YIELD, PROTEIN AND OIL CONTENT OF SELECTED GROUNDNUT CULTIVARS GROWN AT TWO LOCATIONS IN THE EASTERN CAPE, SOUTH AFRICA

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DECLARATION

I, Thozamile Nzuzo Mbonwa hereby declare that except for references to other people's work, which have been duly cited, this work is the result of my own original work. I further declare that this work has neither in whole nor in part been published by another person or presented for the award of degree elsewhere.

Signature _____

Thozamile Nzuzo Mbonwa

I, Albert Thembinkosi Modi, supervised the above candidate in the conduct of his dissertation study.

Signature _____

Prof. A.T. Modi

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GENERAL ABSTRACT

The Eastern Cape Province of South Africa has climatic conditions which differ from region to region. The groundnut (*Arachis hypogaea L.*) cultivars, as it is the case with other crops, do not always perform equally well in the varying conditions. Abiotic stresses such as drought, extreme temperatures, and high soil acidity restrict plant growth. Lack of studies on adaptability of commercial groundnut cultivars in the Eastern Cape necessitated this study. Abiotic and biotic factors are not the only limiting factors: calcium availability in the soil is also a limiting factor in groundnut production. The aim of the study was to identify best suited cultivars for climatic conditions of Mthatha and Lusikisiki regions of the Eastern Cape. Two similar field experiments were conducted in the two locations with different climatic conditions. The results showed significant differences ($P<0.05$) in genotypes with respect to seed yield in both locations. Kwarts produced higher seed yield of 1155 kg ha^{-1} in Mthatha, while the same genotype produced low seed yield of 630 kg ha^{-1} in Lusikisiki location. In Lusikisiki the highest seed yield was recorded in Anel (936 kg ha^{-1}) which produced low yield of 692 kg ha^{-1} in Mthatha. The genotypes that performed well in Mthatha in 2010/11 season included Kwarts, Nyanda, ICGV-SM 95714 and Mwenje. These genotypes were further used to investigate their response to calcium supplementation at flowering stage under conditions of Mthatha in the 2011/12 season. The results were significantly different for calcium absorption ($P<0.05$). Nyanda, Kwarts and Mwenje responded positively to calcium application at flowering stage producing relatively high yield of 153, 150 and 110 kg ha^{-1}, respectively. Oil content was significantly increased by calcium application at flowering in Nyanda with 27.28% compared to 20.7% without Ca.

Key words: Calcium, climatic conditions, groundnut, genotypes, seed yield, oil content, protein content

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1. LITERATUE REVIEW

1.1 Origin and distribution

Groundnut (*Arachis hypogaea L.*) is a self-pollinated leguminous crop which is believed to have originated from Latin America where it was grown by the Indian communities, but now its cultivation has spread throughout the tropical and temperate climates of the world (Lapedes, 1977; Van der Merwe and Joubert, 1995). Two-seeded types originating from Brazil were taken to Africa, whereas three-seeded types originated from Peru and were transported from the west coast of South America to China and islands in the western Pacific (Hammons, 1982). Spanish types were introduced to Europe in the late 1700s from Brazil and grown for oil and for human consumption as chocolate-covered peanuts (Stalker, 1997). Groundnut is among the most important legume crops in Sub-Saharan Africa (Lapedes, 1977).

Groundnuts are grown extensively in most countries in sub-Saharan Africa, and are of major importance to smallholder farmers, being their principal source of cash income and food crop. Production in the region, however, has declined in recent years (Nkambune, 1994). The major constraints are diseases (in all countries except Botswana and Namibia, where rainfall is the major limiting factor) and the lack of suitable varieties (Nkambune, 1994). Yields are low, ranging from 400 to 700 kg ha^{-1}, in marked contrast to yields of 4 t ha^{-1} obtained on research stations and large-scale farms. There is thus considerable potential for increasing smallholder groundnut yields in the region, and thereby improving food security (Nkambune, 1994).

Groundnut is mainly produced in the western regions of South Africa, with 40% of production taking place in the western and north-western Free State, 29% in the North West and 24% in the Northern Cape. In Limpopo and Mpumalanga, production is low. Groundnut production increased significantly (200 000 tons) during the 2000/01 season because of larger planting areas (± 140 000 ha) (ARC-Groundnut production guide, 2010). The commercial sector is highly specialized and accounts for about 80% of the total annual area and production. Besides commercial farming, smallholders produce the crop for home consumption (roasted or boiled). Mathews and Beck (1994) stated that almost all the groundnuts produced by the smallholder farmers in Mpumalanga

are used locally for home consumption. Local sales are made at substantially high price and account for a significant part of farmers' income.

