INFLUENCE OF WOOD ASH AS A SOURCE OF SUPPLEMENTAL CALCIUM ON GROUNDNUT (*Arachis hypogaea* L.) YIELD AND SEED QUALITY

BY

MARIAM SEIF LUGAILA

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE.

1999

ABSTRACT

Groundnut (*Arachis hypogaea* L.) has a peculiar calcium (Ca) requirement particulary for its development during the initial pegging and seed development. For this purpose supplemental Ca is usually recommended when a crop is grown on acid soils with low cation exchange capacity (CEC). To evaluate the influence of supplemental Ca on yield and seed quality of selected groundnut cultivars two field experiments were conducted at Sokoine University of Agriculture in Morogoro region during the months of February - May and April - August, 1998.

The experiment was laid out as a split - plot in a randomized complete block design with three replications. Three groundnut cultivars Baka, ICGV 86112 and Spancross were the main plots, while calcium levels 0, 60, 100, 140 kg Ca/ha obtained from wood ash and one treatment of 140 kg Ca/ha from hydrated lime were the sub plots. Each subplot had eight rows, 2 m long with in - row spacing of 10 cm.

The results show that there was significant ($P \leq 0.05$) cultivar effect on the number of filled pods per plant, seed size, seed yield per plant and seed diameter. Application of Ca had no significant effect on most of the variables analyzed. However, there was significant interaction ($P \leq 0.05$) between cultivar and Ca on seed yield per plant. The lack of response to Ca observed in this study suggests that there was no difference in Ca uptake among cultivars used. Significant interaction between cultivar and Ca level on seed yield per plant in experiment 2 suggests that cultivars used respond differently to applied Ca with respect to this character. Soil analysis at the end of each experiment indicated that the applied Ca levels had an increasing effect on soil pH and exchangeable Ca suggesting that wood ash may be used for liming acid soils.

DECLARATION

I, MARIAM SEIF LUGAILA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor concurrently being submitted for a degree in any other University.

Signed.............................

Date 23/9/1999

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ACKNOWLEDGEMENT

I wish to acknowledge with appreciation the Ministry of Agriculture and Co - operatives in Tanzania for granting me study leave. My special gratitude are to the Canadian International Agency (CIDA) through the Training Fund for Tanzanian Women (TFTW) under the Ministry of Community Development, Women Affairs and Children for granting me the scholarship.

I am most indebted to my supervisor Dr. C. L. Rweyemamu for his guidance, constructive criticism, encouragement and tireless assistance which made this study a success. My sincere thanks are to various members of the Department of Crop Science and Production at SUA for technical advise accorded to me during this research work, classmates are also highly appreciated for their co - operation during my stay at the University. I also owe debts of gratitude to Mrs E. Lazaro, Mr S.S. Kasele and Mr R.J. Temba who helped me during my study. My special thanks are due to my mother, brothers, sisters and brothers in law and their families for moral support.

I would also like to express my heartfelt thanks to my beloved husband Mr Ramadhani Lugaila, my dear daughters Halima and Rehema for their understanding, patience, love and moral support during the period I was engaged in the study.

Finally, I thank "Allah" for the courage and strength I had during the study period, AMEN.

DEDICATION

To my parents, the late Seif Salum and Rehema Abdallah who laid the foundation for my education.

My dear daughters, Halima and Rehema for their love and patience.

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LIST OF ABBREVIATIONS AND SYMBOLS

Al	Aluminium
ANOVA	Analysis of Variance
Ash	Wood ash
BNF	Biological nitrogen fixation
Ca	Calcium
$CaCO_3$	Calcium carbonate, Calcite and Limestone
($CaCO_3.MgCO_3$)	Dolomite
$Ca_3(PO_4)_2$	Calcium phosphate
$CaSO_4$	Gypsum
CEC	Cation exchange capacity
CIDA	Canadian International Development Agency
cm	centimetre
cm^3	centimetre cubed
cmol	centimol
CORR	Correlation
Cu	Copper
CV	Coefficient of variation
DAS	Days after sowing
DMRT	Duncan's Multiple Range Test

EC	Emulsifiable concentrate
e.g.	for example
ET	Evapotranspiration
FAO	Food and Agriculture Organization
g	gram
GRAV	Groundnut rosette assistor virus
GRV	Groundnut rosette virus
ha	hectare
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
ICGV	Groundnut line released at International Crops Research Institute for the Semi Arid Tropics
ICRISAT	International Crop Research Institute for the Semi – Arid Tropics
i.e.	That is
K	Constant
K	Potassium
kg	kilogram
L	Average length
l	litre

LA	Leaf area
LAI	Leaf Area Index
Lime	Hydrated lime
m^2	square metre
MALDC	Ministry of Agriculture Livestock Development and Co –operative
m.a.s.l	metre above sea level
Max	Maximum
Min	Minimum
Mg	Magnesium
mg	milligram
MJ	megajoules
mm	millimetre
ml	millilitre
Mn	Manganese
Mo	Molybdenum
MRTC	Mvumi Rural Training Centre
MRP	Minjingu rock phosphate
MSU	Michigan State University
N	Nitrogen

n	Number of leaves per plant
Na	Sodium
NBF	Nitrogen bacteria fixation
NH_4^+	Ammonium ion
No.	Number
NRI	Natural Resource Institute
ns	Not significant
°C	Degrees Celsius
OC	Organic carbon
P	Phosphorus
$P \leq 0.05$	Significant at less or equal to 5% level
PNUTGRO	Peanut crop growth simulation model
ppm	parts per million
%	Percent
R	Reproductive growth stage
R_1	50% of the plants with at least one open flower
R_2	50% of plant begin to peg
R_3	50% of the plants begin to pod
R_4	Full pod size growth stage
R_5	Beginning to seed

R_6	Full pod size growth stage
R_7	Beginning to mature
R_8	Harvest maturity
r	Sample correlation coefficient
RCBD	Randomized complete block design
RNA	Ribo nucleic acid
*	Significant at 5% level
**	Significant at 1% level
S	Sulphur
SA	Sulphate of ammonia
SADC	Southern Africa Developing Countries
SE	Standard error
SIDA	Swedish International Development Agency
SMKs	Sound mature kernels
SSP	Single super phosphate
SUA	Sokoine University of Agriculture
TANSEED	Tanzania seed company
TARO	Tanzania Agricultural Research Organization
TDM	Total dry matter
TFTW	Training Funds for Tanzania Women

Tsh	Tanzanian shilling
TSP	Triple super phosphate
UNESCO	United Nations, Education and Culture Organization
URT	The United Republic of Tanzania
USA	United State of America
USDA	United State Department of Agriculture
W	Width
Zn	Zinc

CHAPTER ONE

1.0 INTRODUCTION

The groundnut (*Arachis hypogaea* L.) is known by a number of names, that includes peanut, earthnut, monkey, pinder, or zoober in English and *Karanga* in Kiswahili (Fageria *et al.*, 1997). Groundnut is one of the most important oil seed crops, which is widely grown in Tanzania. Small holders predominantly carry out production of groundnut. Nutritionally, groundnut is a good source of protein and fats (MALDC, 1990). Also, it provides a high quality cooking oil and residues can be used as animal feed (Owen and Ireri, 1990). Groundnut seeds contain 25 - 30 % protein, about 50 % oil, 20 % carbohydrate, and 5 % fibre and ash. Properties of groundnut oil are determined by fatty acid composition (Fageria *et al.*, 1997). Although many studies conducted by various researchers have identified genetic differences in fatty acid composition in groundnuts, most have shown a limited number of genotypes (Knauft and Wynne, 1995).

Further, groundnut is beneficial to farmers when intercropped with cereals such as maize, millet and sorghum, as it contributes to soil enrichment and nitrogen economy through symbiotic N fixation (Marschner, 1995). Being a legume, the crop grows rapidly and vigorously to cover the soil, thus minimising exposure of soil to risk of soil erosion and nutrient leaching (MRTC, 1994), reduces weed infestation and checks the build up of insect pests and diseases when included in a crop rotation and intercropping systems

(Kafiriti, 1994). Farmers can sell groundnut in the local market and increase their disposable income (MALDC, 1990). In 1988/1989 season farmers sold 1 240 tonnes of groundnuts to General Agricultural Products Export corporation (GAPEX) then official Marketing Agency and Co-operative Unions (URT, 1993). At national level the crop is a good source of foreign currency if grown on a large scale (MALDC, 1990). In 1988, Tanzania earned 54 million Tanzanian shillings (Tshs.) from export of oil seeds, oilnuts and oil kernels (URT, 1993).

The majority of the soils in the tropics are highly weathered, leached and consequently acidic (Akobundu, 1991). The 1:1 clay minerals and the oxides of aluminium (Al) and manganese (Mn) dominate such soils. Because of the extensive weathering and leaching, these soils is deficient in most of the essential plant nutrients, calcium (Ca^{2+}) being one of them. Some of the essential nutrient elements could occur in substantial amounts in such soils, but not in forms available to plants due to precipitation by some ions and fixations by the soil colloids. Generally, groundnut crop grows best on soils with pH of 5.8 - 6.2 provided nutrients are available in balanced supply (Bunting *et al.*, 1985).

In general terms, groundnut crop does not seem to have any peculiar nutritional needs, except for Ca^{2+} which is important for growing fruits and seeds (Bunting *et al.*, 1985). Calcium is one of the major nutrient element which is deficient in leached soils such as those in Tanzania where groundnut is grown (TARO, 1987). In order to increase yield and seed quality, Ca has to be added to such soils in the form of fertilisers like limestone ($CaCO_3$) and gypsum ($CaSO_4$) just to mention a few. However, most of commercial calcium fertilisers are expensive and the small-scale farmers in Tanzania cannot afford the high prices. Worse still the prices of these industrial fertilisers keep on increasing year after year. Total Ca in highly weathered, coarse, sand soils may be about 0.1 - 0.3 %. Therefore, based on Ca^{2+} deficiency in the soils (Prasad and Power, 1997) and high costs of commercial fertilisers or material such as calcite ($CaCO_3$), dolomite ($CaMg[CO_3]_2$) or gypsum ($CaSO_4 2H_2O$) which could be an important source of Ca, there is a need to encourage farmer to use alternative materials.

Literature shows that use of naturally occurring materials such as wood ash could be the alternative source of Ca^{2+} (Rweyemamu *et al.*, 1998). Such materials are cheap hence affordable by the small scale farmers. Also, the naturally occurring material may be readily available compared to other sources of Ca. Therefore, in Tanzania farmers could be urged to use wood ash found in the area of production as source of Ca in their groundnut production.

Calcium absorbed by the roots is usually not translocated to the developing pods, which means pods in groundnut absorb directly Ca^{2+} needed for pod and seed development from the soil solution (Prasad and Power, 1997). It has been reported that application of

Ca^{2+} reduces the problem of empty pods, commonly referred to as "pops" (Reddy, 1988) thus increasing seed yield and quality of groundnut (Bunting *et al.*, 1985; TARO, 1987; Prasad and Power, 1997; Rweyemamu *et al.*, 1998). The uptake of Ca^{2+} for each 1 000 kg of fruit produced is estimated to be 1 - 2 kg (Bunting, *et al.*, 1985).

Therefore the main objective of this study was to determine the influence of supplemental Ca^{2+} supplied in form of wood ash on groundnut yield and seed quality of three groundnut cultivars.

The specific objectives were:-

(a) To determine the influence of Ca applied in the form of wood ash on groundnut pod and kernel yield.

(b) To determine the effect of wood ash on groundnut seed quality.

(c) To relate seed calcium to supplemental calcium.

(d) To compare performance of three groundnut cultivars to supplemental calcium.

The results obtained in this study will be used for making preliminary recommendation for adequate supply of Ca so as to obtain optimum yields of groundnut in various parts of Tanzania with similar climatic and soil characteristics as those found in areas where the study was conducted. Further, these results will be used in advising farmers on how wood ash may be used as a soil amendment in the areas where groundnut crop is grown.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Classification

The groundnut (*Arachis hypogaea* L.) is a legume belonging to the subfamily *Papiliniodaeae*. The plant is erect or prostrate, sparsely hairy, and 15 - 60 cm high. *A hypogeae* describes the most peculiar trait of species, underground fruit formation (*hypo* means under, and *agea* means ground). The genus *Arachis* contains a diversity of plant types. These include annuals, perennials, rhizomatous (those which reproduce largely through vegetative means) and those which reproduce by seed. It is generally believed that, the groundnut crop cultivated for food and oil i.e. *A. hypogaea* L. is said to have originated from Southern Bolivia or Northern Argentina in South America (Gregory *et al.*, 1980).

2.2 Botany

The genus *Arachis* has more than 70 species existing in nature, of which only *A. hypogaea* is commonly cultivated. Plants of the genus *Arachis* are perennial or annual legumes with three or four foliate, stipulate leaves, papilionate flowers, a tubular hypanthium, and underground fruits (pods). Germination of groundnut is neither epigeal nor hypogeal but intermediate. The hypocotyl carries the cotyledons to the surface and remains there. A structure unique to the genus is the "peg", which is an expanded intercalary meristem at the base of basal ovule (NRI, 1996). The expansion results in a lomentiform carpel of one to five segments, each containing a single seed with two massive cotyledons and a straight embryo (Ramonatha Rao, 1988).

2.3 World Distribution

Groundnut crop is believed to have been taken from South America to Africa, India and the Far East by Portuguese in the sixteenth century (Bunting *et al.*, 1985). The cultivated groundnut, is grown throughout the tropical and warm temperate regions of the world. According to FAO (1991) nearly 19 million hectares were planted with groundnuts world wide, and 22.5 million metric tonnes of dried pods were harvested. About 67% of the world groundnut production occurs in the seem arid tropics. The average yield of groundnut in the seem arid tropics is around 800 kg/ha of dried pods, which is much lower than yields of over 3 000 kg/ha obtained in the developed countries (NRI, 1996).

2.4 Groundnut Production in Tanzania and Ecology

2.4.1 Groundnut production in Tanzania

There are two main groundnut-growing zones with different amount of rainfall and distribution in Tanzania. One zone includes Mtwara, Lindi, Ruvuma, Kigoma, Shinyanga and Mwanza regions where rainfall is unimodal starting from October/November to May/June with a short dry spell in January and February. The second zone has a bimodal rainfall distribution with short rains in November/December and long rains suitable for most crops starting from March ending in June. This zone covers Morogoro, Dodoma, Tabora, Arusha, Kilimanjaro, Tanga, Pwani and Dar es salaam regions. The total area under groundnut cultivation has increased from below 50 000 ha in the early 1960s to nearly 100 000 ha in 1980 (Doto and Mwenda, 1985).

