1} (67. 19) whilst the 0 kg Ca ha^{-1} had the least (59.12). The 100kg Ca ha^{-1} treatment had the highest 100 seed weight (30.5g) whilst the 0 kg Ca ha^{-1} had the least (28.0g) in the minor season. Shelling percentage also varied significantly with calcium application in the minor season. The highest shelling percentage was obtained with 200 kg Ca ha^{-1} similar to that obtained with 100kg Ca ha^{-1} (Table 4.25). Shelling percentage was also positively correlated to seed yield ($r = 0.77$), number of filled pods ($r = 0.64$) and pod yield ($r = 0.47$).

Table 4.22: Effect of phosphorus fertilization (kg/ha) on 100 seed weight and shelling percent of the two groundnut varieties during the major season

P level	100 seed wt	Shelling %
0	31.30	61.64
40	36.80	64.99
Mean	34.05	63.32
LSD (0.05)	4.32	2.32
CV (%)	18.4	5.3

Table 4.23: Effect of phosphorus fertilization on 100 seed weight and shelling percentage of groundnut in the minor season

Phosphorus level	100 seed weight	shelling percentage
0	28.17	57.74
40	30.44	62.89
Mean	29.31	60.32
LSD (0.05)	1.62	3.07
CV (%)	8.0	7.4

Table 4.24: 100 seed weight and shelling percentage of groundnut as affected by calcium fertilization during the major season

Calcium level Kg/ha	100 seed wt	shelling %
0	31.80	59.12
100	37.20	67.19
200	33.20	63.63
Mean	34.06	63.31
LSD (0.05)	4.57	1.28
CV (%)	18.3	27.8

Table 4.25: Effect of calcium fertilization on 100 seed weight and shelling percentage in the minor season

Calcium level	100 seed weight	shelling percentage
0	28.00	57.74
100	30.50	60.25
200	29.40	63.30
Mean	29.31	60.32
LSD (0.05)	1.18	5.31
CV (%)	8.0	8.0

The 100 seed weights of the two varieties were similar (Table 4.26). The results showed a highly significant difference in shelling percentage between the two varieties ($P < 0.001$). The local check had a significantly higher shelling percentage (13%) than the improved variety during the minor season (Table 4.26)

Table 4.26: Effect of groundnut variety on 100 seed weight and shelling percentage in the minor season.

Variety	100 seed weight	Shelling percentage
Nkosour	29.33	56.32

Shitaochi	29.28	64.12
Mean	29.31	60.32
LSD (0.05)	1.62	3.07
CV (%)	8.0	7.4

4.12 Seed and Pod yield

The results of the analysis show that variety and application of calcium had significant effect on seed yield. The improved variety, Nkosour significantly ($P < 0.001$) out-yielded the local check Shitaochi during the major season (Table 4.27). The seed yield of Nkosour (1944kg ha^{-1}) was 21% higher than the local check, Shitaochi (1605kg ha^{-1}). Calcium fertilization also significantly influenced seed yield. Plants treated with 100kg Ca ha^{-1} produced the highest seed yield (2065kg ha^{-1}) which was significantly ($P \leq 0.05$) different from the control but similar to that of 200kg Ca ha^{-1} (1881 kg ha^{-1}) (Table 4.28).

Calcium had a significant ($P< 0.001$) effect on the pod yield of groundnut (Table 4.28). In the major season the highest pod yield was obtained with the treatment 100kg Ca ha^{-1}, followed by 200kg Ca ha^{-1} both of which significantly differed from the control treatment (0kg Ca ha^{-1}). Groundnut pod yield response was also positively correlated ($R^2 = 0.877$) with the shelling percentage (Fig.4.4)

Application of 40kg P_2O_5 ha^{-1} significantly ($P < 0.001$) increased seed and pod yield of the two groundnut varieties in the major season by 29% and 23% respectively (Table 4.29).

Table 4.27: The influence of variety on yield of groundnut during the major season

Variety	Seed yield (Kg/ha ha^{-1},)	Pod yield (kg/ha ha^{-1},)
Nkosour	1944	3048
Shitaochi	1605	2536
Mean	1774.5	2792
LSD (0.05)	1831	300.2
CV (%)	14.9	15.6

Table 4.28: Seed and pod yield of groundnut as affected by calcium fertilization during the major season

Calcium level	Seed yield (kg/ha ha^{-1})	Pod yield (kg/ ha^{-1})

0	1378	2328
100	2065	3076
200	1881	2972
Mean	1775	2792
LSD (0.05)	224.2	367.6
CV (%)	14 .9	15.6

Table 4.29: The effect of phosphorus fertilization (kg ha^{-1}) on yield of the two groundnut varieties during the major season

P level	Seed yield (kg/ ha^{-1})	pod yield (kg ha^{-1},)
0	1550	2501
40	2000	3083
Mean	1775	2792
LSD (0.05)	183.0	300.2
CV (%)	14.9	15.6

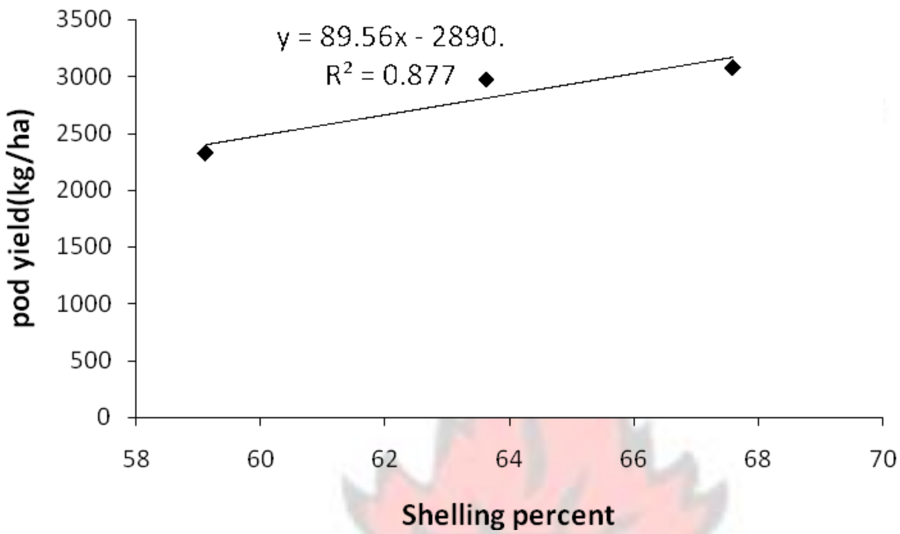


Fig.4.4: Relationship between shelling percent and pod yield of groundnut varieties

The two varieties differed significantly in seed and pod yield. The local check Shitaochi significantly out-yielded the improved variety Nkosour in seed and pod yield by 51 % and 24% respectively in the minor season (Table 4.30). Calcium also had a significant effect on the seed and pod yield of groundnut. The 100kg Ca ha^{-1} application produced the highest pod yield (1080kg ha^{-1}) whilst the 200 kg Ca ha^{-1} produced the highest seed yield (719kg ha^{-1}) (Table 4.31). There was no interaction among variety, calcium and phosphorus fertilization.