1.2 Botany of groundnuts

Arachis hypogaea is an annual herb of indeterminate growth habit which has been divided into the two sub-species*, hypogaea and fastigiata*, each with several botanical varieties. Sub-species and varietal classifications are mostly based on location of flowers on the plant, patterns of reproductive nodes on branches, numbers of trichomes and pod morphology (Stalker, 1997).

The main stem can be upright or prostrate and ranges from 12 to 65 cm in length. Lateral branches can be prostrate and run along the ground or be upright. Stalker (1997) reported that leaflets on the main stem differ in shape and size from those on lateral branches. Branching patterns of reproductive to vegetative nodes on the cotyledonary laterals is one of the primary traits dividing the subspecies, *hypogaea* (alternating pairs of vegetative: reproductive nodes) and subspecies, *fastigiata* (sequential patterns of reproductive nodes) (Stalker, 1997). The groundnut is unique among domesticated plants in that it flowers above ground, but produces seeds below the soil surface. Flowers are borne in the axils of leaves, usually with three flowers per inflorescence.

Pods are elongated spheres which have different amounts of reticulation on the surface or constriction between seeds. They contain two to five seeds, although members of *hypogaea* and *fastigiata var. vulgaris* usually produce two-seeded pods. Seeds may be round or elliptical; have pointed or flattened ends; vary in seed-coat color from off-white to deep purple; and may be solid or mottled (Stalker, 1997). Seed size is an important economic character for peanuts. It is fairly stable for any given cultivar and is highly diagnostic in nature. Seed lengths ranging from 7 to 21

mm and seed diameters from 5 to 13 mm have been observed (Gowda, 1996). Seed size together with the seed mass has been used extensively in agronomic classification of groundnut (Smartt, 1994). Large seed types are preferred for confectionery purposes, while most of the oil types have medium to small seeds.

The size of kernel is one of the important factors for export. Normally varieties with hundred seed mass of 60 g or more are considered as large seeded groundnut and are preferred for confectionary purpose. One hundred-seed mass is a qualitatively inherited trait controlled by additive, dominant and epistatic effects (Upadhyaya and Nigam, 1998). Large seeds of groundnut have a greater consumer preference and fetch higher prices in domestic and international markets.

Botanically, groundnuts (*Arachis hypogaea L.*) may be divided into four main types Virginia, Spanish, Valencia and Runner (Lapedes, 1977). The Virginia types are characterized by flowers on alternate lateral branches - seeds show some dormancy. Cultivars in this type are late-maturing, taking 120 to 170 days with large size kernels, some cultivars are erect while others have a runner (prostrate) growth habit (Stalker, 1997

1.3 Importance of groundnuts

Groundnut is the 13th most important food crop and 4th most important oilseed crop of the world (TARU *et al*., 2008). The groundnut seeds contain 44-56% oil content and 22-30% protein content. It is a rich source of minerals (phosphorus, calcium, magnesium and potassium) and vitamins (E, K and B group) niacin, falacin, zinc, iron, riboflavin and thiamine (Ingale and Shrivastava, 2011; Stigter and Brunini, 2007). The groundnut kernels are consumed directly as raw, roasted or boiled kernels or oil extracted from the kernel is used as culinary oil. It is also used as animal feed (oil pressings, seeds, green material and straw) and industrial raw material (oil

cakes and fertilizer). The crop plays an important role in the dietary requirements of resourcepoor women and children and haulms are used as livestock feed (Pretorius, 2006).

Eating high oleic peanut diet can reduce low density lipoprotein in human (Singkham *et al.*, 2010). These multiple uses of groundnut plant make it an excellent cash crop for domestic markets as well as for foreign trade in several developing and developed countries (Stigter and Brunini, 2007). According to Maiti and Wesche-Ebeling (2002), economic yield of groundnuts is determined by both biotic (temperature and drought) and abiotic (pests and diseases) factors. Factors that influence conversion of solar radiation play a role in determination of yield, because groundnuts are highly branched and mostly prostrate. Components of yield include number of underground pods, number of seeds in each pod, and seed weight. Therefore a highly productive cultivar should have high photosynthetic rates and photosynthesis directed straight to seeds in the underground pods.