While the main groundnut producing countries such as the USA do exceed 3 tons/ha (Bunting *et al.*, 1985), yields of groundnut in Tanzania are low. Average kernel yields are estimated at 600 kg/ha (TARO, 1987), but small-scale farmers usually get about 450 kg/ha (Tarimo and Msekele, 1986). According to TARO (1987), the potential yields of groundnut under normal Tanzanian soil and weather conditions is about 1 000 to 1 500 kg/ha kernel yield depending on the variety grown.

2.4.2 Ecology

2.4.2.1 Altitude

In Tanzania, groundnut grows well in areas below 1500 m a.s.l. because of the need for warm conditions (Acland, 1971; Owen and Ireri, 1990). However, sometimes the crop is cultivated at places above 1700 m a.s.l. such as Mbeya and Ruvuma (Mwenda, 1987).

2.4.2.2 Temperature

Groundnut perform well in dry temperatures ranging between 24 and 33°C, but can survive up to 45°C if adequate moisture is maintained (Saxena *et al.*, 1983).

The optimum temperature for groundnut germination is about 30 - 35°C (Fageria *et al.*, 1997). Temperature has influence on the rate of plant growth because it affects the rate of all the biophysical and biochemical reactions involved in metabolism (McDonald and Paulsen, 1997). According to Ketring (1986), optimum mean air temperature for vegetative growth of groundnut is in the range of 25 - 30°C, while temperature for reproductive growth may be similar or sometimes lower than 20 - 25°C.Temperatures of about 35°C during critical phenophases (pegging, pod formation and kernel filling), affects yield levels. Daily mean temperature of 20 - 30°C reduces the time to flowering by about 14 days in groundnut crop (Ono, 1979). Extreme temperature on either limit prolong the duration of pod development (Reddy, 1988). Furthermore, temperature in combination with water availability sets the length of the growing season (Ketring, 1986).

The optimum soil temperature in the podding zone ranges between 31 and 33°C (Ono, 1979). Low soil temperature around 23°C increases the number of pods and pod weight but longer filling period is required (Dreyer *et al.*, 1981). McMeans *et al.* (1990) observed increase in groundnut seed size at soil temperature of 28.8°C at 5 cm soil depth.

2.4.2.3 Rainfall and water requirement

In Tanzania, groundnut is mostly grown as a rainfed crop. Just like any other crop the amount of water required for the groundnut is not fixed This depends on the duration of the

cultivars grown and plant density in the field. Also water requirement is affected by the rate of expansion of the canopy, and the evaporative demand of the environment. Groundnut grows well in areas receiving about 600 to 1 200 mm of rain even though 500 mm of rain well distributed withinthe growing season would ensure a good crop. Good distribution of rainfall is essential for satisfactory yields as pod filling is favoured by soil moisture availability (Boote *et al.*, 1982). Soil moisture is also required for easy field operations (Acland, 1971; TARO, 1987; Owen and Ireri, 1990). Daily water use by groundnut is low during the early growth stages and increases with increasing leaf canopy. The maximum daily water use rate is reported to be between 5 and 6 mm/day (Bunting *et al.*, 1985; Stansell *et al.*, 1976). Maximum water use rates occur between flowering and physiological maturity (Stansell *et al.*, 1976). Kassam *et al.* (1975) observed that peak evapotranspiration (ET) for Spanish groundnut occurred shortly before peak leaf areas index (LAI) was achieved.

In developed countries such as the USA, groundnut is grown under irrigated conditions so as to obtain high groundnut yield. According to Boote *et al.* (1982) optimum water management appears to be scheduling irrigation to maintain less than 50% soil water deficit in the top 30 cm during early growth and possibly irrigating at 25% soil water deficit during pod formation and seed growth. Under both rainfed and irrigated conditions, growth of groundnut differs between the long season Virginia and short season Spanish cultivars.

Dry surface soil reduce seed yields by affecting either the development of pegs into fully grown pods, and or by influencing seed abortion and hence the number of seeds per pod (Wright, 1989). Drought also decreases Ca uptake and thus induces Ca deficiency in groundnut. Dry condition is needed for harvesting and drying, otherwise many nuts remain in the soil after pulling (Acland, 1971; Owen and Ireri, 1990). Further, in wet conditions, threshing and drying of the crop are difficult. In addition, the fruits may be invaded by *A. flavus*, and seeds that are not dormant may germinate (Bunting *et al.*, 1985).

2.4.2.4 Soil requirements

The most suitable soils are well drained, loose friable, sandy loam, well supplied with Ca and with moderate amounts of organic matter (Owen and Ireri, 1990; Shinde *et al.*, 1990). It can be grown on heavy soils, but this makes harvesting more difficult and some nuts may remain in the soil (Purseglove, 1977). Soils which crusts are unsuitable because they restrict peg penetration into the soil (Rweyemamu and Mushi, 1989; Owen and Ireri, 1990).

Groundnut is highly susceptible to water logging condition (Purseglove, 1977; Fageria *et al.*, 1997).

Groundnut grows best on soils with pH between 5.8 and 6.2, provided nutrient elements are available in balanced supply. This is important for the proper growth of the nodules, since pH affects absorption of some microelements especially molybdenum and boron (Marschner, 1995). Adams and Hartzog (1980) found no correlation between soil pH and yield response of groundnut, but yield was highly correlated with exchangeable Ca.

Groundnut is one of the most acid - tolerant crop with a critical pH of 5.0 - 5.5, but moderately susceptible to soil salinity (Fageria *et al.*, 1997).

2.4.2.5 Day length

Pod yield is greatly influenced by day length (Ketring, 1979) and genotypic variation in yield responses to short and long Ong (1986) has reported that .there was an increase in yield of about 36-106% under short day (11-12 h) ,than in long day (15-16 h) .The differences in yield responses to day length have been attributed due to changes in the number and proportion of large kernels It is well established that long day promotes vegetative growth at the expenses of reproductive growth (Ketellaper, 1969), but there is some uncertainty about the influence of day length on the duration of reproductive phase. In a study of several groundnut cultivars Sengupta *et al.* (1977) found that A day length shorter or longer than 10 h delayed flowering, where as in contrast, Ketring (1979), did not observe any effect of day length at 8, 12 and 16 h on flower initiation.

Generally, ecological variability is a major cause of inability to achieve potential yield in both irrigated and rainfed production areas of groundnut. The production risk associated with ecological variability has severe consequences on both local and regional groundnut production. For these reasons, the use of a groundnut crop – growth simulation model (PNUTGRO) which dynamically responds to daily weather inputs (temperature, rainfall and radiation), to pest and soil - water deficit stresses is a better quantification of potential yield and production risks for possible new groundnut production environments (Hammer *et al.*, 1995).

2.5 Groundnut Production Constraints

There are number of factors that affect groundnut production under Tanzanian conditions. Although drought, diseases and insects are the main yield limiting factors in various regions of the world growing groundnut, in the Semi arid tropics including Tanzania more factors have been identified.

2.5.1 Land preparation

Land preparation, sowing and harvesting dates seem to reduce groundnut production. Previous results obtained have confirmed that sowing as early as possible in the season, or after the first rains are advantageous. Insufficient labour or competition for by subsistence cereal crops such as maize, with a coinciding optimal sowing period, often prevents farmers from timely sowing. Sibuga *et al.* (1990) suggest that sowing before the first rains into dry soil may improve yield per unit area.

2.5.2 Time of planting and harvesting

Delayed sowing may lead to increased rosette virus incidence and early leaf spot severity (Taylor, 1985). Timely harvesting is also important to secure high groundnut yield and quality. After maturity several diseases such as pod rot may attack plants. In Tanzania trials have shown that, losses were more important in the case of an early spanish cultivars than in that of a late virginia one. Timely harvesting is also important in reducing fungal invasion and aflatoxin contamination (Kafiriti, 1990).

2.5.3 Plant density/population

Doto and Mwenda (1987) and Chiteka et al. (1992) have documented the problem of low plant population that is associated with the lack of adequate seed material. Many farmers retain their own seed for sowing which results into seed with very low quality, insufficient plant densities and poor yields (Kafiriti, 1990). In addition, the recommended plant densities are often not attained due to high cost and / or unavailability of the seed (Doto and Mwenda, 1987) and sub -optimal spacing used by most small scale farmers. The recommended plant population for bunch varieties is between 133 000 and 210 000 plants/ha, while for spreading bunch and runner types is 108 000 plants/ha (Acland, 1971; Purseglove, 1977; Rweyemamu and Nyanda, 1990).

2.5.4 Groundnut varietal differences

Lack of cultivars adapted to the varied agroecological requirements and the non availability of improved seeds in Tanzania have also been cited to hinder groundnut production (Chambi, 1989). While it is now more attractive to grow groundnut, the supply of seed has not matched the demand (Mwenda, 1897). However, it may take sometime before improved seed reaches the farmers. As the situation stands, farmers often plant material (cultivars) that is of mixed origin (Doto and Mwenda, 1987).

2.5.5 Plant nutrition and fertilizer needs

Calcium is the soil nutrient most likely to be deficient for groundnut production. To correct such a problem, gypsum is generally band or broadcast at flowering (Prasad and Power, 1997). Phosphorus (P), potassium (K), sulphur (S), magnesium (Mg) or minor elements may have to be added on some soils, molybdenum (Mo), cobalt (Co), boron (Bo), copper (Cu) and zinc (Zn) are needed to support the symbiotic fixation of nitrogen (Bunting *et al.*, 1985). According to Taylor (1985), groundnut in southern Tanzania responded well to P fertilizer application of up to 21.8 kg P/ha. At Morogoro, Tanzania, both triple superphosphate and Minjingu rock phosphate (MRP) showed positive effect on groundnut yield (Rweyemamu and Nyanda, 1990).

Beside the merits that occur from fertilizer application, farmers in Tanzania rarely use fertilisers in groundnut production. This is partly because the crop is regarded as a second or third crop when allocating resources, also there is a lack of information on appropriate nutrient requirements under Tanzanian condition (Sibuga *et al.*, 1992). In addition, it is generally recognized that farmers often cannot afford to use fertilisers in their fields as reported by Doto and Mwenda (1987) because of high fertilizer prices.

2.5.6 Pests

2.5.6.1 Diseases

Many diseases caused by fungi, viruses and bacteria affect groundnut. In Tanzania, there are three important fungal foliar diseases that are a constant menace to the crop namely: Early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Phaeoisariopsis personata*) leaf spot, and rust (*Puccinia arachidis*). Also there is a problem of aflatoxin (*Aspergillus flavus*) contamination. These foliar diseases reduce the photosynthetic surface of the crop and hence lowering the yield, while aflatoxin reduces the crop quality and poses health hazard to man and livestock. Yield losses due to these diseases are estimated at 50% (Mpiri, 1989).

Groundnut rosette which is caused by a complex of three agents, groundnut rosette virus (GRV), it's satellite RNA, and groundnut rosette assistor virus (GRAV) (Reddy *et al.*, 1985), is well recognized as one of the major constraints to groundnut production in Tanzania. Both chlorotic rosette and green rosette occur, but chlorotic rosette is the most prevalent and destructive (Chiteka *et al.*, 1992). Although disease epidemics are sporadic, yield losses approach 100% whenever the disease occurs in epidemic proportions.

Other diseases that occur in Tanzania include groundnutblight (*Sclerotium rolfsii* Sacc.) which causes wilting of the affected plants. The incidence of blight is greater in wet weather and when there is late weeding or heaping weeds around the plant causes high humidity around the base (Acland, 1971; NRI, 1996). Bacterial wilt caused by (*Pseudomonas solanacearum*) also affects groundnut and can lead to complete death of affected plants (Chiteka *et al.*, 1992). In addition to these, anthracnose (*Colletotrichum* spp), alternaria leaf blight (*Alternaria* spp) and Sclerotinia blight (*Sclerotinia* spp) affects groundnut in Tanzania (Acland, 1971; Porter *et al.*, 1984).

2.5.6.2 Insect pests and vermin

Insect pests cause direct damage and also play important role as vectors. The groundnut aphid (*Aphis craccivora* Koch.), is important as the vector of groundnut rosette in the country. Tarimo and Karel (1987) reported groundnut hopper (*Hilda patruelis* Stal.) as being among important groundnut pests in Tanzania. The insect is often said to be associated with cashew cultivation in coastal areas of Tanzania (Sithanantham, 1990).

Termites (*Hodotermes mossambicus* Haig.) is reported to be one of the major insect pest in groundnut particularly under drought condition and may cause losses of 15 to 20% in severe cases (Chambi, 1989). In addition, flower thrips (*Taeniothrips sjostedti*), flower beetles (*Coryna* spp and *Mylabris* spp), and the seedling beetle (*Gonocephalum simplex* F.) also cause damage in the field and considerable reduction in the seed kernel yield (Tarimo and Karel, 1987). Yield losses may also be reduced due to rats and some birds, which are known to dig up the pods and feed on the nuts (Owen and Ireri, 1990).

2.5.6.3 Weeds

Weeds are a serious problem in crop production as they reduce yields through competition, interference and harbouring pests. Serious losses in yield of groundnut may occur if they are not removed up to and beyond critical periods of weed competition. Weeding done within the first six weeks, either once at four or six weeks or twice at two or four weeks after groundnut emergence, had no detrimental effect on groundnut seed yield. Weed infestation beyond the first six weeks may reduce yields by about 46 -53% depending on groundnut genotypes (Sibuga *et al.*, 1989). On a well prepared seed bed, only one weeding operation would be required because the crop grows fast and provides ground cover which suppresses subsequent weed growth (TARO, 1987). Weeding after flowering should be discouraged as this would damage pegs hence reducing yield (Acland, 1971; Purseglove, 1977).

2.5.7 4 Other factors

Other factors that do affect groundnut production in Tanzania include available farming equipment at small - scale level and low price incentive. At present all of the groundnut sales are through middle men who buy the crop at very low prices thus discouraging farmers from expanding the crop production (Doto and Mwenda, 1987). Further, in Tanzania, groundnut is important in traditional farming systems where the staple crops are usually cereals. Therefore, priority is usually given to food crops such as maize and rice when the main rains start. After most of the agronomic practices have been given to such crops, then the family allocates labour, time and attention to other crops such as groundnut. Another reason for late planting is that groundnut seeds are more valuable than those of cereal, therefore farmers do not sow this crop until there is less risk that the crop will be lost due to an early dry spell.

2.6 Role of Plant Nutrients in Groundnut Crop

Nutrient deficiencies are among the reasons for the low groundnut yields. Although groundnut can meet a major portion of its nitrogen (N) requirement through biological nitrogen fixation (BNF) Mohan and Sharma (1992), it also responds well to application of 20 – 40 kg N/ha in sandy soil (Tandon, 1996). A starter dose is recommended before

BNF mechanism becomes functional. Nitrogen increases plant dry matter, nodulation and seed yield. Also, oil content in groundnut kernels increase significantly when 20 kg N/ha is applied. Nevertheless increase in protein content are high at 40 kg N/ha (Mohan and Sharma, 1992).