Table 4.30: The effect of groundnut variety on seed and pod yield in the minor season

Variety	Seed yield (kg ha^{-1})	Pod yield (kg ha^{-1})

Nkosour	503.00	874.00
Shitaochi	763.00	1084.00
Mean	633.00	979.00
LSD (0.05)	91.3	220.6
CV (%)	17.0	26.6

Table 4.31: Seed and pod yield of groundnut as affected by calcium fertilization during the minor season

Calcium level ha^{-1},	Seed yield (kg ha^{-1},)	Pod yield (kg ha^{-1}) Kg
0	521	816
100	659	1080
200	719	1041
Mean	633	979
LSD (0.05)	91.3	220.6
CV (%)	17.0	26.6

4.13 Seed moisture content, germination and vigour percentages

The results of the seed quality test revealed that calcium and phosphorus did not significantly influence the moisture content of the seed. Application of calcium and phosphorus fertilizer significantly affected the vigor and germinability of the seeds.(Table 4.32). Generally, seed vigor and germination percentages were higher in Shitaochi than Nkosour. The Shitaochi with 40P 100Ca ha^{-1} had the highest vigor percentage (78%) whilst Nkosuor without fertilization (control) had the lowest (49%). A similar trend was observed in germination percentage. Shitaochi with 40p100 Ca ha^{-1} fertilizer application had the highest germination percentage and speed of germination index (SGI) (88% and 24.32 respectively) whilst Nkosour without fertilizer application had the least germination percentage and speed of germination index. Significant ($p \leq 0.05$) differences were observed between the treatments that received Ca fertilization and those without in seed vigor of the two varieties but no significant difference between the 100kgCa ha^{-1} fertlizer application and the 200kg Ca ha^{-1} in the two varieties (Table 4.32). The vigor percent from application of 100 and 200 calcium fertilization were 38% and 42% higher than without fertilization in Nkosour. Application of 100Ca and 200Ca ha^{-1} in combination with phosphorus increased vigor by only 8.75% and 6.25% respectively in Nkosour.

The results of the minor season moisture tests also showed that there was no significant difference in moisture content among the different treatments. The mean vigour of the improved variety was significantly lower than the local check in the minor season ($P < 0.001$). Shitaochi with the 40kgP ha^{-1} in combination with 200kg Ca ha^{-1} gave the highest number of vigorous seedlings (80) but was not significantly different from the 100kgCa ha^{-}

[1]. The control had the least number of vigorous plants (26). Germination percentage and speed of germination index of Shitaochi were also higher than the improved variety Nkosour in the minor season experiment. The application of calcium tended to increase the germination percentage in both varieties (Table 4.33).

Table 4.32: Effect of Calcium and Phosphorus fertilization on Seed quality of two groundnut varieties grown in the major season and stored for 3 months

Treatment	Seed moisture content (%)	Vigour	Germination	Speed of germination index
Nkosour 0P 0Ca	8.80	49	57	15.53
Nkosuor 0P 100Ca	8.63	68	75	21.03
Nkosuor 0P 200Ca	8.53	70	72	21.23
Nkosuor 40P 0Ca	9.43	57	60	19.40
Nkosuor 40p 100Ca	9.28	66	77	20.85
Nkosuor 40P 200Ca	9.37	63	70	19.62
Shitaochi 0P 0Ca	8.43	55	74	18.45
Shitaochi 0P 100Ca	9.00	65	78	20.80
Shitaochi 0P 200Ca	8.17	69	78	21.52
Shitaochi 40P 0Ca	9.20	63	69	19.30
Shitaochi 40P 100Ca	9.00	78	88	24.32

Shitaochi 40P 200Ca	8.90	71	79	22.02
Mean	8.89	64	73	20.18
LSD(0.05)	0.28	4.86	4.89	1.18
CV (%)	1.8	5.3	4.7	4.1

Table 4.33: Effect of Calcium and Phosphorus fertilization on Seed quality of two groundnut Varieties Grown in the minor season and stored for one month

Treatment	Seed moisture content (%)	Vigour	Germination	SGI
Nkosour 0P 0Ca	6.86	26	33	8.40
Nkosuor 0P 100Ca	7.06	30	42	10.10
Nkosuor 0P 200Ca	7.23	31	49	11.05
Nkosuor 40p 0Ca	7.50	31	42	11.25
Nkosuor 40P 100Ca	7.23	35	52	12.18
Nkosuor 40P 200Ca	7.26	32	48	11.15
Shitaochi 0P 0Ca	7.33	65	72	20.20
Shitaochi 0P100Ca	7.40	71	76	21.82
Shitaochi 0P 200Ca	7.33	75	91	24.08
Shitaochi 40P 0Ca	7.23	80	91	24.95
Shitaochi 40P 100Ca	7.43	80	87	24.70

Shitaochi 40P 200Ca	7.10	74	88	23.65
Mean	7.25	52	64	16.88
LSD(0.05)	0.36	5.73	6.76	1.43
CV (%)	3.0	7.6	7.4	4.1

4.14 Abnormal seedlings, Hard and Dead seeds

The results also showed that Nkosour recorded the highest number of abnormal seedlings, hard and dead seeds than Shitaochi in the major season. Application of 100kg Ca ha^{-1} in combination with phosphorus decreased the number of abnormal seedlings in both varieties (Table 4.34). Nkosour without calcium and phosphorus fertilization had the highest number of abnormal seedlings and Shitaochi with 40 kgP $ha^{-1}$and 100 kgCa ha^{-1} had the least number of abnormal seedlings.

The results of the germination test in the minor season showed that Nkosour had the highest number of abnormal seedlings, hard and dead seeds. Nkosour without fertilization had the highest number of abnormal seedlings , dead and hard seeds (Table 4.35).

Table 4.34: Percentage of Abnormal seedlings, Hard and Dead seeds of two groundnut Varieties in the Major season germination test

Treatments	Abnormal seedlings	Hard seeds (tr)	Dead seeds(tr)
Nkosour 0P 0 Ca	40.00	3.25	3.26
Nkosour 0P 100 Ca	39.50	3.10	2.76
Nkosour 0P 200 Ca	48.50	2.33	2.86
Nkosour 40P 0 Ca	36.75	2.69	3.02
Nkosour 40P 100 Ca	29.25	2.99	2.67
Nkosour 40P 200Ca	34.75	2.57	2.90
Shitaochi 0P 0Ca	20.75	0.71	2.99
Shitaochi 0P 100 Ca	22.25	0.71	1.40
Shitaochi 0P 200 Ca	6.75	0.71	1.70
Shitaochi 0P 0 Ca	6.50	0.71	1.84
Shitaochi 40P 100 Ca	11.25	0.71	1.65
Shitaochi 40P 200 Ca	9.50	0.71	1.34
Mean	25.48	1.73	2.37
LSD (0.05)	6.50	0.36	0.54