Some important small-holder vegetable crops in the Eastern Cape are cabbage, spinach, onions, peas and carrots and they are grown in gardens of about 0.1 to 0.3 ha next to the homesteads while maize is the dominant crop planted in the fields (Yoganathan *et al.*, 1998; Mkile, 2001; Mandiringana *et al.*, 2005). Thus, the Eastern Cape is among the provinces that do not contribute to the groundnut industry although there are some small scale farmers who produce the crop in very little quantities which do not reach the market (Agricultural statistics, 2010). Therefore it is necessary to do a variety evaluation in order to find commercial cultivars that are suitable to the local climatic conditions of the Eastern Cape.

The household economy of the Eastern Cape Province is mostly dependent on agriculture and the majority of farmers in this province are small scale farmers mainly focusing on maize production. Crop diversification, therefore, becomes an important aspect for farmers and this should be done with crops that can be produced in almost similar practices with that of maize under dry land conditions. Groundnut is a legume crop, therefore it is good in nitrogen fixation (Martin and Leornad, 1952). It is therefore a good option for crop rotation with maize in the case of the small scale farmers of the province as they will use less fertilizer. Groundnut should be grown in rotation with cereals (e.g., maize and sorghum), which have been well fertilized, because

groundnuts respond well to fertilizer applied to the previous crop rather than to the groundnuts themselves (NDA, 2010).

Groundnut production is one of the relevant options for smallholder farmers in the province but lack of studies on groundnut in the province is one factor limiting the production of small amounts farmers need to unleash the potential of this crop in the province. Farmers in this province have not realized the production of the crop as a cash crop due to lack of commercial cultivars and information on the best cultivars suitable to the different climatic conditions of the province. Most farmers just buy and plant any groundnut seed without knowing the name of cultivar and its adaptability. Introduction of this crop will contribute largely to the income improvement of the farmers. It will further reduce the mono-culture of maize production in the regions.

1.4 Oil content

The most important quality requirement of groundnut as a source of oil are high oil content in seed and high oleic acid resulting in high oleic/linoleic acid (O/L) ratio for longer stability or shelf life (Cholin, 2009). Cultivars with high O/L ratio, low oil/fat and high protein are suitable for confectionary purpose. Nutritional quality of oil is determined by its fatty acid composition. In groundnut, there are mainly eight fatty acids, viz. palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2), arachidic (20:0), eicosenoic (20:1), behenic (22:0) and lignoseric (24:0). Among them, oleic acid, a monounsaturated fatty acid and linoleic acid, a polyunsaturated fatty acid account for 75 to 80% of the total fatty acids in groundnut oil. The remaining 20% is contributed as other fatty acids, among them, palmitic acid (10%) has the largest proportion (Kavera, 2008).

The oil content of kernels shows significant genotypic variations. The crop season, habit group, geographical location, soil fertility, moisture availability, maturity of crop at harvest, seed mass have a bearing on the oil content (Misra, 2004). The nutritional and storage qualities of groundnut

depend on the relative proportion of saturated and unsaturated fatty acids in the oil. A high proportion of polyunsaturated fatty acid is desirable because it lowers plasma cholesterol and low-density lipoprotein content, which may reduce the risk of coronary heart disease and atherogenesis (Dwivedi *et al.*, 1996).

Groundnut oil is composed of mixed glycerides and contains a high proportion of unsaturated fatty acids, in particular, oleic (50-65%) and linoleic (18-30%) (Young, 1996). Compared to refined oil, raw groundnut oil is fairly stable, because of its iodine number, saponification number, acetyl number and free fatty acids do not change during heat treatments and hence, groundnut oil is highly reusable. Besides, groundnut oil can be stored at room temperature for 18 months without significant deterioration in quality. Hence groundnut oil is considered as an excellent cooking medium (Misra *et al.,* 2000).

Groundnut lines with a high oleic acid trait (O/L ratio) have been identified. Gorbet (2003) stated that the new market-type groundnut developed by the Florida Experimental Station, SunOleic®/high oleic, will last from three to 15 times longer than regular groundnuts before going rancid (oxidation). Groundnut oil (low in saturated fat and cholesterol and high in monounsaturated fat), when included in a diet, will lower the triglyceride levels. Groundnuts are also important in the confectionary trade and the stable oil is preferred by the deep-frying industries, since it has a smoke point of 229.4°C compared to the 193.5°C of extra virgin olive oil (Singh and Diwakar, 1993).