Shortage of P is common in tropical soils and is the most frequent nutrient stress for groundnut if fertilizer has not been used. Applied P fertilizer and mycorrhiza do increase growth, nodulation and nitrogen bacterial fixation (NBF) in groundnut (Bunting *et al.*, 1985; Taylor, 1985). The nutrient increases root and plant development and consequently increases the uptake of other nutrients (Mayeux and Maphanyane, 1989). At Morogoro, researchers recorded seed yield increase following the application of P using MRP - 14.8% P. The application of MRP at 75 kg P_20_5 resulted in high seed yield levels and oil content (Rweyemamu and Nyanda, 1990).

Potassium deficiencies have been detected on ferratic soils, particularly if they have been over - cultivated. They may be suspected if many fruits are single - seeded, but this condition may also indicate a shortage of Ca (Bunting *et al.*, 1985). Munda *et al.* (1989) observed increase in pods/plant, pod weight, kernels/pod and shelling percentage after application of 25 kg K/ha. Potassium and magnesium improve yield, but the elements alone have no effect except in presence of Ca (Purseglove, 1977). Sulphur increases nodulation and groundnut yield when applied at sowing (Purseglove, 1977).

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Micronutrients such as Zn also affect groundnut pod yields (Yadar *et al.*, 1991).

2.7 Role of Calcium in Groundnut Yield and Quality

Generally, Ca is necessary for proper maintenance of cation uptake likes nitrate nitrogen and utilisation of potassium (Tisdale and Nelson, 1975). Calcium also affects N and K accumulation in plant tissue, thus it is involved in maintaining the structural integrity of membranes (Mengel and Kirkby, 1982). The nutrient is also an integral part of cell wall (Marschner, 1995). It has been shown that in the absence of Ca, lignification does not occur properly thus inhibiting cellwall thickening (Millaway and Wiersholm, 1979). It has also been demonstrated that, cell division fails under Ca deficiency (Tisdale and Nelson, 1975). Calcium is also required for proper functioning of growth hormones (Millaway and Wiersholm 1979; Marschner, 1995).

The element is operative in binding of auxins and thus involved in the moderation of growth and development of plant tissue (Leopold *et al.*, 1973). In addition, calcium plays a role in activating certain enzyme systems (Christiansen and Foy, 1979). At the whole plant level Ca is required for proper growth and elongation of roots which affects the establishment, survival of emerging plants, penetration of young roots into the soil and development (Gerard, 1971; Uriyo *et al.*, 1979). Under adverse soil conditions such as sub optimum temperature and salinity, Ca induces root vigour and growth. The element is also involved in apical dominance of shoots (Millaway and Wiersholm , 1979), and regulates carbohydrate translocation within plant tissue (Tisdale and Nelson, 1975).

Calcium is said to have a major role in the control of physiological ageing of plant tissues and as such, it influences the growth and yield of crop plants (Millaway and Wiersholm, 1979).

Calcium is absorbed as divalent Ca^{2+} mainly by passive process. The same holds for translocation of Ca^{2+} within the plant (Mengel and Kirkby, 1982). Calcium in the xylem sap is translocated in an upward direction with the transpiration system. Thus, to a large extent the intensity of transpiration controls the upward translocation (Marschner, 1995). The rate of downward translocation of Ca^{2+} is very low due to the fact that Ca^{2+} is transported in only very small concentrations within the phloem (Mengel and Kirkby, 1982).Once Ca is deposited in older leaves it cannot be mobilised to the growing tips (Loneragan and Snowball, 1969).

Calcium ions interact with other ions in the plant tissue. In proper ratio with Bo it affects the growth and integrity of stem tissue (Millaway and Wiersholm, 1979). Also antagonises the toxicity of the ammonium ($NH4^{+}$) and Mn ions (Bennett and Adams, 1970; Foy *et al.*, 1972) which can be toxic to plant tissues. In conjunction to this, it is the basic material for neutralising organic acids, thus it acts as a detoxifying agent. In groundnut, the element is important for nodulation, peg formation, seed development

(Purseglove, 1977), early maturity and good seed production (Uriyo *et al.*, 1979). With this function Ca decreases the number of shrivelled kernels and empty pods,thus improves the shelling percentage (Reddy *et al.*, 1987).

Since Ca is essential for growth of the seeds and is taken up by roots, pegs and fruits, it must be available in the soil layers in which pegs form the fruits (Bunting *et al.*, 1985). Aerial parts of the plant are supplied with Ca passively through transpiration (Marschner, 1995), but the pegs and fruits do not transpire, and so they rely on diffusion, and active uptake (Boote *et al.*, 1982).

Although fertilizer application may provide immediate solution to the problem, the amount of Ca in the pegging zone is very important. Experiments have shown that for groundnut to develop normal pods, adequate Ca must be present in the fruiting zone (Seshadri, 1962). Calcium applied at the time of flowering can provide an adequate supply for large - seeded Virginia cultivars. The need for small - seeded cultivars is usually met by the proper use of liming materials (Adams *et al.*, 1993).

Groundnut requires 100 - 223 kg Ca/ha for it's optimum growth (Weiss, 1983). However, a value of 290 kg Ca/ha is considered to be the upper limit at which a response to Ca application can be expected (Prasad and Power, 1997). Calcium in form of gypsum is generally band or broadcasted at blooming stage (Prasad and Power, 1997), but at higher levels two applications are preferable; the first is applied at first - bloom stage (R_1) and the second split 20 - 25 days after flowering (R_4) according to Bledsoe and Harris (1960).

2.8 Soil Related Factors Affecting Calcium Nutrition

The mean Ca content of the earth's crust is about 3.6%. It is higher than the other major nutrient cations required by plants (Kirkby, 1979). Release of Ca^{2+} from the exchange complex and its availability to crops depends on factors that are interdependent. These factors are :-

(a) total Ca^{2+}

(b) type of clay mineral present

(c) cation exchange capacity (CEC) of soil

(d) percent saturation of CEC with Ca^{2+}

(e) soil pH and ratio of Ca^{2+} to other cation in soil solution.

Soils having a 2:1 layer silicates have a higher CEC and can thus retain larger amounts of Ca, which may be too low to be available to plants. However, soils having a 1:1 layer silicates do release exchangeable Ca into the soil solution at only 20 to 40% Ca saturation of the exchange complex (Prasad and Power, 1997).

Soil pH is inversely related to exchangeable Ca. In acid soils, Ca concentrations are very low. Under field condition, also Ca deficiency are usually due to Al - Ca antagonism (Foy, 1992). Availability of Ca^{2+} and its uptake by plants is largely influenced by the ratio of Ca^{2+} and Mg^{2+} with other cations (Mengel and Kirkby, 1982). At high pH values greater than 6.0 such soils have plenty of exchangeable Ca and calcium carbonate ($CaCO_3$) (Uriyo *et al.*, 1979). Available phosphate reacts with both Ca ion and its carbonate, to form calcium phosphate ($Ca_3(PO_4)_2$ which is insoluble and unavailable to crops (Kitua, 1996). Excessive leaching of Ca does result into Ca responsive soils.

2.9 Plant Related Factors Affecting Calcium Nutrition

Considerable quantities of Ca can be lost by guttation process. Reports indicate losses exceeding 30% of total uptake. Guttation loss can create Ca deficiency in environmental conditions of cool night temperature and dry days (Christiansen and Foy, 1979). It has also been documented that water stress can restrict Ca uptake and distribution, the depressing effect of NH4 - N on water uptake may also impair Ca nutrition. Furthermore, any root growth inhibiting factor such as adverse temperature, inadequate aeration, poor nutrient status, Kirkby (1979), and high light intensity and duration Millaway and Wiersholm (1979) will restrict Ca uptake and hence impair translocation (Kirkby, 1979).

Nitrogen that stimulates rapid tissue growth, can seriously affect Ca as it is relatively immobile nutrient. Where N is available in high amounts over the entire growing season, Ca deficiency can become very significant (Millaway and Wiersholm, 1979). This situation is aggravated by simultaneous effect of N in depressing root growth and so retard Ca uptake (Kirkby, 1979). In addition, growth stimulation with fertilisers can induce high levels of salt which can significantly reduce the amount of Ca absorbed by plants (Gerard, 1971).

Potassium at high levels has been observed to reduce Ca translocation, also its movement is retarded from roots to shoots (Gerard, 1971). Similarly, sodium (Na) hampers the translocation of Ca to the leaves (Millaway and Wiersholm, 1979). While Al depresses the long distance transport of Ca (Gerard,1971). Finally, large fraction of Ca is held on adsorption sites in cellwall (Christiansen and Foy, 1979). The provision of a plant canopy such as groundnut cover can greatly reduce the leaching of Ca from a soil (Prasad and Power, 1997).

2.10 "Pop" Research

There are few reported studies on "pop" in Tanzania. Research reports by Mbowe (1975) and TARO (1987) using virginia and spanish-valencia groundnut cultivars and Ca supplements from lime and gypsum, have indicated that there is an increase in seed yield due to reduction in "pop" percentage. Series of experiments have been conducted in other countries such as Zambia, Zimbabwe and Malawi to determine the cause of ``pops" in groundnut. The results of these experiments have shown a significant seed yield increase and low percentages of "pops" when lime was applied. This suggested that Ca deficiency was the cause of high "pops" percentage and low seed yield in groundnuts (Syamasonta, 1990; Hartmond *et al.*, 1992). Other causes of "pops" include unfavourable conditions, such as drought at pod filling. The root hairs of the pods are unable to absorb nutrients from the surrounding soil during dry condition and "pops" will occur even if the amount of Ca is high in the soil (Syamasonta, 1990).

2.11 Calcium Deficiency Symptoms in Groundnut

Since Ca is generally immobile in plants, there is little translocation of Ca in the phloem (Bunting *et al.*, 1985). This leads to a poor supply, and consequently deficiency symptoms often result in fruits and seeds (Bunting *et al.*, 1985; Fageria *et al.*, 1997). In groundnut production areas, if Ca is deficient, one or more of the seeds in each fruits may abort or be shrivelled. Sometimes there may be failure in seed formation resulting in empty pods known as "pops"(Reddy, 1988; Hartmond *et al.*, 1992). Further, the plumule become dark in colour, and seed germinate poorly (Bunting *et al.*, 1985; Adams *et al.*, 1993). Thus, seeds and seed quality are reduced due to poor seed size and germination potential (Bunting *et al.*, 1985; Conkerton *et al.*, 1989).

2.12 Sources of Calcium Nutrient

Calcitic lime and gypsum have been used as sources of Ca where its deficiency seems to be a limiting factor in groundnut production. The fertilizer materials are incorporated into the soil at sowing or applied at flowering stage have resulted in reduction of "pops", increasing shelling percentage and seed yield (Mbowe, 1985; TARO, 1987; Nyirenda *et al.*, 1992). In Zimbabwe, application of lime at 500 -800 kg/ha significantly increased groundnut yields (Mpofu, 1992). In Malawi, application of both calcitic lime and gypsum on groundnut increased shelling percentage and seed yield (Nyirenda *et al.*, 1992). It has also been shown that, the phosphate fertilizers such as triple super phosphate (TSP) and single super phosphate (SSP) may supply adequate Ca nutrient to the crops (Ong *et al.*, 1985), since they contain 13.8% and 20.1% Ca by weight, respectively.

Wood ash is an ancient soil amendment. Several studies have been conducted on the potential of wood ash to supply plant nutrients (Clapham and Zibilske, 1992). Wood ash major plant nutrients of agronomic importance have been reported to include K, Ca, Mg, P, Fe, Mn and S (Krejsl and Scanlon, 1996). In a study which involved wood ash from different sources, Clapham and Zibilske (1992) showed that electrical conductivity of soil increased with an increase in wood ash amendment compared to lime treatments, suggesting high concentration of soluble ions in wood ash. They also observed that soil Ca and K increased with increasing wood ash application rate. Results for ash analysis revealed that, it had Ca 29.1% and a pH of 12.1. Analysis conducted by Ngowi (1997) on wood ash from *Combretum* spp popularly known as *Mlama* tree in Tanzania, showed that the ash contained 6.9% Ca, 4.5% P and a pH value of 10.49.

2.13 Crop Growth Response to Wood ash Application

Studies on crop response following wood ash application have received considerable attention in various parts of the world. Growth variations have mainly been due to wood ash composition, rates of application, soil type and crop grown (Erich and Ohno, 1992). In a field experiment done in Washington DC (in the USA) which consisted of three ash treatments (30, 40, and 50 kg/ha), one dolomitic lime treatment (7.4 kg/ha) provided benefits to bean growth on acidic soils. Ash increased yields and the calculated agronomic rate of ash (30 kg/ha) was appropriate for the crop (Krejsl and Scanlon, 1996). Application of wood ash has also been shown to increase the growth and yield of soybean (Clapman and Zibilske, 1992). There are few studies reported on the application of wood ash as a source of Ca element to field crops in Tanzania. Ngowi (1997) reported the application of wood ash as a source of Ca which increased the number of leaves/plant and shelling percentage of bambara groundnut. In another study where wood ash was applied as a source of Ca on groundnut cultivars Baka and Spancross resulted in 6 - 30% leaf area increase and "pops" were reduced by 17 - 55% depending on the level of wood ash applied (Rweyemamu *et al.*, 1998).

2.14 Effect of Wood ash on Environment

2.14.1 Soil chemical characteristics

Wood ash causes rise in soil pH due to it's higher content of oxide and hydroxide, which react quickly in the soil, and neutralises the hydrogen ions (Conyers and Scott, 1989).

Clapman and Zibilske (1992); Kimbi (1997) reported increase in pH value when wood ash was applied. The magnitude depends on physicochemical differences between soil types. Soil pH is expected to be higher in sandy soils that are dominated by macropores compared to the dominant micropores in clay and silty soils. Thus, in sandy soils there is higher alkalinity movement.

Literature shows that higher rates of wood ash and hydrated lime results in soil pH close to or above 7.0 reaching cation saturation thus decreasing the ability of the sandy soil to hold additional cation (Clapman and Zibilske, 1992; Kimbi, 1997). Application of wood ash at very high rates may cause cationic imbalance due high solubility of wood ash K which results in a significant rise of K in the soil (Kimbi, 1997).The residual exchangeable Ca also increases (Ndakidemi, 1992).