CV (%)	17.8	14.7	16.0

Table 4.35: Percentage of abnormal seedlings, hard and dead seeds of two groundnut varieties in the minor season

Treatments	Abnormal seedlings	Hard seeds (tr)	Dead seeds(tr)
Nkosour 0p 0 Ca	35.5	1.32	2.37
Nkosour 0p 100 Ca	18.50	1.18	2.25
Nkosour 0p 200 Ca	22.00	1.47	2.13
Nkosour 40p 0 Ca	33.75	1.40	1.98
Nkosour 40p 100 Ca	19.75	1.05	1.40
Nkosour 40p 200Ca	25.76	1.18	1.34
Shitaochi 0p 0 Ca	24.25	0.71	0.70
Shitaochi 0p 100 Ca	19.75	0.71	1.05
Shitaochi 0p 200 Ca	21.75	0.71	1.27
Shitaochi 0p 0 Ca	28.50	0.71	1.40
Shitaochi 40p 100 Ca	11.25	0.71	1.40
Shitaochi 40p 200 Ca	18.75	0.71	1.56
Mean	23.29	0.98	1.56
LSD (0.05)	5.62	0.46	0.63

CV (%)	16.8	32.0	28.2

4.15. Oil and protein content

Significant differences were observed in the oil and protein content of the seeds of the different treatments ($P < 0.001$). Oil content ranged from 39.50% to 46.75%. The mean oil content of Nkosour (44.24%) was significantly higher than Shitaochi (41.8). Nkosour with 40kg P ha^{-1} combined with 100kgCa ha^{-1} produced the highest oil content (46.75%) whilst Shitaochi without fertilization produced the lowest oil content (Table 4.36). Crude protein content ranged from 20.34 to 23.31 %. Generally the protein content of treatments with phosphorus application had higher protein percentages than those without phosphorus application (Table 4.36). The mean protein percentage of the Nkosour (23.18%) with phosphorus application was significantly higher than Nkosour without phosphorus application (21.79%).

Table 4.36: Percentage Protein, Oil, Calcium, Phosphorus, Potassium and Magnesium content of two groundnut genotypes as affected by Calcium and Phosphorus fertilization in the major season

Treatments	Protein content	Oil content	Ca	P	K	Mg
Nkosour 0P 0 Ca	21.87	41.50	0.60	0.47	2.01	0.54
Nkosour 0P 100 Ca	21.88	44.50	0.60	0.54	1.95	0.65
Nkosour 0P 200 Ca	21.64	44.45	0.72	0.54	1.90	0.77
Nkosour 40P 0 Ca	23.31	43.00	0.72	0.60	2.08	0.61
Nkosour 40P 100 Ca	23.31	46.75	1.04	0.60	1.94	0.77
Nkosour 40P 200Ca	22.93	45.25	1.12	0.77	1.91	0.76
Shitaochi 0P 0 Ca	20.94	39.50	0.59	0.42	2.00	0.65
Shitaochi 0P100 Ca	21.44	42.45	0.72	0.32	2.24	0.72
Shitaochi 0P 200 Ca	21.87	41.50	0.96	0.33	2.24	0.84
Shitaochi 0P 0 Ca	20.55	41.50	0.76	0.88	1.82	0.79
Shitaochi 40P 100 Ca	21.43	42.95	0.79	0.83	2.09	0.77
Shitaochi 40P 200 Ca	21.85	42.95	0.99	1.34	2.11	1.00
Mean	21.84	42.97	0.79	0.62	2.02	0.74
LSD (0.05)	0.83	1.78	0.01	0.02	0.01	0.02
CV (%)	1.7	1.9	0.3	1.1	0.3	0.09

In the minor season nutritional analysis shows that there was significant variation among the treatments with respect to oil and protein content. The mean oil content of Nkosour was slightly higher than Shitaochi though not significant. The application of phosphorus fertilizer seems to increase the protein content of the seeds whilst calcium had an effect on the oil content (Table 4.37).

Table 4.37: Percentage Protein, Oil, Calcium, Phosphorus, Potassium and Magnesium content of two groundnut genotypes as affected by Calcium and Phosphorus fertilization in the minor season

Treatments	Protein content	Oil content	Ca	P	K	Mg
Nkosour 0P 0 Ca	20.44	44.50	0.21	0.43	1.94	0.42
Nkosour 0P 100 Ca	21.38	49.25	0.31	0.48	2.00	0.42
Nkosour 0P 200 Ca	21.44	48.25	0.28	0.44	1.95	0.40
Nkosour 40P 0 Ca	22.30	47.25	0.20	0.54	1.83	0.40
Nkosour 40P 100 Ca	22.74	47.50	0.27	0.54	1.84	0.41
Nkosour 40P 200Ca	22.74	50.00	0.23	0.54	1.74	0.37
Shitaochi 0P 0 Ca	22.74	45.00	0.20	0.59	1.92	0.36
Shitaochi 0P 100 Ca	22.74	46.75	0.22	0.65	1.91	0.38
Shitaochi 0P 200 Ca	23.62	47.25	0.24	0.67	1.94	0.36
Shitaochi 0P 0 Ca	21.88	48.00	0.33	0.69	1.82	0.38
Shitaochi 40P 100 Ca	21.88	50.50	0.40	0.65	1.81	0.35
Shitaochi 40P 200 Ca	21.88	48.75	0.36	0.74	1.80	0.40.
Mean	22.15	47.83	0.27	0.58	2.02	0.38
LSD (0.05)	1.35	3.03	0.03	0.06	0.01	0.01
C V (%)	2.8	2.9	5.0	4.8	0.03	1.7

4.16 Calcium and phosphorus content

Generally, Ca content of the seeds tended to increase with calcium application. Seeds of Nkosour with 40 kg P and 200 kg Ca ha^{-1} application had the highest Ca content (1.12%) whilst Nkosour 0kg P and 0 kg Ca ha^{-1} had the lowest Ca content (0.60%). However the mean Ca content of the two varieties were similar (0.80%) in the major season. There was a positive correlation between calcium content of the seed and the protein and oil content (r = 0.48 and 0.49 respectively). Phosphorus content ranged from 0.32 to 1.34%. Treatments with phosphorus application had higher P content than those without phosphorus fertilization in both varieties (Table 4.37). There was a weak relationship between phosphorus content and protein and oil content (r = 0.02 and 0.17 respectively). Calcium and phosphorus contents of the seeds also differed significantly among the treatments in the minor season. The treatment with 40 kg P ha^{-1} in combination with 100 kg Ca ha^{-1} produced seeds with highest calcium percentage whilst Shitaochi without fertilization had the least. Phosphorus content was higher in the Shitaochi than Nkosour in the minor season (Table 4.37).

4.17 Potassium and magnesium content

There were significant differences in K and Mg content among the treatments (Table 4.36). The relationship between calcium and potassium content of the seeds was negative in both the major and minor seasons. Generally, seeds with lower calcium content tended to have higher K content in their seeds. The K content of the seeds ranged from 1.82 to 2.24%. The Magnesium content of the seeds ranged from 0.54 to 1.00. There was positive correlation between calcium and magnesium content in the seeds (r = 0.70).