1.5 Protein content

Groundnut is a rich source of essential amino acids, minerals, and vitamins. Singh and Diwakar, (1993) reported that groundnut has good digestibility in both raw and roasted forms. Its protein is

increasingly becoming important as food and feed sources, especially in developing countries where protein from animal sources are not within the means of the majority of the population (Yaw *et al.,* 2008). The kernels contain high quality protein than meat, eggs and most of other vegetables. Hence, it is important for children, women and people eating more meatless meals (Misra *et al.,* 2000).

Its proteins are composed of about 90% globulins and about 10% albumins (Mohamed-son 1984). The two major globulins, arachin and conarachin or nonarachin (labeled in the pure form as alpha-arachin and alpha-conarachin, respectively), have been isolated by Mohamed-son (1984). Protein comprises almost entirely of two globulins *viz.,* arachin (63 percent) and conarachin (33 per cent). As both arachin and conarachin contain 18.3 per cent nitrogen, the nitrogen protein conversion factor for groundnut is 5.46. However, there is a possibility of variation in the value of nitrogen to protein conversion factor due to differences in genotypes and geographical locations (Misra *et al.,* 2000). Nutritional quality of the seed is strongly influenced (Dwivedi, 1993) by production location, cultivar and season, particularly soil moisture and temperature during crop growth and seed maturation and seed size (Dwivedi, 1996). Protein content varies much between accessions of botanical varieties, but between accessions of botanical varieties it ranges from 16.10 to 34.00 per cent (Cholin, 2009).

1.6 History of groundnuts in South Africa

Groundnut research in South Africa started in the early 1970s, with work on Spanish types. Research over the years has largely focused on practical problems (Swanevelder, 1994). Several aspects have been covered, including disease control (leaf spot), insect pests, the effect on yield of various management variables (e.g., sowing depth, seed size, spacing, and sowing/harvest dates),

growth regulators and fertilization on yield (Swanevelder, 1994). Research over the years has resulted in improved cultivation practices, better cultivars, and successful disease control (Swanevelder, 1994). Groundnut production in South Africa can be divided into three categories — intensive, extensive, and communal. Intensive production is practiced under irrigation, mostly by commercial farmers, while extensive production under rainfed conditions also occurs. Research over the years has resulted in improved cultivation practices, better cultivars, and successful disease control (Swanevelder, 1994).

Resistance to black hull (Chalara elegans) and the pod rot nematode (*Ditylenchus destructor*) has been found (Swanevelder, 1994). The crop is commercially produced in Northern Cape, Free State, and North West provinces whereas in KwaZulu-Natal, Mpumalanga and Limpopo groundnut is produced on a small scale (Methews *et al.,* 2007). Estimates indicate that between 50 000 and 150 000 t of groundnuts are produced per annum in South Africa mostly by commercial farmers depending on rainfall (Swanevelder 1994; Pretorius, 2006). Groundnut is produced in SA in a variety of systems, from smallholder plots to intensive production under irrigation. About 32% is taken up by the confectionery market, 8% for seed, 39% utilized for oil, and 21% exported (Swanevelder 1994).

1.7 Factors constraining groundnut production in South Africa

The average yield in South Africa is low due to lack of good quality seed, drought periods at pod filling, foliar diseases, and poor agronomic practices (Nkambune, 1994). The majority of small scale farmers use the cultivars Natal Common and Sellie, which are highly susceptible to the leaf disease complex of early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeoisariopsis per sonata),* and rust (*Puccinia arachidis*) (Mathews and Beck, 1994). Foliar diseases cause

considerable yield reduction and chemical control is beyond the affordability of the small scale famers. None of the groundnut cultivars released in South Africa are resistant to the foliar disease complex of early leaf spot (*Cercospora arachidicola*), late leaf spot (*Cercosporidium personatum*) and rust (*Puccinia arachidis*) (Methews *et al*., 2007).