2.14.2 Other environmental considerations

Metals, which can potentially be toxic to plants and animals, have been reported to be present in wood ash. These include Zinc (Zn), Copper (Cu), Lead (Pb) etc (Kimbi,1997). Toxicity levels in ash amended soils are influenced by application rates , type of soil and plant factors These heavy metals may have a negative effect on water quality and also contaminate ground water. Apart from heavy metals, sodium (Na) which is easily leached from the soil treated with wood ash clapham and Zibilske, (1992) can contaminate water sources. Its accumulation on the soil surface may cause dispersion of soil particles, resulting to poor soil structure.

2.15 Seed Quality

Seed size is one of the categories into which seeds can be graded. It is generally held that larger seeds result into higher germination rates, vigorous growth and eventually higher yields (Haper and Obeid, 1967). It has also been observed that, plants raised from large seed outyielded small size seeds by producing the highest pod yield (Vindhavarmaan *et al.*, 1990). In contrary, Detroja *et al.* (1993) reported that seed size did not influence yield components of groundnut. Generally, cultivars belonging to variety *hypogaea* have larger and heavier seeds, and those belonging to variety *fastigiata* have smaller seeds (Reddy, 1988).

Seed size has an effect on seed diameter of groundnut. A well filled groundnut pod normally has a greater seed diameter. Hard soil causes small shrivelled nuts which results in small seed diameter (Acland, 1971). Seed diameter is an important parameter during crop establishment, as larger seed results into high germination rate, vigorous growth and eventually higher yields.

Groundnut seeds are rich in oil content, the amount of oil varies according to the type of cultivars. Virginia types contain 38 to 47% oil and Spanish types have 47 to 50% oil (Purseglove, 1977). Most of the lipid in groundnut seed is triglyceride, which is accumulated in the fat body with half unit membrane consisting phospholipid. Literature shows that Ca has an effect on groundnut oil content (Reddy, 1988). When Ca is deficient in the fruiting zone, many immature seeds and unfilled pods are produced due to suppressed biosynthesis of lipid in groundnut seed. Also, it has been observed that Ca decreases phospholipid content of groundnut seed deficiency (Inanaga *et al.*, 1990)

According to Syamasonta (1992) application of Ca has been observed to increase oil content in groundnut seeds. Also, it has been documented that larger seeds are associated with low oil content, while medium size seeds have greater percentage of oil content. Sibuga *et al.* (1995) reported that in an experiment done in Mpwapwa district the oil content was between 41.7 and 46.9%, and that obtained in Kilosa district was between 43.0 and 46.0%. In the two districts cultivars Baka, Spancross and ICGV 86112 were used in the village trials. Shelling percentage of groundnut increases when Ca is applied to the crop by reducing the number of empty pods (Purseglove, 1977). According to Acland (1971) the shelling percentage of groundnut is 65 to 75%. Syamasonta (1992) reported higher shelling percentage of sound kernels after Ca application in an experiment done in Southern Africa. It was also noted that shelling percentage differed genotypically among the cultivars. Under Dodoma condition, the shelling percentage was 34.5, 60.0 and 61.0% for cultivar Spancross, ICGV 86112 and Baka, respectively (Sibuga *et al.*, 1995). In addition, it was found that there was an association between shelling percentage and large seed size (Sibuga *et al.*, 1990). Seed diameter ranging between 5.4 and 8.0 has been reported under Morogoro condition (Sibuga *et al*., 1995).

2.16 Factors Affecting Groundnut Seed Quality

Excessive collections of germplasm of cultivated groundnut have been made from many countries, particularly those in South America and Tropical Africa. The largest collection of over 10 000 accessions, is maintained by the International Crops Research Institute for Semi - Arid Tropics (ICRISAT) at Patancheru, Hyderabad, India. Large number of accessions of cultivated groundnut have been evaluated in respect to potential yield, morphological and chemical characters, tolerance to environmental stresses, and resistance to pest and diseases (Bunting *et al*., 1985). In collaboration with the Regional centres such as that of Southern Africa Developing Countries (SADC) based in Malawi and national programs in several groundnut growing countries such as that at Naliendele, Mtwara and Sokoine University of Agriculture at Morogoro in Tanzania have come up with valuable findings regarding groundnut production. Good genotypes tested under such programs have been found to resist or tolerate several important diseases such as Late leaf spot and Groundnut rosette (Acland, 1971; Waliyar *et al*., 1989). Resistance or tolerance to several pests has been found in genotypes such as ICG 2271, ICG 5044 and ICG 5045 that are resistant to termites, pod borers and leaf miner Sithanantham *et al*., 1990). Drought tolerant cultivars of both early and late maturing types have also been identified. These include AH 139 and Spancross, which are drought resistant under Morogoro, condition (Tarimo and Mambo, 1995). Also ICGS 20 and ICGS 5 have been found to be drought tolerant in Botswana (Mayeux and Maphanyane, 1989).

Adams *et al.* (1993) reported that germination percentage and seedling survival is both highly correlated with seed - Ca concentration. Minimum seed Ca needed for maximum germination ranges between 368 and 414 mg/kg. Giller (1982) reported that, a well developed groundnut seed has a germination percentage of 85%. However, due to field problems, a standard seed can have germination percentage between 70 and 95% (Reddy, 1988). Mineral deficiencies may also reduce maximum viability at maturity leading to poor germination (Feistritzer, 1975).

Impurities such as weeds, other crop seeds or inert materials, may cause poor seed germination (Chatterjee and Battacharyya, 1986). It has also been documented that delayed harvesting has a profound effect on seed sprouting, pod rot and vermin attacks (Kafiriti, 1990). Thus, timely harvesting is important in maintaining seed quality. Other factors which affect seed germination include effects of seed treatments, destruction of seeds during lifting and moisture at harvesting time (Feistritzer, 1975).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

Field experiments were conducted at Sokoine University of Agriculture (SUA) Crop Museum and Horticulture Unit situated at Latitude 6°45" South and 37°40" East in the Morogoro region situated at 525 meters above sea level (m.a.s.l), Tanzania. Sokoine University of Agriculture is situated on the leeward side of Uluguru mountains which rise up to 2 200 m.a.s.l. The University is in an area which receives mean annual rainfall of between 600 mm and 800 mm. Rainfall distribution is bimodal with short intermittent rains falling between October and January and long rains between March and May. The temperatures are warm with a monthly average of 20°C to 30°C. The soils at the experimental sites were Oxic Haplustult and Dystric Nitisols according to USDA and FAO - UNESCO respectively as reported by Kaaya (1989).

The area under the 1st experiment had been previously cropped for several years after which it was left fallow for one year prior to its allocation to the experiment in January, 1998. The area under experiment 2 was grown with tomato crop before the experiment was set.

3.2 Soil Sampling

At planting for each experimental site, 45 soil samples were collected, one from each plot at 0 - 30 cm depth. Samples were mixed and a single composite sample was obtained for the determination of physical and chemical characteristics. This was repeated a week after harvesting to determine calcium level and pH value. Soil characteristics were determined using methods described by Bray and Kurtz (1945) and Walkley and Black (1965).

3.3 Land Preparation

In both experiments, land preparation was done using hoes. Extra care was taken so as to remove all the weeds such as sedge (*Cyperus* spp) and couch grass (*Digitaria* spp) in the experimental areas.

3.4 Experimental Design and Treatments

3.4.1 Experiment No. 1 (February - May, 1998)

3.4.1.1 Experimental layout

The experimental design was a split-plot in a randomised complete block with three replications planted at the crop Museum on 16 th February, 1998. The main plot gross size was 38 m^2, net plot size was 30 m^2. The subplot gross size was 6 m^2 while net size was 1 m^2. The main plot (factor A) was made of three groundnut cultivars (Baka, ICGV 86112 and Spancross). The sub plots (factor B) was comprised of calcium levels i.e. 0, 60, 100 and 140 kg Ca/ha obtained from wood ash and one treatment of 140 kg Ca/ha from hydrated lime. Each sub plot had six rows and two guard rows resulting into a total of eight rows per subplot. Each row was spaced at 50 cm and a length of 3 m. The spacing between plants was 10 cm giving a total population of 20 plants/m^2 or 200 000 plants/ha.

3.4.1.2 Planting and treatment application

Seeds were obtained from SUA's groundnut seed bank in the Department of Crop Science and Production. The seeds were shelled then grouped into grades as follows: first group contained seeds with large size, second group had seeds with medium size and third group was with seeds, which were very small and rotten. The grouping was done by visual observation and thereafter, large and medium seeds were tested for germination percentage before planting using blotters test method as described by Feistritzer (1975).

The tested cultivars were upright bunch of spanish - valencia types. The cultivars used take about 90 - 110 days to mature depending on prevailing weather condition. Cultivar Spancross had small seeds, light pink in colour. It was developed in USA. Where as Baka is a SUA landrace, with large seeds which are pink in colour. Cultivar ICGV 86112 is ICRISAT selection. Its seeds are large and pink in colour.

One seed was planted per hole at 5 cm depth in both experiments. Final emergence counts was done 10 DAS. Gap filling was done (11 DAS) so as to attain the plant population required per plot. At planting compound fertilizer in form of NPK 6:18:14 was applied at the rate of 22 kg P/ha. At early blooming (R_1) sulphate of ammonia (SA) with 21% N was applied at 13 kg N/ha so as to attain the required amount of 20 kg N/ha.

Wood ash applied in this study was mainly from the tree locally known as *Mlama* (*Combretum* spp) belonging to the family *Combretacea*. The wood ash was collected from Greek and Jambo bakeries in Morogoro Municipal. Hydrated lime bought from a dealer in Morogoro was also applied as one of the treatments. Before application, wood ash and hydrated lime nutrient content were determined using the methods described by Okalebo *et al.* (1993). The treatments were applied by banding method at early blooming (R_1).

3.4.2 Experiment No. 2 (April - August, 1998)

Similar experimental layout procedures were followed as explained in experiment No.1. However, this experiment was planted at SUA Horticulture Unit on 23 rd April, 1998.

3.5 Other Agronomic Activities

3.5.1 Weed control

Plots were maintained weed free by weeding whenever it became necessary. Weeds between the rows were removed using hoes and dibbling equipments. However, to avoid roots and peg disturbance weeds close to plants were hand pulled.

3.5.2 Earthing - up

Earthing - up was done at early blooming (when flowers were first noticed). The operation was carried out at the time of weeding, whereby the lower parts of the plant were buried in order to cover the pegs so that they could penetrate the soil surface to form pods. This process of Earthing - up also improves water infiltration by reducing the risk of water logging and plant lodging.

3.5.3 Disease and insect control

Leaf eating insects were controlled using Landecyhalothrin (Karate 5 EC) at the rate of 400 ml/20 L of water/ha. Termites were controlled by spraying aldrin at the rate of 75 g/15 L of water/ha. Zinc phosphide and bromadiolone (lanirate) were used to control rodents. No control measures were taken for diseases as the incidences were not high.

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3.5.4 Harvesting

Harvesting was done at physiological maturity (R_8) during the dry period when the leaves were rapidly senescing. At this stage few pods per plot were inspected and their nuts were found to be matured as their inner surface of the shells was beginning to turn brown in colour. Before harvesting, plots were irrigated to facilitate lifting.

3.6 Data Collection

3.6.1 Soil and wood ash physical and chemical characteristics

Before planting, soil samples from experimental sites were taken and sent to the Department of Soil Science at SUA laboratory for physical and chemical analysis. Also, one week after harvest, soil samples were taken again from the 15 cm upper layer and 5 cm from the rows and reanalysed for pH and exchangeable Ca.

3.6.2 Weather data

Weather data was collected from SUA Meteorological Station. These included: maximum and minimum temperature (^oC), rainfall (mm), evaporation (mm) and radiation (MJ/m^2).

3.6.3 Crop growth data

3.6.3.1 Growth stages

Growth stage descriptions were determined based on visually observable vegetative (V) and reproductive (R) events as described by Boote (1982). Both the vegetative and reproductive stages were taken when 50% of the plants in the sample demonstrated the desired trait.

3.6.3.2 Plant population

The plant population was taken after the crop had emerged fully i. e. 11 DAS, then at early blooming (R_1) and finally at harvest maturity (R_8) by counting all plants in the one metre square area of central part of each subplot. This plant population was used to determine plant population per metre squared.

3.6.3.3 Leaf area index

Leaf area index (LAI) was determined at full pod stage (R_4) at least when 50% of the plants in each subplot had one fully - expanded pod, depending on the dimensions of characteristic of the cultivar). To determine the leaf area, the length (L) of each foliate (leaflet) and maximum width (W) were determined using a ruler to the nearest centimetre. Leaf area was then determined as a product of length, width and a factor (K) determined for each leaflet. To obtain K, several leaflets had their areas determined using graph papers. Regression analysis between leaf area determined by using ruler and that of graph papers was used to determine K (IBSNAT, 1990). Thereafter, leaf area was calculated by multiplying the average number of tetrafoliates per plant (n) by the average length (L) and width (W) of tetrafoliate by an area constant K:-

LA = L x W x K x n

3.6.3.4 Biomass determination

Total dry matter (TDM) was determined at early blooming (R_1), full pod (R_4) and at harvest maturity (R_8). This was done by uprooting three plants from each subplot. Plants were then washed, partitioned into roots, stems and flowers, leaves, (pegs and pods when available). Sub samples were then oven dried to constant weight at 60°C for 48 hours and then weighed.

3.7 Crop Yield Data

3.7.1 Yield and yield components

Groundnut crop was harvested from one metre squared in the two centre rows of each subplot. Harvested nuts from each subplot were dried to about 10% moisture content.

Yield and yield components were then analysed. Yield components were determined as follows:-

3.7.1.1 Number of filled pods per plant

Counting of pods was done on each plant harvested from each subplot. A pod was regarded as a gynophore, which had developed seed or seeds in it. Average number of seeds per plant was determined by the use of the following relationship:-

$$\text{Number of pods/plant} = \frac{\text{Number of pods per } m^2}{\text{Number of plants harvested per } m^2}$$

3.7.1.2 Number of empty pods ("pops") per plant

The number of empty pods ("pops") per plant was determined by counting number of pods that had no seed (s) at shelling from each subplot and calculated using the following relationship:-

$$\text{Number of pops/plant} = \frac{\text{Number of pops per } m^2}{\text{Number of plants harvested per } m^2}$$

3.7.1.3 Number of seeds per pod

This was determined by calculating the number of seeds per 10 pods from each subplot using the following relation:-

$$\text{Seeds/pod} = \frac{\text{Number of seeds}}{\text{Number of pods}}$$

3.7.1.4 Seed size (seed weight)

One hundred seeds were picked from each seed lot of each subplot. After weighing, seed size was calculated using the following relationship:-

$$\text{Seed size (weight/seed)} = \frac{\text{100 seed weight}}{\text{100 seeds}}$$

3.7.1.5 Kernel yield

3.7.1.5.1 Seed yield per plant (g/plant) and kernel yield per m^2 and (kg/ha)

Seed yield per plant was determined using the following relationship:-

Number of pod/plant x number of seeds/pod x seed size (mg), while kernel yield per m^2 was determined by using the following relationship:-

Kernel yield/plant x plant population at harvest maturity (R_8). Then yield per m^2 was converted to yield per hectare basis.