Significant differences were also observed in K and Mg content of the seeds from the different treatments in the minor season. The treatment 0 kg P ha^{-1} in combination with 100kg Ca ha^{-1} had the highest K content and magnesium content. The improve variety Nkosour had a higher Mg content in the seeds than Shitaochi (Table 4.37).

CHAPTER FIVE

5.0 Discussion

5.1 Soil physical and chemical properties

Soil analysis of the study area showed that the soil was sandy loam and slightly acidic (pH range of 4.9 -5.25). At these low pH levels, bacteria grow poorly while fungi thrive and organic matter does not readily accumulate. The low pH of the soil may be attributed to low levels of bases in the soil, since pH is largely determined by the amount of these bases. Similar observations were made by Murata (2003) who reported that smaller amount of bases in the soil resulted in low pH. In addition, the high acidity could also be attributed to the fact that, the field has been under continuous cropping coupled with the use of chemical fertilizers. The soil was low in phosphorus and exchangeable cations; Ca, Mg and K. The low Ca could be due to the low CEC and organic matter resulting in the inability of the soil to hold nutrients such as Ca, Mg and K. The cation saturation range of 26% to 33% is below the optimum range of 40% -80% for calcium suggesting a deficiency of Ca in the soil. In terms of the major nutrients, the fertility status of the soil at the site could be considered poor. The nutrient status of the soil implies that macronutrient deficiency could be the major limiting factor to crop growth.

5.2 Field emergence and establishment

The results of both the major and minor seasons indicated phosphorus fertilization had no significant effect on emergence. This could be attributed to the fact that the germination process is mainly controlled by the viability of the seed, adequate moisture, proper temperature and good soil aeration and not dependent on soil fertility. The embryo grows at the expense of stored food materials and did not require any external nutrition as reported by Khan *et al.* (2009). In both seasons, the percentage emergence of Shitaochi was higher than Nkosour. The relatively poor emergence of Nkosour in the major season could be due to the marked dormancy exhibited by subspecies *hypogaea*. This agrees with the observation made by Zade *et al*. (1986), who observed that seeds of some groundnut genotypes possess seed dormancy ranging from 30 to 360 days. The field emergence of the minor season was higher than the major season probably due to adequate moisture and warmth during the germination period.

5.3 Vegetative and Reproductive growth of groundnuts

Generally, the vegetative growth of the major season was better than the minor season. The plants of the first season were much taller and produced higher number of branches and leaves than the minor season plants. This could be due to the high rainfall during the major season. Misari *et al*. (1988) stated that groundnut requires 500–1600mm rainfall for its normal development. The major season rainfall data is in conformity with this requirement. The total rainfall of 215 mm in the minor season was too low for normal growth and development of the crop. Phosphorus application increased plant height and leaf number while the 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 significantly influence vegetative growth and the improved variety had a much poorer vegetative growth due to poor rainfall.

In both the major and minor seasons, slow early growth of the crops were observed which is similar to most crops due to limited leaf production and consequently low percentage of sunlight interception. Normally, rapid increase in crop growth rate occurs as the crop develops with its attendant increase in leaf area and subsequent increase in light interception. The application of phosphorus fertilizer increased 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 Yaday, 1997; Gobarah *et al*., 2006) and thus enabled the plants to absorb more water and nutrients from the soil. This in turn enhanced the production of more assimilates as reflected in the high biomass. Similar results have been obtained in previous studies (Tomar *et al*. 1990; El- Habbasha *et al*., 2005 and Gobarah *et al*., 2006).

The results of both major and minor seasons showed that the local variety Shitaochi, Spanish type produced flowers and reached maturity earlier than Nkosour, a Virginia type. The results are in conformity with 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 market types. The minor season plants took longer time to reach maturity probably due to water deficits during the pod formation stage resulting in a delay in establishment of a full pod load as a result of late flowering. Similar findings were reported by Boote *et al*. (1976) and Wright *et al*. (1991).

5.4 Seasonal and fertilization effects on yield and yield components of groundnut

5.4.1 Number of filled and unfilled pods

The improved variety had greater number of filled pods than the local variety Shitaochi in the major season probably due to adequate rainfall which facilitated the uptake of minerals. In the minor season, a reverse trend occurred with the local check producing more number of filled pods, probably due to its short growth cycle. Generally mean number of filled pods reduced by 114.7 % during the minor season, considering both varieties, which may be due to inadequate rainfall. Application of calcium and phosphorus fertilizers increased the number of filled pods in both seasons. Application of phosphorus fertilizer in combination with 100kg Ca ha^{-1} or 200kgCa ha^{-1} reduced the number of empty pods in both seasons. Smith (1954) found out that the proportion of empty segments in the developed pods increased from 18 to 47% under low Ca conditions. Similar results were also obtained by Rahman (2006). The results of the current study have confirmed that Ca application is desirable for good pod yield, seed quality and a higher number of filled pods.

5.4.2 Shelling percentage and 100 seed weight

The treatments with 100kg Ca ha^{-1} or 200kgCa ha^{-1} gave higher shelling percentages and 100 seed weight. The treatment with 100 kg Ca ha^{-1} application had the highest shelling percentage in both seasons. Rahman (2006) had observed that calcium application had a positive effect on the 100 seed weight and shelling percentage. The soil used in the current experiment was originally poor in P and Ca, and as such response to 40P in combination with 100 and 200 Ca applications were 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 the number of filled pods and shelling percentage. There was a positive relationship between the number of filled pods and shelling percentage, confirming the value of shelling percentage as an index of seed yield (Hartmond *et al*., 1993). The observations made by Hartmond *et al*. (1993) also indicated a positive correlation between the percentage of locules that filled and the shelling percentage. The 100 seed weight of the minor season crop was 16.2% lower than that of the major season. The low soil moisture due to low rainfall and high temperature might have affected dry matter accumulation leading to smaller seed sizes and yield.

5.4.3 Seed and pod yield

The seed and pod yields of the major season were higher than those of the minor season irrespective of fertilizer application. The lower yields obtained in the minor season could be attributed to the low rainfall and high temperatures. The total amount of rainfall recorded (215.3mm) was far below the optimum requirement for groundnut production.

According to Nageswara Rao *et al.* (1985), Wright *et al*. (1991) water deficits during pod filling period reduce pod and kernel weight. The rainfall data of the minor season conforms to this as the period of pod filling coincided with the period of water stress. Gadgil (2000) also observed that variation in groundnut yield arises to a large extent from the variation in total rainfall during the growing season.

During the major season, Nkosour had higher seed and pod yields than Shitaochi whilst in the minor season the reverse occurred. Cox *et al*. (1982) reported that pods of Virginia lines require a higher concentration of Ca in the soil for satisfactory yield than Spanish and Valencia types. The low yield of the Nkosour during the minor season could be attributed to the long maturity period of the variety; it may not have accumulated enough dry matter before the drought set in. The drought affected the availability and uptake of nutrients and water from the soil. Berringer and Taha. (1976) reported that large-seeded Virginia cultivars have frequently been shown to be more sensitive to drought-induced Ca deficiency than smaller seeded types. This is in agreement with the results of this study.