Initial studies showed significant resistance to foliar diseases; however the kernel yield of the cultivars was significantly lower due to poor pod filling. Methews *et al.* (2007) reported in the study conducted in the Mpumalanga province of South Africa 2004-2006 that out of fifteen cultivars selected based on the resistance to foliar diseases and drought tolerance ICGV98369, showed high yield potential. Cultivars ICGVSM99529 and ICGV96294, among the short duration, were the only ones that were drought tolerant. Early leaf spot (ELS) is one of the most important foliar diseases of groundnuts in SA and can cause considerable yield losses, particularly when the infection appears early in the season (Pretorius, 2006). Fungicides are effective for the control of early leaf spot but the most cost effective control measure will be resistant cultivars.

Significant control of ELS has been achieved by crop rotation with bahiagrass, cotton, grain sorghum and maize (Pretorius, 2006). Deep ploughing of crop residue suppresses the spore forming ability of the pathogen. Minimum tillage practice can also suppress (Brenneman *et al*., 1995) the occurrence of early leaf spot disease as compared to conventional tillage (Pretorius, 2006). Although fungicidal control is effective, it is not economically feasible for subsistence farmers due to their limited financial and other resources. It also adds to input costs of commercial farmers.

1.8 Environmental conditions limiting production of the crop

Groundnut is grown widely under rain-fed conditions in the semi-arid tropics, where drought is a major constraint of groundnut productivity, especially during the pod and seed forming stages that can greatly reduce pod yield (Songsri *et al.,* 2008). Drought resistant varieties have been used to stabilize groundnut productivity under drought conditions. Breeding for drought resistance has been an important strategy in alleviating the problem. Food productivity is decreasing due to detrimental effects of various biotic and abiotic stresses. Therefore, minimizing these losses is a major area of concern to ensure food security under changing climates (John *et al.,* 2012).

Environmental abiotic stresses, such as drought, extreme temperature, cold, heavy metals, or high salinity, severely impair plant growth and productivity worldwide (Shao *et al.,* 2009). Drought is the most important environmental stress, because it severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factor (Shao *et al.,* 2009). Plant experiences drought stress either when the water supply to roots becomes difficult or when the transpiration rate becomes very high. Constant drought is the most important yield limiting factor affecting groundnut (*Arachis hypogaea* L.) production in rain-fed regions of sub-Saharan Africa and Asia. Improvement of crop adaptation to drought is needed and this starts by having a thorough assessment of a large and representative set of germplasm (Hamidou *et al.*, 2012). Numerous physiological traits have been shown to potentially contribute to yield under stress, but the development of an efficient breeding method for drought resistance in groundnut is still a long-standing objective (Clavel *et al.,* 2005). Groundnut has developed earliness strategy to cope with drought stress, which is a key factor

under severe end-of-season water deficit conditions. This was observed in cultivar Fleur 11 with the high yield and cultivar 73-30 the poor yielding one, even though the latter developed avoidance mechanisms (Clavel *et al.,* 2005).

1.9 Nutrient requirements

The effect of higher level of fertilization on nodulation, symbiotic N fixing bacteria and nitrogen fixation in the peanut rhizosphere, as compared to applying lower level or no fertilizer application indicated that nodule formation and symbiotic N fixation could be reduced by mineral N, while small starter doses of applied N may stimulate nodule formation (Basu *et al*., 2008). The carbon and nitrogen in kraal manure could be easily used as energy and nutrient sources for soil microorganisms, and this resulted in increased population of symbiotic bacteria and nitrogen fixation (Basu *et al*., 2008).

Improved nitrogen fixation by peanut due to liming might be attributed to the fact that nodules on the lower part of the root system (Basu *et al*., 2008) were able to fix more nitrogen than crown nodules throughout the growing season and they might contribute most of the nitrogen fixed by the legume plant. Liming increased the root length and lateral root distribution because of increase in exchangeable Ca^{2+} and Mg^{2+} levels in the soil and improved soil structure providing better aeration in the rhizosphere of peanut, which was helpful in better nodulation (Raychaudhury *et al.,* 2003). The favourable effect of optimum level of nutrients through both organic and inorganic nutrient sources in improving the leaf area index and fixation of nitrogen could be one of the reasons for higher dry matter production of peanut (Basu *et al*., 2008).