3.8 Tissue Analysis

3.8.1 Determination of Ca concentration in leaves and stems

Calcium concentration was determined in leaves and stems at R_5 to assess the adequacy of the nutrient in the crop. Composite plant samples from each treatment were first cleaned with tap water, then distilled water and oven dried at 60°C for 48 hours. After grinding the samples, the groundnut material was digested for Ca determination using atomic spectrophotometer method as described by Robert and Kerber (1971).

3.8.2 Determination of seed calcium

At harvest maturity (R8), dried seeds of each treatment were digested and Ca was determined using atomic spectrophotometer method as described by Robert and Kerber (1971).

3.9 Seed Quality Determination

3.9.1 Shelling percentage

Shelling percentage was determined for each subplot using the following relationship:-

$$\text{Shelling percentage} = \frac{\text{Seed weight (dry)}}{\text{Pod weight (dry)}} \times 100$$

3.9.2 Seed size and germination test

Seed size was determined by weighing as described in section 3.7.1.4 and by measuring the diameter. Ten seeds from each harvested area were selected and their diameter measured using an electronic calliper (Sibuga, K. P, personal communication, 1998).

After grading according to the sizes, sub samples were taken from each seed lot for seed - Ca analysis and germination studies. Germination test was done for all seeds from each subplot using method described by Feistritzer (1975). Germination percentage data was taken after seven days.

3.9.3 Oil content

After harvesting sub samples were taken from each seed lot for oil determination using soxhlet method as described by Pomeranz and Meloan (1971).

3.10 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using a randomized complete block design (RCBD) for a split plot experiment as provided by MSTAT – C computer programme (MSU, 1993). Treatment means were separated using Duncan's multiple range test (DMRT). Seeds/pod, seed size, kernel yield, germination percentage etc were regressed against Ca levels applied using the CORR subroutine as provided by MSTAT - C statistical program. However, a number of variables such as LAI, Ca concentration in leaves , stems, and seeds, oil content and soil chemical characteristics at harvesting were not subjected to statistical analysis due to financial constraints involved in data collection.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 General Observations

The soils at both experimental sites were slightly acidic with the pH values of 6.6. The soils were clay and sandy clay loam with bulk density of 1.46 and 1.38 g/cm^3 for experiment 1 and 2, respectively. Both sites had low N, OC and CEC. However, the sites were found to have medium Ca, K, Mg and Na content (Table 1).

The major climatic variables such as temperature, rainfall, evaporation and radiation are shown in Table 2a and 2b. The parameters varied greatly between experiments. Mean maximum temperature was 33.8°C while the minimum temperature was 23.8°C during the February and March of the dry season, after which it decreased steadily to 31.8°C and 22.5°C for maximum and minimum temperatures, respectively, during the dry season. During the months of April and May average temperature were 29.1°C and 18.3°C for maximum and minimum, respectively. This was the time of the main rainy season. The June, July and August months were relatively very cool months averaging low values of 17.0°C for June, 16.0°C for July and 17.6°C for August.

Total weakly rainfall gradually decreased from February to August, while the evaporation was fluctuating during the same period depending on the average

Table 1. Physical and chemical characteristics of the soil at the experimental sites before planting

Soil properties	Determination Method	Experiment			
		Values		Comments[a]	
		1	2	1	2
pH (water)	pH meter	6.6	6.6	Slightly acidic	Slightly acidic
Bulk density (g/cm^3)	Core	1.5	1.4	Low	Low
Partical size distribution	Bouyoucos hydrometer				
Sand		33.2	60.8	Medium	High
Silt		15.8	14.0	Low	Low
Clay		51.0	25.2	High	Medium
Textural class				Clay	Sand clay loam
Moisture content (%)	Volumetric	44.6	10.0	Medium	Low
Total N (%)	Micro Kjeldahl	0.2	0.1	Low	Low
OC (%)	Walkley and Black, (1965)	0.9	0.8	Very low	Very low
Exchangeable cations:	Ammonium acetate extraction				
Ca (cmol/kg)		4.7	4.6	Medium	Medium
K (cmol/kg)		0.5	0.1	Medium	Medium
Mg (cmol/kg)		1.9	3.0	Medium	Medium
Na (cmol/kg)		0.5	0.2	Medium	Medium
CEC (cmol/kg)	Ammonium acetate extraction	12	10	Low	Low
Total P (ppm)	Bray 1and Kurtz, (1945)	35.0	14.7	Medium	Low

[a] According to Landon (1991).

Table 2a. Experiment 1. Weekly weather data

Month	Week	Temperature °C[a]		Radiation[a] MJ/m^2	Rainfall[b] (mm)	Evaporation[b] (mm)
		Maximum	Minimum			
February	1	32.7	25.6	21.2	72.7	43.9
	2	31.2	22.4	13.7	121.4	23.5
	3	31.7	21.4	16.2	68.5	25.1
	4	39.6	25.9	20.8	0.0	34.0
		(33.8)[c]	(23.8)[c]	(18.0)[c]	(262.6)[d]	(126.5)[d]
March	1	32.8	23.4	21.8	0.0	51.0
	2	30.7	22.9	17.0	44.1	37.6
	3	32.7	21.9	20.5	0.0	35.7
	4	31.0	21.9	16.6	70.7	35.0
		(31.8)	(22.5)	(19.0)	(114.8)	(159.3)
April	1	31.9	22.1	17.8	43.1	32.9
	2	26.1	19.3	12.9	78.9	28.2
	3	29.1	21.6	13.7	23.2	21.3
	4	29.1	19.2	11.5	71.9	24.9
		(29.1)	(20.6)	(14.0)	(217.1)	(107.3)
May	1	29.6	20.9	15.8	32.9	35.2
	2	30.7	21.3	17.6	10.1	26.6
	3	25.8	14.4	16.9	0.0	27.0
	4	29.3	16.7	16.9	1.7	25.1
		(28.9)	(18.3)	(16.8)	(44.7)	(113.9)

[a] Mean ambient air temperature

[b] Weekly totals

[c] Weekly means

[d] Monthly totals

Source: Meterological station, SUA, Morogoro, Tanzania.

Table 2 b. Experiment 2. Weekly weather data

Month	Week	Temperature°C[a]		Radiation[a] MJ/m^2	Rainfall[b] (mm)	Evaporation[b] (mm)
		Maximum	Minimum			
April	1	31.9	22.1	17.8	43.1	32.9
	2	26.1	19.3	12.9	78.9	28.2
	3	29.1	21.6	13.7	23.2	21.3
	4	29.1	19.2	11.5	71.9	24.9
		(29.1)[c]	(20.9)[c]	(14.0)[c]	(217.1)[d]	(107.3)[d]
May	1	29.6	20.9	15.8	32.9	35.2
	2	30.7	21.3	17.6	10.1	26.6
	3	25.8	14.4	16.9	0.00	27.0
	4	29.3	16.7	16.9	1.7	25.1
		(28.9)	(18.3)	(16.9)	(44.7)	(113.9)
June	1	29.7	19.9	14.9	11.1	23.9
	2	28.5	16.2	15.8	0.00	24.0
	3	28.0	14.2	14.6	0.00	28.0
	4	28.8	17.7	15.1	19.9	29.4
		(28.8)	(17.0)	(15.0)	(31.0)	(105.3)
July	1	27.4	15.4	11.9	0.00	24.0
	2	28.4	15.4	18.3	0.00	22.5
	3	26.6	16.3	12.6	0.00	23.5
	4	28.4	16.9	14.5	4.4	39.4
		(27.7)	(16.0)	(14.3)	(4.4)	(109.4)
August	1	28.5	18.6	14.7	0.00	33.0
	2	29.8	16.8	17.5	2.3	34.3
	3	29.5	17.0	16.9	4.0	32.5
	4	29.9	17.0	17.7	3.6	38.6
		(29.4)	(17.6)	(16.7)	(9.9)	(138.4)

[a] Mean ambient air temperature

[b] Weekly totals

[c] Weekly means

[d] Monthly totals

Source: Meterological station, SUA, Morogoro, Tanzania.

ding on the average temperature. The average daily incoming radiation during the second season was approximately 8.8% lower than that of the first season (Table 2a and 2b).

Germination of the groundnut crop was found to be neither epigeal nor hypogeal, but intermediate as the cotyledons were found to remain on the soil surface. Days to different growth stages for the cultivars used in the study are shown in Appendix 1. Number of days taken by the crop to attain specific growth stages in both experiments depended on the cultivar and the environmental conditions when the experiment was conducted. Cultivar Baka took 89 and 109 DAS to mature in experiments 1 and 2, respectively, while ICGV 86112 took 89 and 102 DAS, and Spancross took 83 and 109 DAS to mature. All cultivars took relatively longer period to reach harvest maturity growth stage in experiment 2 because of lower temperatures experienced during the cropping season (April to August) as shown in Table 2a and 2b. Cultivar and environmental conditions did not significantly affect days to first flowering i.e. R_1 growth stage.

The common diseases was seed rot due to (*Aspergillus* spp) as revealed from seed culturing results, early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Phaeoisariopsis personata*). Plants were also infected by groundnut rosette and pod rot disease. Disease severity was heavy in experiment 1 than in experiment 2. In both experiments cultivar Spancross was heavily affected by (*Aspergillus* spp) than cultivar Baka and ICGV 86112. Groundnut rosette infected severely cultivar ICGV 86112.

Insect pest attacks were observed and the insects included: Groundnut hopper (*H. patruelis* Stal.), army worm (*Spodoptera* spp), foliage beetle (*Ootheca bennigseni* salhb.), and termite (*Hodotermes mossambicus* Hagen.), dust brown beetle (*Gonocephalus simplex* F.) and bean fly (*Ophomia phaseoli* Tyron.). In addition to the above insects, the plants were destroyed by birds and rodents "Shamba rat" (*Mastomys natalensis*). Insect's infestation was heavy in experiment 1 than experiment 2.

The experiment sites were heavily infested with mixed sedges (*Cyperus* spp), couch grass (*Digitaria* spp) and star grass (*Cynodon dactylon*). Other weeds included: Goat weed (*Ageratum conyzoides*), black jack (*Bidens pilosa*), P.W.D weed (*Tridex procumbens*), wandering jew (*Commelina bengalensis*), wild finger millet (*Eleusine indica*), itch grass (*Rottboellia cochinchinensis*) and wild sorghum (*Sorghum halepense*).

Wood ash applied had a pH of 12.5 and 11.2 for experiment 1 and 2, respectively. However, the Ca contents for the two types of wood ashes used were 1.8 and 5.3%, for experiment 1 and 2, respectively. Although the hydrated lime had a pH of 12.1 similar to that of wood ash, its Ca content was more than 40 times higher than that of wood ash applied (Table 3

Table 3. Chemical properties of wood ash and hydrated lime used in the study

Property	Wood ash	Lime
	Value	
pH (Water)	12.5 (12.0)[1]	12.1
Total N (%)	0.9 (0.9)	ND
P (%)	0.1 (0.2)	0.7
K (%)	0.1 (0.2)	4.4
Ca (%)	1.8 (5.3)	59.1
Mg (%)	0.3 (0.4)	ND
Na (%)	0.5 (0.6)	ND
Mn (mg/l)	46 (52)	ND
Cu (mg/l)	118 (127)	ND
Zn (mg/l)	147 (139)	ND
Mo (mg/l)	14 (19)	ND

[1] Values in parantheses are for wood ash characteristics applied in experiment 2.

ND = Not determined.

4.2 Growth and Development

4.2.1 Plant population

There was significant cultivar effect ($P \leq 0.05$) on plant population at emergence (V_E), blooming (R_1) and at harvest maturity (R_8) in both experiments as shown in Table 4. The average number of plants/m^2 was 15.8, 17.7 and 16.5 in experiment 1, while in experiment 2 the average values were 13.6, 15.4 and 12.9 plants/m^2 at emergence , blooming and harvest maturity, respectively. Calcium levels applied had no significant effect on plant population in both experiments. At all sampling times the precision within treatments were reliable as the coefficient of variations ranged between 9.9% to 15.6% with the exception of that at harvest maturity (R_8) which was 19.4%. Such variation within the experiment may have been caused by birds, termites and rodents that attacked the crop at crop maturity. In general terms plant population at harvest maturity decreased by 5.5%, 8.0% and 49.5% for Baka, ICGV 86112 and Spancross cultivars, respectively.

4.2.2 Leaf area index

Leaf area index (LAI) at full pod stage (R4) was 3.8 for Spancross, 4.8 for ICGV 86112, and 5.6 for Baka in experiment 1, while in experiment 2 the LAI values ranged from 3.0 to 5.6 for the three cultivars (Table 5). The values obtained in the three cultivars are in agreement with the range of 3.3 to 7.0 as maximum LAI values for groundnut as reported by Enyi (1977) and Saxena *et al.* (1983). The present results show that

Table 4. Plant population (plants/m^2) at emergence, blooming and at harvest maturity

Treatment	Experiment					
	1			2		
Cultivar	V_E	R_1	R_8	V_E	R_1	R_8
Baka	18.9a	19.3a	18.9a	16.1a	17.5a	13.7b
ICGV 86112	18.3a	19.8a	18.4a	17.1a	18.7a	15.0a
Spancross	10.1b	14.1a	12.3b	7.5b	10.1b	10.1c
Mean	15.8	17.7	16.5	13.6	15.4	12.9
SE±	0.8	0.7	1.3	0.5	0.5	0.3
Calcium levels (kg/ha)						
0	16.8a	17.6a	17.1a	12.3a	14.9a	11.6a
60	16.2a	18.4a	17.7a	14.1a	16.1a	13.0a
100	15.8a	18.0a	16.4a	14.0a	15.9a	13.4a
140 (Ash)	14.8a	17.4a	15.9a	13.6a	15.2a	14.2a
140 (Lime)	15.4a	17.2a	15.6a	13.9a	15.2a	12.4a
Mean	15.8	17.7	16.4	13.6	15.4	12.9
SE±	0.7	0.6	0.7	0.6	0.8	0.8
CV (%)	13.1	9.9	12.7	12.4	15.6	19.4

Means in the same column followed by the same letter do not differ significantly ($P \leq 0.05$) according to Duncan's Multiple Range Test (DMRT).