Application of Ca fertilizer affected yield in both seasons. The high yields obtained from the 100kg Ca ha^{-1} and 200 kg Ca ha^{-1} could have been due to increased cation exchange and pH of the soil which elicited positive effects on the growth and productivity of the groundnut (Murata, 2003).

Phosphorus application also positively affected the yield of groundnut in both seasons.
The control plots without phosphorus fertilization had the lowest seed and pod yields in both experiments. These observations are consistent with Islam and Noor (1982) who reported that groundnut plants grown without P fertilizer had the lowest pod yield.

5.5 Effect of season and fertilization on the seed quality of groundnut

5.5.1 Seed moisture content, germination and vigour percentage

The moisture content of groundnut seed was not affected by fertilization. The seeds of the major season had higher moisture percentage than those of the minor season. This could be due to the high relative humidity in the major season at the time of harvest and storage. These findings are in conformity with the report by El Tinay (1989) who found that moisture content of groundnut seeds was not affected by biological, chemical or organic fertilizers but rather by relative humidity of the surrounding atmosphere at the time of harvest and during storage. The local check, Shitaochi had higher vigour and germination percentages in both seasons after one and three month's storage. This could be attributed to its lack of dormancy as a Spanish type. Although the seeds of the second season had lower seed weight, they had higher vigour and germination percentages. On the contrary, Nautiyal (2009) reported that lower seed weight was insufficient in the supply of reserved food stored in cotyledons to ensure vigorous seedlings. The application of calcium and phosphorus fertilizers increased the vigour and germination in both seasons even for the Shitaochi with smaller seeds. The high number of seedling abnormality and hard seeds of Nkosour may be the result of dormancy which is characteristic of Virginia market types. Duangpatra (1987) reported that seeds with high Ca and P contents were high in germination and seed vigour, while seeds with high K were low in seed germination and seed vigour, which was similar to the results obtained in the present study.

5.5.2 Oil and protein content

Oil content of the varieties was in line with the observations of Asibuo *et al*. (2008) who reported that oil content of groundnut ranged from 33.6 – 54.95%. The higher oil content observed in Nkosour, a Virginia market type was in conformity with the results of Dwivedi *et al*. (1993) who observed that the Virginia cultivars had higher oil content than Valencia and Spanish cultivars.

Calcium application increased the oil content of the groundnut. The oil content of groundnut also differed with growing season and growing conditions as reported in earlier work (Holaday and Pearson, 1974; Young *et al*., 1974, and Brown *et al*., 1975). In the present study, similar results were found, where oil content differed with season and fertilization. The results also showed that phosphorus fertilization increased the protein content of the seeds in both seasons, as observed by Gobarah *et al*. (2006) and Desmukh *et al*. (1993).

CHAPTER SIX

6.0 Conclusions and Recommendations

6.1 Conclusions

This study was undertaken to determine the effect of phosphorus and calcium on the pod yield, seed and nutritional quality of two groundnut varieties in Ghana. Findings from the two experiments suggested that the use of oyster shell as a source of calcium offered an alternative source of calcium fertilizer for obtaining higher yield of groundnut in Ghana. From the study, the following conclusions can be made:

1. The application of 40kg P ha^{-1} in combination with 100kg Ca ha^{-1} improved the vegetative growth, pod yield and seed quality of groundnut.

2. Higher pod and seed yield can be obtained in the major season but for good quality seeds, high oil and protein content it is preferable to grow groundnut in the minor season.

3. The variation in flowering and maturity of the two varieties can be attributed to differences in their genetic make-up.

4. The high yield of Nkosour in the major season could be due to its ability to respond favourably to better soil fertility, moisture and crop management than Shitaochi.

5. Application of 100 kg Ca per hectare was as good as 200 kg per hectare. Farmers should apply 100 kg of Ca to reduce cost.

6. The seed and pod yields of groundnut in this study were determined largely by the number of pods per plant and were influenced by Ca and P application and the amount of rainfall in the growing season.

6.2 Recommendations

From the findings of these trials, it is recommended that;

1. The trials should be repeated in multi-locations to confirm the results of this study.

2. Late maturing varieties should be planted in the major season to take full advantage of the long growing season and early maturing varieties should be grown in the minor season since they can easily escape water stress because of their short life cycles.
3. Seed dormancy of Nkosour should be investigated further to determine its duration.
4. Pathological test be conducted to establish the cause of the high number of dead seeds in Nkosour.
5. The potential is there to increase yield and seed quality in the minor season under irrigation. I therefore recommend that fields designated for seed production in the minor season should be irrigated.

References

AOAC (1990). Association of Official Analytical Chemists, 15th edition.Washington, D.C pp.1298.

Asibuo, J. Y., Akromah, R, Adu-Dapaah, H. and O. Safo-Katanka (2008). Evaluation of nutritional quality of groundnut (*Arachis hypogaea* L.) from Ghana. *African Journal of Food, Agriculture, Nutrition and Development.* **8**(2): 133-150.

Asiedu, E. A, van Gastel, A. J. G and B. R. Gregg (2000). Extension agents technical crop guidelines for assisting seed producers in Ghana.p.9. Unpublished

Association of Official Seed Analysts (AOSA) (2002). Seed vigor testing handbook, No. 32. Association of Official Seed Analysts, Lab Crucas , N.M.

Atuahene-Amankwa, G.,Hossain, M. A. and M. A Assibi (1988). Groundnut production and improvement in Ghana. First ICRISAT Regional Groundnut Meeting for West Africa, Niamey, Niger. pp. 45 – 47 (ICRISAT).

Balasubramanian, V., Singh, L. and L. A. Nnadi, (1980). Effect of long-term fertilizer treatments on groundnut yield, nodulation and nutrient uptake at Samaru, Nigeria. *Journal of Plant and Soil*. **55 (2)**: 171-180. Springer Netherlands

Berringer, H. and M. A. Taha (1976). Calcium absorption by two cultivars of groundnut (*Arachis hypogaea* L.). *Experimental Agriculture*. **12,** 1-7.

Bharati (2009). Growth of groundnut plant. Posted by Shelly In: Production technology. Groundnut. Andra Pradesh, India. http://agropedia.iitk.ac. March, 2009

Bhatol, D. P, Patel, N. A. and R. P. Pavaya (1994). Effect of nitrogen, phosphorus and zinc application on yield and uptake of nutrients by groundnut. *Indian journal of Agricultural Research* **28**: 209- 213.

Black, C. A (1965). Methods of Soil Analysis . Part 2. Chemical and Microbiological properties. First edition. American society of Agronomy and soil Science Society of America. Madison, Wisconsin, USA.

Boote, K. J., Varnell, R. J. and W. G. Duncan (1976). Relationships of size, osmotic concentration and sugar concentration of peanut pods to soil water. *Proceedings Crop and Soil Science Society, Florida,* 35, 47 – 50.