The combined use of inorganic fertilizers, organic manures and lime enhanced the inherent nutrient supplying capacity of the soil with respect to both macro and micronutrients (Stevenson *et al.,* 1998). This also improved the physical properties of the soil, which promoted better rooting, higher nutrient uptake by the crop, and increased the dry matter production and seed yield of peanut. Basu *et al*. (2008) reported that the application of chemical fertilizers at 20:40:30 kg ha^{-1} N, P and K, along with farmyard manure at 2.5 t ha^{-1} was effective in improving the growth, nitrogen fixation, and yield and kernel quality like oil content, protein content, mineral composition and hydration coefficient of peanut crop. Integrated plant nutrient management system comprising farmyard manure and chemical fertilizers in conjunction with soil amendment (lime) was superior as compared to sole application of inorganic fertilizers.

About 90% of the world's groundnut production occurs in the tropical and semi-arid tropical regions (Hamidou, 2012). Much of the world's groundnut production regions are characterized by high temperature and low or erratic rainfall (Hamidou, 2012). Groundnut is sensitive to temperature with an optimum for most processes being between 27 and 30 °C, while drought is estimated to cause millions in revenue losses to crop production (Hamidou, 2012). Therefore, heat and water stress occurring simultaneously are considered to be two the major environmental factors limiting groundnut growth and yield. Plant responses to high temperature vary with plant species and phenological stages (Wahid *et al*., 2007).

Reproductive processes are markedly affected by high temperatures in most plants, which lead to reduced crop yield. Under field conditions drought stress is often associated with high temperatures the impacts of drought and high temperature stress on groundnut productivity have mostly been studied independently. Ntare *et al*. (1998) reported that temperature tolerance is an

important component of drought resistance and a necessary attribute for varieties. Hamidou (2012) reported that drought stress decreased pod yield in both moderate temperature and high temperature seasons but the effect was higher during the high temperature (72%) than during the moderate temperature season (55%). Under drought conditions, the harvest index also decreased more during the high temperature season (50%) than during the moderate temperature season (25%).

1.10 Justification and problem statement

Groundnut is grown in tropical, sub-tropical and warm temperate regions of the world (Upadhyaya, 2006). Early maturing groundnut cultivars with improved yield are required for several agro-ecological situations. Such situations include short growing seasons, necessitated by end-of-season droughts, cooler temperatures, and early frosts and sometimes winter rainfall. Therefore cropping systems either intercropping or as sequence crops is important for poor resource farmers to reduce crop failures and improve soil fertility (Upadhyaya, 2006).

Very little groundnut is produced in the Eastern Cape of South Africa because of lack of known suitable varieties. There is no documented research in the province for adaptability which makes it difficult for farmers to use the suitable cultivars. However, there is a potential for producing the crop for both small-scale and commercial purposes. It is therefore important to examine suitability of the crop in the Eastern Cape province by examining some known commercial cultivars grown on other parts of the country, such as the Western and North-western Free State, the North West, the Northern Cape, Limpopo and Mpumalanga (NDA, 2010). Since the crop is grown for oil and protein, it is important to examine these as they are affected by environmental conditions.

1.11 Aim and objectives

The aim of the study was to determine the agronomic suitability of nine groundnut cultivars for production at two sites in the Eastern Cape, Mthatha and Lusikisiki, where there is a potential to introduce the crop for purposes of developing small-scale subsistence farmers.

Specific objectives were:

i. To determine the growth and yield characteristics of nine groundnut cultivars.
ii. To determine the response of selected cultivars to calcium supplementation at flowering.
iii. To determine the oil and protein content in each cultivar, with and without Ca supplementation.

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2. FIELD PERFORMANCE OF NINE GROUNDNUT CULTIVARS AT TWO LOCATIONS IN THE EASTERN CAPE

2.1 Introduction

In many parts of the world, groundnut (*Arachis hypogaea* L.) is grown under dry land conditions. The crop often suffers from drought stress of varying intensity and duration leading to adverse effects on pod yields (14 - 88% decrease) and seed mass of groundnut (Dwivedi *et al.,* 1996). Low rainfall and prolonged dry spells during the crop growth period were reported to be the main reasons for low average yields in most of the regions of Asia and Africa (Stigter and Brunini, 2007). In the dry conditions of the Eastern Cape, it would be ideal for smallholder farmers to produce the crop on a rotational system rather than intercropping with maize, since it is a dominant crop.