V_E = Emergency R_1 = Blooming R_8 = Harvest maturity

SE = Standard error CV = Coefficient of variation

Table 5. Leaf area index (LAI) at full pod stage as influenced by groundnut cultivar and calcium levels applied

Treatment	Experiment	
Cultivar	1	2
Baka	5.4	3.3
ICGV 86112	4.8	3.3
Spancross	3.5	3.0
Mean	4.5	3.2
Calcium levels (kg Ca/ha)		
0	3.8	3.0
60	4.7	3.2
100	5.3	3.5
140 (Ash)	5.0	3.4
140 (lime)	3.9	3.0
Mean	4.5	3.2

Data was not subjected to statistical analysis.

maximum LAI values were in plots applied with 140 kg Ca/ha in form of wood ash. The high LAI values obtained due to application of wood ash may have been due to the effect of Ca, P and K released from the applied materials. Similar observation have been reported by Kimbi (1997) and Krejsl and Scanlon (1996) working with alfalfa and beans, respectively. Overall LAI values were higher in experiment 1 than those of experiment 2. In the studies conducted by Enyi (1977) on growth aspects of groundnut at Morogoro showed that Maximum 5.5 to 5.8. The peak LAI values were between 74 to 100 DAS depending on the types of groundnut cultivar and plant population level used.

4.3 Dry Matter Production

The dry matter production (accumulation) at R_4 growth stage increased by more than four times in some plots at harvest maturity (R_8) in both experiments as shown in Table 6. This increase was more pronounced in experiment 2 than in experiment 1. Most of the dry matter produced after treatment application occurred in the pods and stems. Similar results have been reported by Enyi (1977) in the study conducted at Morogoro using Natal common and Dodoma edible groundnut cultivars. The cultivar effect had no significant effect on TDM production at both sampling stages in experiment 1, but it had significant effect ($P \leq 0.05$) on TDM production at harvest maturity (R_8) in experiment 2. Cultivar Spancross had the highest TDM of 60.0 g/plant at harvest maturity (R_8), while Baka cultivar had the lowest TDM production of 28.5 g/plant. All these values were recorded in experiment 2. This results suggests that large leaf areas were not

Table 6. Total dry matter production response of three groundnut cultivars to calcium applied in form of wood ash and lime

Treatment	Experiment			
	1		2	
	g/plant			
Cultivar	R_4	R_8	R_4	R_8
Baka	16.6a	28.5a	13.3a	46.1b
ICGV 86112	20.2a	33.0a	14.7a	48.2b
Spancross	18.1a	34.7a	10.2a	60.0a
Mean	18.3	32.1	12.7	51.4
SE±	1.0	2.5	1.0	1.5
Calcium levels (kg Ca/ha)				
0	17.5a	27.8b	13.2a	54.1a
60	16.6a	32.7ab	14.8a	46.4a
100	17.5a	28.8b	11.3a	51.2a
140 (ash)	19.8a	40.7a	11.1a	52.7a
140 (lime)	20.3a	30.3b	13.1a	53.6a
Mean	18.3	32.1	12.7	51.4
SE±	1.4	3.0	1.0	4.2
CV (%)	22.3	27.6	23.6	24.7

Means in the same column followed by the same letter do not differ significantly ($P \leq 0.05$) according to DMRT.

R_4 = Full pod stage R_8 = Harvest maturity

SE = Standard error CV = Coefficient of variation necessarily an advantage as mutual shading could have occurred (Table 5). High CV (%) values could have been due to senescence where by, the crop shed its leaves and flowers.

4.4 Yield and Yield Components

Results on yield components are summarized in Table 7a and 7b. The three important components, which were used to determine yield of groundnut, were the number of pods/plant, seeds/pod and seed size (mg) as described by Fageria *et al.* (1997).

4.4.1 Number of filled pods/plant

The cultivar effect was significant ($P \leq 0.05$) with cultivar Spancross resulting into highest number of filled pods of 50.4 pods/plants, almost twice the number found on Baka and ICGV 86112 cultivars in experiment 1. In experiment 2, the cultivar effect was significant ($P \leq 0.05$) with cultivar Spancross producing 45.8 filled pods/plant, almost 40% higher than other cultivars used in the study. There was no significant interaction effect among cultivars and Ca levels applied in both experiments. These results show that this character is more related to genetic than environmental factors. This is supported by the observations that pods per plant were not significantly influenced by the amount applied in both experiments although the number ranged from 28.8 to 35.5 pods/plant in experiment 1, and 29.9 to 36.7 in experiment 2. The coefficient of variation for the number of filled pods per plant was 22.7 and 20.4% in experiment 1 and 2, respectively.

Table 7a. Experiment 1. Influence of applied calcium on yield and yield components of three groundnut cultivars

Treatment	Number of filled pods/plant	Seeds/pod	Seed size (mg)	Seed yield/plant (g)	Kernel yield (kg/ha)
Cultivar					
Baka	26.4b	1.9a	340.1b	17.1b	3 325.0a
ICGV 86112	25.3b	2.0a	380.5a	19.3b	3 599.0a
Spancross	50.4a	1.9a	283.7c	27.2a	3 418.0a
Mean	34.0	1.9	334.8	21.6	3 447.0
SE±	1.5	0.1	7.8	1.6	320.2
Calcium levels (kg Ca/ha)					
0	28.8a	1.9a	324.1a	17.7a	2 718.0a
60	35.3a	1.9a	344.2a	22.4a	3 831.0a
100	35.2a	2.0a	344.2a	23.5a	3 878.9a
140 (Ash)	35.5a	2.0a	329.3a	23.4a	3 462.0a
140 (Lime)	35.3a	2.0a	331.8a	23.4a	3 347.0a
Mean	34.0	2.0	334.7	22.8	3 447.0
SE±	2.6	0.1	7.2	1.8	337.8
CV (%)	22.7	8.3	6.4	25.3	29.4

Means in the same column followed by the same letter do not differ significantly at ($P \leq 0.05$) according to DMRT.

SE = Standard error

CV = Coefficient of variation

Table 7b. Experiment 2. Influence of applied calcium on yield and yield components of three groundnut cultivars

Treatment	Number of filled pods/plant	Seeds/pod	Seed size (mg)	Seed yield/plant (g)	Kernel yield (kg/ha)
Cultivar					
Baka	28.6b[1]	1.9a	392.1a	21.3a	2 862.0a
ICGV 86112	29.3b	2.0a	357.7b	21.0a	3 084.0a
Spancross	45.8a	1.7a	297.9c	23.2a	2 382.0a
Mean	34.6	1.9	349.2	21.8	2 776.0
SE±	3.1	0.1	5.0	2.0	229.0
Calcium levels (kg Ca/ha)					
0	36.1a	1.7a	344.5a	21.1a	2 478.0a
60	35.9a	1.9a	358.0a	24.4a	2 975.0a
100	36.7a	1.9a	356.5a	24.9a	3 163.0a
140 (Ash)	34.4a	1.9a	342.4a	22.4a	2 929.0a
140 (Lime)	29.9a	1.8a	344.7a	18.6a	2 335.0a
Mean	34.6	1.8	349.2	22.3a	2 776.0
SE±	2.4	0.1	12.8	1.7	321.2
CV (%)	20.8	12.8	11.0	23.7	34.7

Means in the same column followed by the same letter do not differ significantly at ($P \leq 0.05$) according to DMRT.

SE = Standard error

CV = Coefficient of variation

4.4.2 Seeds per pod

Statistical analysis showed that both cultivar and calcium levels applied had no significant effect ($P \leq 0.05$) on seed production per pod in both experiments. In all cultivars used and Ca levels applied seed per pod varied from 1 to 2. The results show that the average number of seeds per pod from 1.9 to 2.0 in experiment 1 and from 1.8 to 2.0 in experiment 2. These results show that the cultivar used are of Virginia group (Acland, 1971; Fageria *et al.*, 1997).

4.4.3 Seed size (100 kernel weight)

Seed size (mg) for cultivar Spancross was 283.7, 380.5 for cultivar ICGV 86112 and cultivar Baka had an average of 340.1 mg per seed in experiment 1. However, in experiment 2, the results were slightly different in the sense that although Spancross had the smallest seed, cultivar Baka had the heaviest seed of 392.1 mg while ICGV 86112 had seed size of 357.7 mg. Although cultivar effects were significant ($P \leq 0.05$) on seed size in both experiments, Ca levels and interaction between cultivars and Ca levels had no statistical significant effect. Similar results have been reported by Ngowi (1997) in the study conducted at Morogoro using bambara groundnut as a test crop.

The mean seed size values reported in this study 334.8 mg in experiment 1 and 349.2 mg in experiment 2 are within the seed values reported by Enyi (1977) and ICRISAT (1987). This differences might probably be due to genotypic variation, fertilizer application and climatical condition prevailed during the growth period. Similar results have been reported by Fageria *et al.*, (1997) The current study results indicated that the three yield components were more sensitive to cultivar effect than other conditions.

4.4.4 Seed yield

Groundnut yield per plant in this study is a function of filled (mature) pods per plant, seeds per pod and seed size (mg). Seed yield per plant was significantly ($P \leq 0.05$) influenced by cultivar used in this study (Appendix 2c). Cultivar Baka had a lowest seed yield per plant in both experiments averaging 17.1 g/plant in experiment 1 and 21.7 g/plant in experiment 2. In both experiments Spancross had highest seed yield/plant averaging 27.3 and 23.2 g/plant in experiment 1 and 2, respectively (Table 7a and 7b). In experiment 1 there was no significant interaction effect between cultivars and Ca levels applied on seed yield/plant.

On the other hand, there was significant ($P \leq 0.05$) interaction effect between cultivars and Ca levels applied on seed yield per plant in experiment 2 (Appendix 2d). The lowest seed yield/plant was observed in cultivar Spancross in combination with 140 kg Ca/ha (Lime), and the same cultivar in combination with 100 kg Ca/ha gave the highest seed yield/plant (Fig.1). As there was a significant interaction effect of Ca levels applied and seed yield/plant this suggests that seed yield responded differently to the Ca levels. Similar condition has been reported by Adams *et al.* (1993).

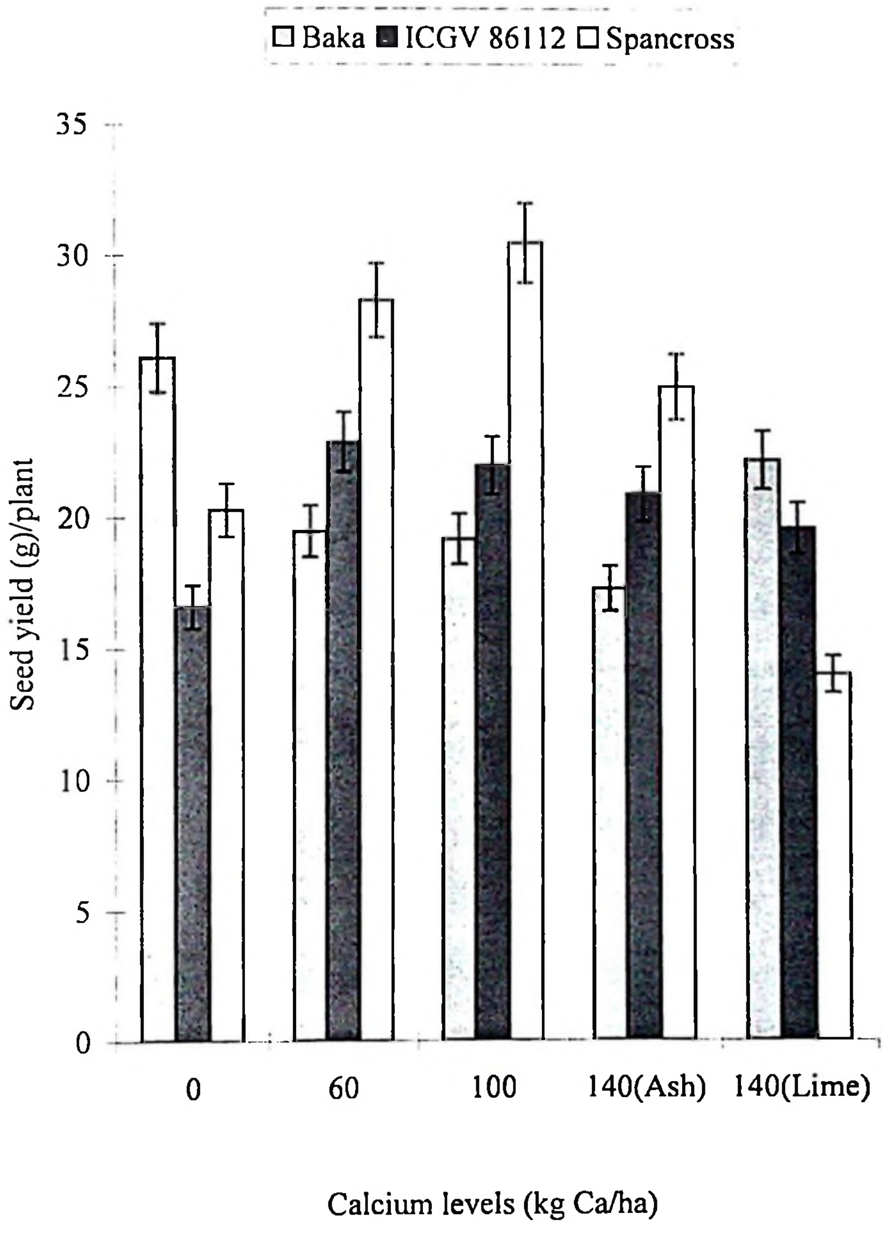

Fig.1. Experiment 2. Interaction effect between groundnut cultivars and Ca levels on seed yield per plant at harvest maturity. Bars denote standard errors.

4.4.5 Kernel yield per unit area

Kernel yield per unit area (ha) which was a product of pods per plant, number of seeds per pods, seed size (mg) and plant population (m^2) at harvest maturity (R_8) was not significant affected neither by cultivar nor Ca levels applied. Cultivar ICGV 86112 recorded the highest kernel yield per unit area (3 599 kg/ha) and lowest with cultivar Baka (3 325 kg/ha), whereas with Ca levels applied the range was between 3 878 kg/ha with 100 kg Ca/ha in form of wood ash and 2 718 kg/ha in experiment 1 with the control treatment (Table 7a). In experiment 2, kernel yield was highest in cultivar ICGV 86112 3 084 kg/ha and Spancross had the lowest kernel yield 2 382 kg/ha. Calcium levels of 100 kg applied per ha resulted into higher kernel yield of 3 163 kg/ha and lowest kernel yield of 2478 kg/ha in form of ash (Table 7b). Number of filled pods/plant, seed yield/plant and kernel yield (kg/ha) had high CV (%) values partially due to vermin attack at crop maturity. In experiment 1, high CV (%) values could also be due to pod rot caused by water logging which was the result of "El nino" effect.