Bray, R. H. and L. T. Kurtz (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Science*. **59**:39-45.

Bremner, J. M. and C. S. Mulvaney (1982). Total nitrogen. In: Page, A.L., Miller. R.H. and Keeney, D.R. (eds). Methods of soil analysis Part 2. Chemical and microbiological properties. American Society of Agronomy and soil Science of America, Madison, Wisconsin. Inc. pp.593 – 624.

Brown, D. F., Mattil, K. F. and J. G. Darroch (1975). Effect of variety, growing location and their interaction on the fatty acid composition of peanuts .*J. Food Sci*. 40: 1055-1060.

Caliskan, S., Caliskan, M. E., Arsian, M and H. Arioglu (2008). Effects of sowing date and growth duration on growth and yield of groundnut in a Mediterranean type environment in Turkey. *Field Crops Res*. **105 (1-2)**: 131-140.

Copeland, L. O. and M. B McDonald (2001). Seed vigor and vigor testing..In; *Principle of Seed Science and Technology*. 4thedition. pp 165-191. Kluwer Academic.

Cox, F. R. (1979). Effect of temperature on vegetative and fruit growth. *Peanut Science* **6**: 14-17

Cox, F. R., Adams, F. and B. B. Tucker (1982). Liming, fertilization and mineral nutrition. In: (H Pattee, H.E. and C.T. Young, eds. *Peanut Science and Technology*. American Peanut Research and Education Soc. Inc. Yoakum. TX.

Cummins, D. J (1986). Groundnut: The unpredicted legume. Production and constraints and research needs. In: *Agrometeorology of groundnut. Proceedings of an international symposium*. Sivakumar, M.V.K., Virmani, S.M., and Beckerman, S.R., (eds.). Pp 21-26 August, 1985.

Davidson *et al.* (1983). Effect of gypsum and calcium carbonate on plants. http.//www.fao.org/doCrept032e05.htm. Accessed 13 April 2010.

Deshmukh, V. N., Atre, A. H., Rangacharya, R. P. and S. S. Rewakar (1993). Effect of phosphorus and Potassium application on growth, yield, quality and nutrient uptake by groundnut. *Journal of Potassium Research* **9**: 72-75.

Duangpatra, J. (1987). Effect of Ca, Mg and S on seed yield and quality of some promising groundnut varieties. Groundnut improvement project phase 11 progress report for 1986. **99**: 44-49.

Dwivedi, S. L., Nigam, S. N, Jambunathan, R, Sahrawat K. L, Nagabhushanam, G and G.V.S.K. Raghunath (1993). Effect of genotypes and environments on oil content and oil quality parameters and their association in peanut (*Arachis hypogaea* L.). *Peanut Sci.* **20**: pp 84-89.

El-Dsouky, M. M. and K. K., Attia (1999). Effects of inoculation with phosphate solubilizing bacteria , organic manuring and phosphate fertilization on peanut grown on sandy calcareous soil. *Assiut j. agric. Sci.*, **30**: 177-188.

El-Habbasha, S. F., Kandil, A. A, Abu-Hagaza, N. S., Abdel-Haleem, A. K., Khalafallah, M. A. and T.G Behiary (2005). Effect of Phosphorus levels and some Biofertilizers on dry matter, yield and yield attributes of groundnut. *Bull.Fac.Agric.Cairo Univ*.**56:** 237-252

Elsheikh, E. A. E and E. M. M. Mohamedzein (1989). Effect of Bradyrhizobium, VA mycorrhiza and fertilizers on seed composition of groundnut. *Ann. appl. Biol.* (1998), **132:** 325-330.

El Tinay, A. H., Mahgoub, S. O., Mohamed, B. E. and M. A. Hamad (1989). Proximate composition and mineral and phytate contents of legumes grown in Sudan. *Journal of Food composition and Analysis* **2**: 69-78.

Fageria, N. K., Baligar, V. C. and C. Jones (1997). Growth and mineral nutrition of field crops 2nd Ed. Marcel Dekker, Inc, New York 1001 k, pp: 494.

FAO (2006). *Food Production Yearbook*. Vol. 60, Rome, Italy. http//apps.fao.org. Accessed 10 January 2009.

FAOSTAT (2008). Available at http://faostat.fao.org. Accessed 17 March 2009.

FAO/UNESCO legend (1986). Technical Paper1. Soil classification and characteristization, FAO, Rome.

Frimpong, A, Nyarko, G, Bayor, H and J. A Apeliga (2004). Effects of different seed treatment methods on the seedling vigor and biomass production of groundnuts in Ghana. *Pakistan journal of Biological Sciences* 7(6): 1024-1028.

Gadgil, S (2000). Farming strategies for a variable climate. An Indian case study, in: Proceedings of the international forum on climate prediction, agriculture and development, April 26-28, 2000, International Research Institute for climate prediction, New York, USA pp 27-37.

Gajanan, G. N., Shetty, Y. V. and M. A. Singlachar (1991). Response of groundnut to different levels of calcium saturation.*Current Res. Uni.Agric.Sci*. *Bangalore*. **20(5)**: 83-84.

Gascho, G. J and J. G. Davis (1994). Mineral nutrition. In: Smartt J. (ed.). *The groundnut crop. A scientific basis for improvement.* pp 214 – 254. Chapman and Hall. London SEI 8HN, U.K.

Gbehounou, G. and E. Adango (2003). Trap crops of *Striga hermonthica*: In vitro identification and effectiveness in situ. *Crop Prot*. **22(2**); 395-404.

Gervey, R (1987). *Fertilizer and Agriculture*. IFA Ltd. July 1987. 28 Rue Marberf. 75008. Paris. Pp 37 and 95.

Gobarah, M. E., Mohamed, M. H. and M. M. Tawfik (2006). Effect of phosphorus fertilizer and foliar spraying with zinc on growth, yield and quality of groundnut under reclaimed sandy soils. *Journal of Applied Science Research*, 2(80): 491496.

Gregory, W. C., Krapovickas , A and M. P. Gregory (1980). Structure, variation, evolution and classification in *Arachis*. Pp 409-411. In: *Advances in Legume sciences.* R.J Summerfield and A.H Bunting (eds). Royal Botanical Gardens , Kew.UK.

Hammons, R. O (1982). Origin and early history of Peanut. In: *Peanut Science and Technology*. H. E. Patee and C.T. Young, (ed.) pp. 1-20. American Peanut Res. Educ. Soc. Inc. Yoakum, Texas (Am. Peanut Res. Educ. Soc.)

Hammons, R. O (1994**)**. The origin and history of groundnut. In: J. Smart (ed.), *The Groundnut crop. A scientific basis for improvement*. New York, Chapman Hall, pp: 56- 78

Hartmond, U., Williams, J. H. and F. Lenz (1993). The influence of plant growth habit on calcium nutrition of groundnut (*Arachis hypogaea* L.). *Plant and Soil* 160: 113118.

Hogendons, J. S (1978). *Nigeria Groundnut exports origin and early development*. ABU Press Zaria, Nigeria pp 36.

Holaday, P. E. and J. L. Pearson (1974). Effects of genotype and production area on the fatty acid composition, total oil and total and total protein in peanuts. *J. Food Sci.* **39**: 1206-1209.

Hossain, M. A., Hamid, A. and S. Nasreen (2007). Effect of nitrogen and phosphorus fertilizer on N/P uptake and yield performance of groundnut (*Arachis hypogaea* L.). *J. Agric.Res*.,**45 (2)**: 119-127.

Hull, F. H (1973**)**. Inheritance of rest period of seeds and certain other characters in the peanut. *Fla Agric. Exp.Sta*. Bull., **314**: 1- 46.

Hunt, R (1978). *Plant Growth Analysis*. Edward Arnold, London, United Kingdom.

ICRISAT (1994). International Crop Research Institute for Semi-Arid Tropics. West African Programs Annual Report, 1994. Niger.

ICRISAT (2009). International Crop Research Institute for Semi-Arid Tropics Annual Report. Patancheru, India.

Ikisan (2000). Biological nitrogen fixation. In http.//www.Ikisan.com/links/ap.groundnut Nitrogen fixation.sht ml. Accessed 18 January 2010.

ISTA (2007). International Seed Testing Association. International Rules for Seed Testing. *Seed Sci. & Technology*. Edition 2007/1.

Islam, M. S. and S. Noor (1985). Performance of groundnut under different levels of phosphate fertilization in grey floodplain soil in Bangladesh. *Bangladesh J. Agric. Res*.**7**: 35-40.

Jones, D. B (1931). Circular No.183. U.S. Dep. Agric.

Khalil, J. L. and M. I. D. Chughatai (1982). Chemical composition and nutritional quality of five peanut cultivars grown in Pakistan. *Plant Food Hum. Nutr*. 33:63-70.

Khan, N, Faridullah, M.D. and I. Uddin (2009). Agronomic characters of groundnut (*Arachis hypogaea* L.) genotypes as affected by nitrogen and phosphorus fertilization under rainfed condition. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, **8(1)**: 61-68.

Krapovickas, A (1968). The origin, variability and spread of groundnut (*Arachis hypogaea* L.) In: *The domestication and exploitation of plants and animals.* Ucko, P.J. and G.W. Dembleby (eds.) Duckworth, London, U.K. Pp 424-440.

Larinde, M (1999). Groundnut seed multiplication and constraints. FAO's experience, In: Aliyu, A and G.O.N Watfor (Ed.). Restoring the status of groundnut in National economy. Proceedings of the national Workshop on groundnut rehabilitation in Nigeria . FAO/ FDA Kano, Nigeria, 11-12 May. Pp: 23-34.

Marfo, K. O., Denker, N. N., Adu- Dapaah, H. K., Asafo Agyei, B., Marfo, K. A., Adjei, J and J. Haleegoah (1999). Groundnut Production in Ghana. Proceedings of a national workshop on groundnut aflatoxins, Kumasi. Ghana pp 11-16.

McDonald, M. B (1980). Assessment of seed quality. *Hort.Science* **15**: 784-788

Megdoff, F. R. and R. J. Bartlett (1980). Effects of liming acid soils on potassium availability. *Soil Science*, **129:** 12-14.

Meena, S., Malarkodi, M. and P. Senthilvalavan (2007). Secondary and micronutrients for groundnut. A review. *Agricultural Reviews* .**28**(4): 1 (Abstract).

Misari, S. M., Boye, G. S and B. K. Kangama (1988). Groundnut Production management and utilization in Nigeria : Problems and prospects. First ICRISAT Regional Groundnut meeting for West Africa, Niamey, Niger. Pp 61-64.

Motsara, M. R. and R. N. Roy (2008). Guide to laboratory establishment for plant nutrient analysis. FAO communication Division, Rome Pp 3-112

Murata, M. R (2003). The impact of soil acidity amelioration on groundnut production on sandy soils of Zimbabwe. Thesis submitted in partial fulfillment for the degree PhD Plant production Agronomy . University of Pretoria.

Murata, M. R., Zharare, G. E, and P. S Hammers (2003). pH of the pod –zone affects reproductive growth of groundnut. *Journal of Plant Nutrition* (**31)**: 69-79.

Murty, U. R., Rao, N. G. P., Kirti, P. B. and M. Bharati (1980). Fertilization in groundnut. *Arachis hypogaea L. Oleagineux*, **36**: 73-76.

NAES (1994). Annual Report. Nyankpala Agricultural Experimental Station, pp: 4-14.

Nageswara Rao, R. C., Singh, S., Sivakumar, M. V. K., Srivastava, K. L. and J. H. Williams (1985). Effect of water deficit at different growth phases of peanut. I. Yield responses. *Agronomy Journal* **77**: 782-786.

Nasr-Alla, A. E., Osman Fatima, A. A. and K. G. Solima (1998). Effect of increased Phosphorus and Potassium or Sulphur application in their different combinations on yield, yield components and chemical composition of Peanut in a newly reclaimed sand soil. *Zagazig J. Agric. Res.*, **30**: 335-358.

Nautiyal, P. C (2009). Seed and seedling vigour traits in groundnut (*Arachis hypogaea* L.). *Seed Science and Technology*. 32 pp. 721-735(15). ISTA.

Nigam, S. N., Vasudeva Rao, M. J and R. W. Gibbons (1990). Artificial Hybridization in groundnut. ICRISAT Information Bulletin no. 29. Patancheru, Andra Pradesh 502 324, India.

Nigam, S. N., Upadhayaya, H. D., Chandra, S., Nageswara Rao, R. C, Wright, G. C. and A.G.S. Reddy (2001).Gene effects for specific area and harvest index in three crosses of groundnut (*Arachis hypogaea* L.) *Annals of applied biology*. **39(3**): 301-306.

National Peanut Council (1990). Peanut Industry Guide 1990-1991. The Peanut farmer, 26(8): 270.

Ntare, B. R, Diallo, A. T, Ndjeunga, A. T and F. Waliyar (2008). Groundnut Seed Production Manual. Patancheru 502324, Andhra Pradesh, India. International Crops Research institute for the Semi-Arid Tropics (ICRISAT). 20pp.

Nwokolo, E (1996). Peanut (*Arachis hypogaea* L.). In*: Food and feed from legumes and oilseeds*, E.Nwokolo and J. Smartt , Eds. Pp 49- 63. New York. Chapman and Hall.

Owusu-Bennoah, E (1997). Review of indigenous fertilizer resources of Ghana. Proceedings of the 14th and 15th Annual General Meetings of the Soil Science Society of Ghana, November, 1997, Kumasi.

Pande, S, Bandyopadyhay, R., Blummel, M., Narayana Rao, J., Thomas, D. and S. S Navi (2003). Disease management factors influencing yield and quality of sorghum and groundnut crop residues. *Field Crops Research*. **84 (1-2**): 89-103.

Perry, D. A. (ed.) (1981). *Handbook of vigour testing methods*. International Seed Testing Association, Zurich.