In this study groundnut kernel yield/ha was higher than the values reported by Rweyemamu *et al.* (1998) which ranged between 1 385 and 1 797 kg/ha for different Ca levels applied under Morogoro condition. Increased kernel yield could probably be due to proper pod filling, better agronomic practices and favourable climatic conditions during the flowering and pod filling growth stages.

4.4.6 Number of "pops" per plant

In both experiments, there was no significant effect of neither cultivar nor Ca levels applied on the number of "pops"/plant (Appendices 2c and 2d). Also, there was no correlation between Ca levels applied and the number of "pops"/plant (Appendices 3a and 3b). However, the number of "pops"/plant was low in all cultivars compared to the range between 17 and 55% reported by Rweyemamu (1998). In this study, the number of "pops"/plant in experiment 1 ranged between 3.5 and 9.2%, while in experiment 2, the lowest was 1.2% and the highest was 4%. The reason for low "pop" incidence might possibly be due to adequate soil moisture at pod filling stage.

Failure of groundnut cultivars in this study to respond to application of supplemental Ca, implies that soil Ca deficiency alone may not be the only cause of "pops", although in practice Ca application remain the most acceptable method of reducing their occurrence. Furthermore, "pop" problem is more severe in varieties with three seeds per pod than those with two seeds per pod as reported in this study (Table 7a and 7b). Similar results have been reported by Keerati - Kasikorn *et al.* (1991).

4.5 Calcium Concentration in Leaves, Stems and Seeds

4.5.1 Calcium concentration in leaves and stems

Calcium concentration in leaves and stems are presented in Table 8a. The values recorded in experiment 1 are within the range shown by the literature, but those of stems

Table 8a. Effect of applied calcium on percentage calcium concentration in leaves and stems of three groundnut cultivars at R5 growth stage

Treatment	Experiment			
	1	2	1	2
	Leaves		Stems	
Cultivar				
Baka	1.5	0.7	0.8	0.5
ICGV 86112	1.4	0.8	0.8	0.5
Spancross	1.2	0.7	0.7	0.4
Mean	1.4	0.7	0.8	0.5
Calcium levels (kg Ca/ha)				
0	1.4	0.8	0.8	0.5
60	1.4	0.8	0.8	0.5
100	1.3	0.7	0.8	0.5
140 (Ash)	1.4	0.7	0.8	0.5
140 (Lime)	1.3	0.8	0.8	0.5
Mean	1.4	0.7	0.8	0.5

Data was not subjected to statistical analysis.

R_5 = beginning to seed

and for experiment 2 are slightly lower than the values indicated in the literature for adequate concentration of Ca when determined at early pod filling stage (R_5) with values from 1.3 to 1.8% (Jones *et al.*, 1991). In the present study the values ranged between 1.2 and 1.5% in leaves and between 0.7 and 0.8% in stems analysed from experiment 1, while in experiment 2 Ca concentration ranged between 0.7 and 0.8, and 0.4 and 0.5% in leaves and stems respectively.

In experiment 1, calcium concentration in leaves was within sufficient levels probably because there was adequate soil moisture for Ca to dissolve and translocated in the plant by transpiration system. Similar results have been reported by Mengel and Kirkby (1982) and Marschner (1995). The Ca concentration in stems was below expected levels probably due to the fact that large fraction of Ca might have been held on adsorption sites in the cell walls of the roots, pegs and pods as postulated by Bledsoe *et al.* (1949), Christiansen and Foy (1979), Mengel and Kirkby (1982). In experiment 2, low Ca concentration in leaves and stems might have been due to Ca immobility in the plants as its translocation is very little in the phloem (Mengel and Kirkby, 1982; Bunting *et al.*, 1985). Furthermore, high levels of K could have reduced Ca translocation and distribution from roots to shoots as K was rated medium in both experiments (Table 1). Therefore, with application of wood ash probably K rose to the extent of retarding Ca translocation (Kirkby, 1979). Generally, Ca concentration values were higher in experiment 1 than in experiment 2 probably due to environmental stress.

4.5.2 Calcium concentration in seeds

Seed - Ca concentration at harvest maturity (R_8) was 736.4 mg/kg 819.4 mg/kg and 912.8 mg/kg for cultivar Baka, ICGV 86112 and Spancross, respectively. In experiment 1, 100 kg Ca /ha had the highest values of 921.7 mg/kg and 140 kg Ca/ha registered the lowest seed - Ca concentration of 605.3 mg/kg. Whereas in experiment 2 the highest seed - Ca concentration value was recorded in Spancross 126.0 mg/kg, while the lowest was obtained in cultivar Baka. Concentration of Ca in seeds between Ca levels applied ranged from 80.7 to 132.3 mg/kg (Table 8b).

The results in experiment 1 were above the values between 368 and 414 mg/kg as reported by Adams *et al.* (1993), while those in experiment 2 were below the reported values in all cultivars and Ca levels applied. The reason for high concentration in experiment 1 could possibly be due to adequate Ca that was present in the pegging zone before peg development, thus roots and pegs were able to utilise Ca for seed development. In addition, soil moisture may have been adequate for diffusion and active processes to take place which facilitated Ca to be taken by fruits (Table 2a).

4.6 Seed Quality

4.6.1 Seed diameter

As observed earlier groundnut seed size was significantly affected by cultivars used as shown in Tables 7a and 7b. In experiment 1, cultivar had no significant effect on seed

Table 8b. Effect of applied calcium on calcium concentration in Seeds (mg/kg) of three groundnut cultivars at harvest maturity

Treatment	Experiment	
Cultivar	1	2
Baka	736.4	73.0
ICGV 86112	819.4	126.0
Spancross	912.8	114.0
Mean	822.9	104.3
Calcium levels (kg Ca/ha)		
0	855.0	104.7
60	855.0	111.3
100	921.7	80.7
140 (Ash)	605.3	92.7
140 (Lime)	877.3	132.3
Mean	822.9	104.3

Data was not subjected to statistical analysis.

diameter (Table 9a), whereas in experiment 2, seed diameter was significantly ($P \leq 0.05$) influenced by groundnut cultivars used in this study as shown in Table 9b. Cultivar Baka had the highest diameter of (8.2 mm) followed by Spancross and finally ICGV 86112 (7.6 mm). On average, seeds from experiment 1 had smaller seeds than those from experiment 2, which averaged 7.4 and 7.9 mm, respectively (Table 9a). The applied Ca levels in both wood ash and lime did not significantly influence seed diameter in both experiments (Table 9a and 9b).

Differences in seed diameter between the two experiments might possibly be due to differences in soil type between the two sites. Experiment 1 had clay type of soil (Table 1), which could have restricted the expansion of pods resulting to reduced seed diameter as reported by Owen and Ireri (1990) on tuber crop. This could have been true for groundnut, which has its gynophore first penetrating the soil, then the pod developing close to the soil surface.

In experiment 2 sandy clay loam allowed more pod expansion, thus resulting to higher seed diameter. Further, this could have been due to positive interaction between cultivar and Ca levels applied, which influenced seed quality (size). Some workers have reported significant effect of Ca nutrient on seed quality (size) (Bunting *et al.*, 1985; Conkerton *et al.*, 1989).

Table 9a. Experiment 1. Influence of applied calcium on seed quality factors of three groundnut cultivars

Treatment	Seed diameter (mm)	Germination (%)	Shelling (%)	Oil Content (%)[1]
Cultivar				
Baka	7.6a	70.0b	72.2a	48.7
ICGV 86112	7.5a	77.3b	73.7a	48.4
Spancross	7.1a	92.7a	69.2a	49.7
Mean	7.4	80.0	71.7	48.9
SE±	0.2	5.5	2.3	
Calcium levels (kg Ca/ha)				
0	7.2a	82.2a	73.4a	48.9
60	7.5a	83.3a	70.4a	48.9
100	7.5a	86.7a	75.4a	48.2
140 (Ash)	7.5a	74.4a	69.6a	48.4
140 (Lime)	7.4a	73.3a	69.7a	50.1
Mean	7.4	80.0	71.7	48.9
SE±	0.1	6.1	3.1	
CV (%)	4.1	22.8	12.8	

Means in the same column followed by the same letter do not differ significantly at ($P \leq 0.05$) according to DMRT.

SE = Standard error of the mean

CV = Coefficient of variation

[1] Data was not subjected to statistical analysis

Table 9b. Experiment 2. Influence of applied calcium on seed quality factors of three groundnut cultivars

Treatment	Seed diameter (mm)	Germination (%)	Shelling (%)	Oil content (%)[1]
Cultivar				
Baka	8.2a	48.0a	73.4a	44.3
ICGV 86112	7.6b	50.7a	75.4a	42.5
Spancross	7.8b	64.7a	78.6a	44.9
Mean	7.9	54.5	75.8	43.9
SE±	0.1	7.1	2.7	
Calcium levels (kg Ca/ha)				
0	7.8a	50.0a	78.5a	44.3
60	7.9a	50.0a	76.0a	44.2
100	8.0a	56.7a	76.8a	43.5
140 (Ash)	7.9a	57.8a	74.5a	44.5
140 (Lime)	7.9a	57.8a	73.2a	43.1
Mean	7.9	54.5	75.8	43.9
SE±	0.1	8.0	2.3	
CV (%)	3.3	43.8	8.8	

Means in the same column followed by the same letter do not differ significantly at ($P \leq 0.05$) according to DMRT.

SE = Standard error of the mean

CV = Coefficient of variation

[1] Data was not subjected to statistical analysis

Seed diameter is an important characteristic as it is generally held that, larger seeds results into high germination rates, vigorous growth and eventually high yields (Haper and Obeid, 1967). Thus, increased seed size attributed to large seed diameter contributes to an increase in yield and marketable seeds. In addition, increased seed diameter is useful during mechanical sowing.

4.6.2 Seed germination of sound mature kernels

Cultivars, Ca levels, and interactions between cultivar and Ca levels were not significant at ($P \leq 0.05$) level in the analysis of variance (Appendices 2c and 2d). At the time of conducting this study 75.0% germination was the minimum permitted for labelling seed as certified in Tanzania. This is according to the rules and regulations given by the Tanzanian government (URT, 1976).

Overall germination percentage values were higher in experiment 1 (averaging 80.0%) than in experiment 2 (averaging 54.5%) as indicated in Table 9a and 9b. The average germination percentage in experiment 1 was approximately 26% higher than that of experiment 2. Such variation in germination percentage among experiments could be critical for groundnut farmers in Tanzania. The disparity in seed germination percentages in this study is probably due to fungal infection (*Aspergillus* spp), period required to break seed dormancy in groundnut and seed - Ca in case of experiment 2 which were below the minimum values (Table 8b) and the medium soil Ca recorded at planting

(Table 1). Also, low germination percentage in experiment 2, may be due to the fact that groundnuts usually have variable germination tests results (Sullivan and Wynne, 1979) and reasons contributing to such variability have not been determined (Wynne and Sullivan, 1978; Sullivan and Wynne, 1979). Such germination test results have also led TANSEED to deal with other crops such as beans, soybean etc and not groundnut. Germination percentage tests had higher CV (%) values in both experiments due to fungal infection and seed dormancy.

When the Ca levels applied were correlated with germination percentage, correlation coefficient in experiment 1 and 2 were positive for all cultivars, although the coefficients were not significant (Appendices 3a and 3b). Literature shows that soil Ca is required for producing high quality seed (Adams *et al.*, 1993). Therefore, application of Ca in seed multiplication may result into relatively seed with better quality for higher yields.

4.6.3 Shelling percentage

In both experiments there was no significant effect among cultivar and between Ca levels applied. Also, there were no significant differences on shelling percentage. (Table 9a and 9b). The entries with relatively high shelling percentage values gave relatively higher kernel yield/ha possibly due to larger seeds Table 7a and 7b. Furthermore, there was a significant positive correlation between applied Ca with seeds/pod and seed yield (g/plant) r = 0.96 and r = 0.99, respectively (Appendices 3a and 3b).

In experiment 2 cultivar Baka had the lowest shelling percentage of 73.4% followed by ICGV 86112 with intermediate values of 75.4% and Spancross had the highest shelling percentage of 78.6% among the three cultivars. The shelling percentage between Ca levels applied ranged between 73.2 and 78.5% (Table 9b). Again the cultivars with relatively highest shelling percentage gave relatively higher seed yield (g/plant). The values reported in this study is in agreement with those reported by Acland (1971) and Raman (1988). The reasons of higher shelling percentage in experiment 2 could possibly be associated with better pod filling and efficient in photosynthesis.

4.6.4 Oil content

There was no interaction effect of cultivars x Ca levels on oil content. In experiment 1, oil content ranged between 48.4 and 49.7% and between 48.2 and 50.1% among cultivars and between Ca levels respectively (Table 9a). The values reported in this study were slightly higher than the range of 41.7 and 46.9% observed at Nghambi village Mpwapwa district, Dodoma as reported by Sibuga *et al.* (1995). In experiment 2, oil content ranged between 42.5 and 44.9% among cultivars and 43.1 and 44.5% between Ca levels applied (Table 9b). These values were within the range of 43.0 and 46.1% recorded in Madoto village Kilosa district, Morogoro as reported by Sibuga *et al.* (1995). The oil content results in this study indicate stability of this character under different cultivars and varying rates of Ca applied. Also it shows that cultivars are genotypically same in amount of oil content they contain.

4.7 Soil Chemical Characteristics at Harvest Maturity

Some soil chemical characteristics at harvest maturity (R_8) as influenced by applied Ca treatments are shown in Table 10. In experiment 1, there were slight changes in soil pH compared to the initial values. The mean value among the cultivars and between Ca levels applied was 6.9, which was an increase of 4.5%. Whereas in experiment 2, the average pH value was 7.4 among cultivars and between Ca levels applied resulting into 10.8% increase compared to the initial soil pH (Table 1). In both experiments, plot treated with wood ash had highest pH values.

Overall increase in soil pH could be due to the fact that, wood ash and hydrated lime neutralised hydrogen ions as they normally have high content of oxide and hydroxide ion which reacts more quickly to cause rise in soil pH. This is supported by Conyers and Scott (1989) findings. Other workers have also reported increase in soil pH as a result of wood ash and hydrated lime application (Clapham and Zibilske, 1992; Kimbi, 1997).