Poehlman, J. M (1991). *The Mungbean*. Oxford and IBH Publishing Co.Pvt. Ltd.,New Delhi,India..

Prihar, S. S and R. S. Tripathi (1989). Dry matter, nodulation and nutrient uptake in chickpea as influenced by irrigation and phosphorus. *Expt. Agric*. **25**: 349 - 355.

Purseglove, J. W (1988). *Tropical crops*. Dicotyledons, Longman. London. Pp.196-232.

Rahman, M.A (2006). Effect of Calcium and Bradyrhizobium inoculation of the Growth, Yield and quality of groundnut (*A. hypogaea* L*.). Bangladesh J.Sci. Ind. Res*. **41(3-4**), 181-188.

Ramanatha Rao, V (1988). Botany. In: *Groundnut* (Reddy, P.S., ed.). Indian council of Agricultural Research, New Delhi, pp. 24-64

Ranjit, R, Dasog, G. S, and P. L. Patil, (2007). Effect of lime and phosphorus levels on the pod , Haulm and oil yield of two groundnut genotypes in acid soils of coastal

AgroEcosystem of Karnataka. *Karnataka Journal of Agricultural sciences*: **20(3)**: 627-630.

Reddy, L. J. and A. K. Kaul (1986). Status and prospects of groundnut in Bangladesh. *Bangladesh Agric. Res. Coun*., Dhaka, Bangladesh, pp. 1-51.

Reddy, P.S ed (1988). Groundnut. Publication and information division, Indian council of Agriculture Research. Krishi Anushandan Bhavan, Pusa, New Delhi.

Rhodes, E. R (1983). Tropical Grain legume. Bulletin no. 27, 1983. The International Grain Legume Centre, IITA, PMB 5320, Ibadan , Nigeria.

Sankar, A. S., Reddy, P. R. and I. V. S Rao (1984). Nodulation and nitrogen fixation in groundnut as affected by seed size and phosphorus. *Legume Research*.**7**: 1-5.

Savage, G. P and J. I. Keenan (1994). The composition and nutritive value of groundnut kernels. In: Smart J(ed.). *The groundnut Crop: A scientific basis for improvement*: Chapman and Hall. London, pp 173-213.

Sharma, B. M and J. S. P Yaday (1997). Availabilty of phosphorus to grain as influenced by phosphatic fertilization and irrigation regimes. *Indian J. Agric Sc*. **46**: 205210

Singh, F. and D. L. Oswalt (1995). Groundnut Production Practices. Skill Development series No. 3. ICRSAT Training and Fellowship Program International Crops Institute for the Semi- Arid Tropics, Patancheru, Andra Pradesh 502 324, India.

Skelton, B. J., and G. M. Shear (1971). Calcium translocation in the peanut (*Arachis hypogaea* L.). *Agronomy Journal*, **63**: 409-412.

Smith, B. W (1954). *Arachis hypogaea*, reproductive efficiency. *American Journal of Botany*, **41**, 607 – 616.

Spears, J. P., Jordan, D. C and J. E Barley (2002). Peanut seed production. A guide for producers of Virginia type peanut seed. N.C Coop. Ext. Serv. Bull. AG- 662 pp 1-7.

Taru, V. B, Khagya, I. Z, Mshelia, S. I and E. F. Adebayo (2008). Economic efficiency of resource use in groundnut production in Adamawa State of Nigeria. *World Journal of Agricultural Science* 4(s) 896-900.

Tekrony D. M. and D. B. Egli (1977). Relationship between laboratory indices of soybean seed vigor and field emergence. *Crop Sci*. **17**: 573-577.

Teng, W, Zhai, Y, Du, Y, Sun, D., Zhang, Z., Qu, L, Sun, G and W. Li (2008). QTL analysis of seed weight during the development of soybean (*Glycine max* L. Merr.). Published online 29 October 2008 http:// nature.com/hyd/journal/v102/nu/full/hyd2008 108a.html.

Tomar, R. A. S., Kushwaha, H. S, and S. P. S. Tomar (1990). Response of groundnut (*Arachis hypogaea* L.) varieties to phosphorus and zinc under rain fed conditions. *Indian J. Agron*.**,** **35**: 391-394.

Tsigbey F. K, Brandenburg, R. L and V. A. Clottey (2003). Peanut Production Methods in Northern Ghana and Some Diseases Perspectives. Proceedings of Sod Based cropping system Conference. North Florida Research and Education Centre-Quincy University of Florida. pp 1-9

Upadhaya, H. D., Reddy, L.J., Gowda, C. C. L and S. Singh (2006) Identification of diverse groundnut germplasm: Sources of early maturity in a core collection. *Field Crops Res*. **97(2-3**): 261-271.

Velasquez, M. J. R. and R. Ramirez (1985). Effect of Ca localization on the soil on development and formation of groundnut fruit (*Arachis hypogaea* L.). *Agronomia- Tropical*. **35(4-6)**: 29-39.

Walker, M. E., Keisling, T. C and J. S. Drexler (1976). Response of three peanut cultivars to gypsum. *Agronomy Journal*, **68**, 527-528.

Walkley, A. and I. A. Black (1934**)**. An examination of Degtareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil. Science*. **37**: 29-37.

Weiss, E. A. (2000) .*Oilseed crops*. Blackwell Science. London

William, E. and D. S. Drexler (1981). A non-destructive method of determining peanut pod maturity. *Peanut Science*. **8**: 134-141.

Williams, J. H., Wilson, J. H. H., and G. C. Bate (1975). The growth of groundnuts (*Arachis hypogaea* L.cv. Makulu Red) at three altitudes in Rhodesia. *Rhodesian Journal of Agricultural Research*, **13**: 33-43.

Wood, I. M. W (1968). The effect of temperature at early flowering on the growth and development of peanut (*Arachis hypogaea* L.). *Australian Journal of Agricultural Research* **19**: 241-251.

Wright, G. C., Hubick, K. T. and G. D Farguhar (1991). Physiological analysis of peanut cultivar response to timing and duration of drought stress. *Australian Journal of Agricultural Research*, **42**: 453 – 470.

Young, C. T., Worthington R. E, Hammons, R. O., Matlock, R. S.,Walker, G. R. and R. D Morrison (1974). Fatty acid composition of Spanish peanut as influenced by planting location, soil moisture conditions, variety and season. *J.Am.Oil Chem.Soc*.**51**: 312-315.

Zade, R., Deshmukh, S. N. and P. S. Reddy (1986). Magnitude of dormancy in the released Virginia group cultivars of groundnut. *Seed Res*., **14**: 235- 238

Zhang, E. and Y. Zhao (1995). A preliminary report on Ca levels in soils and the effect of Ca application on peanut. *Field Crop Abst*. **49(12)**: 1195.

Zharare, G. E., Blamey, F. P. and C. J. Asher (1998). Initiation and morphogenesis of Groundnut (*Arachis hypogaea* L.) pods in Solution Culture. *Annals of Botany* **81**: 391-396.