In the present study, results shows that there was an increase in soil residual exchangeable Ca in both experiments after harvest. The average Ca content in experiment 1 was 16.3 cmol/kg and in experiment 2 it was 7.7 cmol/kg. The residual

Table 10. Some soil chemical characteristics at crop harvest as influenced by cultivars and calcium levels applied

Treatment	Experiment			
Cultivar	1		2	
	PH	Ca (cmol/kg)	PH	Ca (cmol/kg)
Baka	7.0	18.0	7.4	8.5
ICGV 86112	6.8	14.0	7.5	7.2
Spancross	7.0	16.9	7.4	7.3
Mean	6.9	16.3	7.4	7.7
Calcium levels (kg Ca/ha)				
0	6.4	10.4	6.6	6.5
60	7.1	13.2	7.4	7.5
100	7.2	20.0	7.7	8.8
140 (Ash)	7.4	26.7	7.8	9.3
140 (Lime)	6.6	11.3	7.6	6.3
Mean	6.9	16.3	7.4	7.7

Data was not subjected to statistcal analysis.

exchangeable Ca was high in experiment 1 and medium in experiment 2. In this study, both wood ash and hydrated lime increased the exchangeable Ca above the proposed critical levels of 4.5 cmol/kg reported by Ndakidemi (1992). This could be attributed to the fact that, most of the Ca may have come from the soil rather than from the applied materials as reported by Kimbi (1997). For example the type of clay with a 2:1 layer such as that at experiment site 1 does retain large amounts of Ca during the crop growth period (Prasad and Power, 1997).

Present results show that cultivar treatments had significant effects ($P \leq 0.05$) on most variables analysed in both experiment 1 and 2. However, Ca levels applied and interaction of cultivars x Ca levels had no significant effects (Appendices 2a, 2b, 2c and 2d). Such results may have been influenced by the type of clay found at the experimental sites. Literature shows that clay with 2:1 layer has a great capacity to absorb water and swell in vertical direction. This was the case at experiment 1 site. Further, soils with 2:1 layer silicates have a high CEC and can thus retain larger amounts of Ca. In such acid soils, Ca levels may be too low to be absorbed by the plants (Prasad and Power, 1997).

Experiment 2 was grown during the dry season. Therefore, although irrigation was applied, water stress experienced at different growth stages after flowering may have affected Ca uptake and distribution in the groundnut crop (Hartmond *et al.*, 1992). Although the exchangeable Al was not determined, Al - Ca antagonism may also have affected the availability of Ca to plants as reported by Foy (1992). Another reason for a non significant response to applied Ca could have also been partially due to the initial soil Ca levels, which were found to be of medium levels at both sites (4.7 and 4.6 cmol/kg at experiment 1 and 2, respectively as shown in Table 1). In addition, the groundnut cultivars used in this study were bunch types which give somewhat lower response to Ca application than do runner types (Hartmond *et al.*, 1992).

Under normal conditions, Ca requirements for plant growth are very low when other cation are in balance (Kirkby, 1979). In this study application of wood ash may have created cationic imbalance as it also contained other nutrients such as Mg and K beside Ca (Table 3). Thus, the antagonism effect in Ca uptake with other elements such as Mg and K could have resulted as described by Kirkby and Mengel (1979) and Marschner (1995).

4.8 Limitation of Wood ash Use in Tanzania

Basing on the results of this study it can be deduced that, although wood ash can be used as a direct source of Ca to groundnut production, there are some limitations which could hinder the effective use of the material under Tanzanian conditions.

Firstly, the chemical properties of wood ash do depend on the type of wood ash used, the temperature of combustion and the type of combustion system used (Campbell, 1990).

Such conditions may result into wood ash with a wide range of chemical characteristics. Secondly, the availability of nutrients in wood ash depends also on the rate of wood ash applied in the soil and subsequent soil chemical reactions (Ohno, 1992). Thus, if the soil is alkaline, Ca in wood ash is much less soluble and less available for crop uptake (Ohno and Erich, 1990) which may result in requirement to apply larger amounts of wood ash so as to attain the required amount of Ca for the crop. Such conditions may result in non availability, transportation and application problems in some places especially at small scale farming.

Thirdly, since different plant spp vary greatly in the richness of ash nutrient content, therefore all wood ash ought to be applied after chemical analysis have been conducted for both wood ash to be applied and to the soil where it is to be applied. This may be expensive or even impossible at small scale farm level under Tanzanian conditions.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The results of this study indicate that environmental conditions, initial soil conditions, the amount and distribution of rainfall and temperature during the crop growing periods had a large influence on the effect of the performance of groundnut growth, kernel yield and seed quality.

Groundnut cultivars had a significant effect on yield components, kernel yield and seed quality. The number of filled pods/plant, seed size, seed yield/plant and seed diameter differed significantly ($P \leq 0.05$) among the cultivars. Cultivar Spancross had the highest number of filled pods and seed yield/plant due to its genotypic characteristics and proper pod filling. The highest kernel yield/ha was recorded with cultivar ICGV 86112 in both experiments due to better plant establishment and proper pod filling. Seed diameter was significantly influenced by cultivar effect in experiment 2 than 1 (Appendices 2c and 2d). Due to its superior character on yield components, cultivar Spancross can be used in groundnut producing areas , for that case better agronomic practices are required to ensure optimum plant density per ha is achieved.

Also, there was mostly no significant Ca level and cultivar -by - Ca level interaction effect suggesting that cultivars did not respond to additional Ca, or that there was no difference in Ca uptake among the cultivars used in this study. However, a significant cultivar - by - Ca level interaction on seed yield/plant does suggest that cultivars responded differently to additional Ca on this character.

The result of correlation between germination percentage and applied Ca levels may have been influenced by the method used to select kernels for testing as this may have worked against the significant correlation. This assumption is so because only the sound mature kernels (SMKs) were chosen thus eliminating all shrivels and immature kernels which may have resulted in low germination. Therefore, the major effect of Ca on groundnut may have been reduced due to kernel sampling technique used in this study (Appendices 3a and 3b).

Soil chemical properties taken after crop harvest do show that the applied Ca levels had an increasing effect on soil pH and exchangeable soil Ca at the end of each experiment indicating that with large production of wood ash, these materials may be used for liming acid soils. Therefore, wood ash disposal may both be environmentally and economically friendly contributing to a more sustainable agricultural system.

Finally, the present preliminary results do show that wood ash may be more advantageous in sustaining long - term site productivity and supply of Ca element in groundnut production.

5.2 Recommendations

Since the present study results are based from experiments conducted at one location, it is recommended that some more data are needed to extrapolate current responses across a range of sites in Tanzania where groundnut crop is grown.

Spancross being superior cultivar among the three tested in terms of yield and yield components, breeder may use this cultivar to improve other local varieties.

More studies should also be conducted so as to ascertain the wood ash environmental effects due to potentially toxic heavy metals and nutrients under Tanzanian conditions.

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APPENDICES

Appendix 1. Groundnut growth stage description used in the study

Groundnut cultivars and days taken to attain the growth stage			Growth stage code[1]	Growth stage description[1]
Baka	ICGV 86112	Spancross		
5 (8)*	4 (8)	5 (12)	VE	Emergence, cotyledons near the soil surface and some part of the plant visible
25 (32)	24 (32)	24 (35)	R_1	50% of the plants with at least one open flower.
36 (39)	36 (39)	27 (42)	R_2	50% of plants beginning to peg i.e. with one elongated peg (gynophore)
42 (49)	42 (49)	37 (50)	R_3	Beginning to pod
48 (54)	48 (53)	44 (56)	R_4	Full pod size
60 (67)	60 (59)	58 (63)	R_5	Beginning to seed
75 (74)	75 (69)	69 (74)	R_6	Full seed size
86 (88)	86 (81)	76 (88)	R_7	Beginning to mature
89 (109)	89 (102)	83 (109)	R_8	Harvest maturity

[1] According to Boote (1982).

* Values in parentheses refer to data collected from experiment 2.

Appendix 2a. Experiment 1. Summary of analysis of variance showing mean squares for various variables determined at different growth stages

Variable analyzed	Cultivar effect (factor A)	Ca level effect (factor B)	Interaction (AxB)
Plant population/m^2 at V_E	362.6 **	5.1 ns	6.4 ns
Plant population/m^2 at R_1	146.9 **	2.1 ns	2.7 ns
Plant population/m^2 at R_8	199.3 *	6.7 ns	4.1 ns
Stem dry matter (g/plant) at R_4	29.4 **	4.2 ns	6.3 ns
Leaf dry matter (g/plant) at R_4	2.4 ns	7.2 ns	4.9 ns
Peg dry matter (g/plant)at R_4	0.1 ns	0.0 2 ns	0.02 ns
Pod dry matter (g/plant) at R_4	1.1 ns	0.3 ns	0.4 ns
Root dry matter (g/plant) at R_4	0.1 *	0.03 ns	0.02 ns
Total dry matter (g/plant) at R_4	49.4 ns	23.8 ns	17.4 ns
Stem dry matter (g/plant) at R_8	2.4 ns	12.9 ns	5.0 ns
Leaf dry matter(g/plant)at R_8	51.5 ns	14.0 ns	13.9 ns
Peg dry matter (g/plant) at R_8	2.5 **	0.1 ns	0.1 ns
Pod dry matter (g/plant) at R_8	20.5 ns	89.8 ns	30.0 ns
Root dry matter(g/plant) at R_8	0.0 ns	0.01ns	0.02 ns
Total dry matter (g/plant) at R_8	155.8 ns	239.9 *	84.3 ns

* = Significant at ($P \leq 0.05$)

** = Significant at ($P \leq 0.01$)

ns = Not significant

Appendix 2b. Experiment 2. Summary of analysis of variance showing mean squares for various variables determined at different growth stages

Variable analyzed	Cultivar effect (factor A)	Ca level effect (factor B)	Interaction (AxB)
Plant population/m^2 at V_E	423.9 **	4.7 ns	5.7 ns
Plant population/m^2 at R_1	325.4 **	2.4 ns	1.5 ns
Plant population/m^2 at R_8	98.5 **	9.1 ns	7.0 ns
Stem dry matter (g/plant) at R_4	8.4 **	3.2 ns	1.4 ns
Leaf dry matter (g/plant) at R_4	29.8 ns	4.8 ns	10.0 ns
Peg dry matter (g/plant) at R_4	0.04ns	0.1 ns	0.2 ns
Pod dry matter (g/plant) at R_4	1.5 ns	0.3 ns	1.2 ns
Root dry matter (g/plant) at R_4	0.0 ns	0.01 ns	0.03 *
Total dry matter (g/plant) at R_4	77.7 ns	20.5 ns	18.9 ns
Stem dry matter (g/plant) at R_8	149.0 *	1.2 ns	16.8 ns
Leaf dry matter (g/plant) at R_8	213.8 *	8.8 ns	12.3 ns
Peg dry matter (g/plant) at R_8	10.8 **	0.4 ns	1.1 ns
Pod dry matter (g/plant) at R_8	4.3 ns	24.7 ns	32.9 ns
Root dry matter (g/plant) at R_8	1.6 *	0.1 ns	0.1 ns
Total dry matter (g/plant) at R_8	842.5 **	77.5 ns	181.8 ns

* = Significant at ($P \leq 0.05$)

** = Significant at ($P \leq 0.01$)

ns = Not significant

Appendix 2 c. Experiment 1. Summary of analysis of variance showing mean squares for various variables determined after harvest maturity

Variable analyzed	Cultivar effect (factor A)	Ca level effect (factor B)	Interaction (AxB)
"Pops"/plant	2.7 ns	0.7 ns	2.0 ns
Filled pods/plant	3 005.4 **	77.0 ns	31.1 ns
Seeds/pod	0.1 ns	0.04 ns	0.04 ns
Seed yield (g)/plant	430.3 *	76.8 ns	26.2 ns
Kernel yield (g/m^2)	2 909.2 ns	19 694.3 ns	10 539.4 ns
Kernel yield (kg/ha)	29 092.4 ns	1 969 430.3 ns	1 053 942.9 ns
Seed size (mg)	35 458.4 **	744.3 ns	448.8 ns
Seed diameter (mm)	0.1 ns	0.03 ns	0.1 ns
Shelling (%)	77.3 ns	60.0 ns	26.6 ns
Germination (%)	2 006.7 ns	305.6 ns	378.9 ns

* = Significant at ($P \leq 0.05$)

** = Significant at ($P \leq 0.01$)

ns = Not significant

Appendix 2 d. Experiment 2. Summary of analysis of variance showing mean squares for vaious variables determined after harvest maturity

Variable analyzed	Cultivar effect (factor A)	Ca level effect (factor B)	Interaction (AxB)
"Pops"/plant	1.0 ns	0.9 ns	0.3 ns
Filled pods/plant	1 425.9 *	68.5 ns	86.5 ns
Seeds/pod	0.2 ns	0.04 ns	0.1 ns
Seed yield (g)/plant	45.6 ns	42.2 ns	70.0*
Kernel yield (g/m^2)	19 346.8 ns	1 169.4 ns	11 626.9 ns
Kernel yield (kg/ha)	1 935 036.6 ns	1 116 823.8 ns	1 162 635.8ns
Seed size (mg)	34 045.7 **	495.7 ns	494.4 ns
Seed diameter (mm)	1.2 **	0.04 ns	0.04 ns
Shelling (%)	103.5 ns	37.6 ns	49.3 ns
Germination (%)	1 202.2 ns	150.0 ns	530.0 ns

* = Significant at ($P \leq 0.05$)

** = Significant at ($P \leq 0.01$)

ns = Not significant

Appendix 3a. Experiment 1. Simple correlation between calcium levels applied and various groundnut characteristics

Characteristics	Cultivars		
	Baka	ICGV 86112	Spancross
Pegs/plant	-0.27 ns	0.79 ns	0.47 ns
Number of filled pods/plant	0.77 ns	0.94 *	0.59 ns
"Pops"/plamt	0.27 ns	-0.93 **	-0.39 ns
Seeds/pod	0.68 ns	0.96 **	0.17 ns
Seed yield/plant (g)	0.73 ns	0.99 **	0.58 ns
Seed size (mg)	0.45 ns	-0.58 ns	0.30 ns
Seed Ca (mg/kg)	0.73 ns	0.28 ns	-0.48 ns
Germination (%)	0.67 ns	0.53 ns	0.76 ns

* = Significant at ($P \leq 0.05$)

** = Significant at ($P \leq 0.01$)

ns = Not significant

Appendix 3b. Experiment 2. Simple correlation between calcium levels applied and various groundnut charactristics

Characteristics	Cultivars		
	Baka	ICGV 86112	Spancross
Peg/plant	-0.14 ns	-0.98 **	0.63 ns
Number filled pods/plant	-0.84 ns	0.31 ns	0.40 ns
"Pops"/plant	-0.81 ns	-0.84 ns	0.23 ns
Seeds/pod	-0.99 **	0.79 ns	0.93 *
Seed yield/plant (g)	-0.94 *	0.64 ns	0.54 ns
Seed size (mg)	-0.05 ns	0.61 ns	-0.60 ns
Seed Ca (mg/kg)	0.08 ns	-0.17 ns	0.29 ns
Germination (%)	0.50 ns	0.55 ns	0.40 ns

* = Significant at ($P \leq 0.05$)

** = Significant at ($P \leq 0.01$)

ns = Not Significant