Climatic conditions vary with location(s) in the same year or growing season. Peanut genotypes do not always respond similarly under these varying climatic conditions. The phenotype reflects non-genetic as well as genetic influence on a plant's growth and development . Effects of genotype and environment are not independent (Mekontchou *et al.,* 2006). Environmental abiotic stresses, such as drought, extreme temperature, cold, heavy metals, or high salinity, severely restrict plant growth and productivity worldwide (John *et al*., 2012). Drought, being the most important environmental stress, severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factor (Shao *et al.,* 2009). Drought resistant varieties have been used to stabilize groundnut productivity under drought conditions. Breeding for drought resistance has been an important strategy in alleviating the problem. Food productivity is decreasing due to detrimental effects of various biotic and

abiotic stresses; therefore minimizing these losses is a major area of concern to ensure food security under changing climate (John, *et al.,* 2012).

Plants experiences drought stress either when the water supply to roots becomes difficult or when the transpiration rate becomes very high. Drought occurs at any stage of crop development and groundnut is at risk even under irrigated production due to water scarcity in many countries and high cost of energy to draw water (John, *et al.,* 2012). Drought stress at a later stage during the peg development to pod filling can largely reduce pod yield but during the pre-flowering growth it has less or no effect instead it can even increase pod yield (Wunna, *et al.,* 2009). Rainfall is the most significant climatic factor affecting groundnut production, as 70% of the crop area is under semi-arid tropics characterized by low and erratic rainfall. Low rainfall and prolonged dry spells during the crop growth period were reported to be main reasons for low average yields in most of the regions of Asia and Africa (Stigter and Brunini, 2007).

The total rainfall in the leading production areas ranges from 2208 mm to 3442 mm. Groundnut is essentially a tropical plant and requires a long and warm growing season. The favorable climate for groundnut is a well-distributed rainfall of at least 500 mm during the crop-growing season, and with abundance of sunshine and relatively warm temperature (Stigter and Brunini, 2007). Temperature in the range of 25 to 30ºC is optimum for plant development (Stigter and Brunini, 2007). A rainfall of 500 to 1000 mm will allow commercial production, although crop can be produced on as little as 300 to 400 mm of rainfall (Stigter and Brunini, 2007). Groundnut thrives best in well-drained sandy loam soils, as light soil helps in easy penetration of pegs and their development and their harvesting. The productivity of groundnut is higher in soils with pH between 6.0-6.5 (Stigter and Brunini, 2007). However, a pH of 5.3 to 7 has been reported by

Cilliers (2011) to be suitable for groundnuts. Nutritional quality of the seed is strongly influenced by production location, cultivar and season, particularly soil moisture and temperature during crop growth and seed maturation (Dwivedi *et al.,* 1996). Groundnut is grown in tropical, sub-tropical and warm temperate regions of the world (Upadhyaya, 2006). Early maturing groundnut cultivars with improved yield are required for several agro-ecological situations. Such situations include short growing seasons, necessitated by end-of-season droughts, cooler temperatures, and early frosts and sometimes winter rainfall. Therefore cropping systems either intercropping or as sequence crops is important for poor resource farmers to reduce crop failures and improve soil fertility (Upadhyaya, 2006).

Very little groundnut is produced in the Eastern Cape of South Africa because of lack of known suitable varieties. There is no documented research in the province for adaptability which makes it difficult for farmers to use the suitable cultivars. However, there is a potential for producing the crop for both small-scale and commercial purposes. It is therefore important to examine suitability of the crop in the Eastern Cape province by examining some known commercial cultivars grown on other parts of the country, such as the Western and North-western Free State, the North West, the Northern Cape, Limpopo and Mpumalanga (NDA, 2010). Since the crop is grown for oil and protein, it is important to examine these as they are affected by environmental conditions.

The aim of the study was to identify suitable commercial cultivars for climatic conditions of Mthatha and Lusikisiki regions to assist farmers to grow recommended cultivars. The specific objective was to determine the growth and yield characteristics of nine groundnut cultivars identified as suitable for other South African growing conditions.

2.2 Materials and methods

2.2.1 Materials and field layout

Nine groundnut cultivars namely: Akwa, Kwarts, SA Juweel, ICGV-SM-95714, Anel, ICG-SM-90087, Harts, Nyanda and Mwenje were planted in plots measuring 4m x 3.6m. Each plot was planted with five rows with an inter-row spacing of 90cm and the intra-row spacing of 7cm and a planting depth of 6 cm to give the plant population of 169922 plants per hectare.

2.2.2 Experimental sites

2.2.2.1 Mthatha

Mthatha is geographically located between 31°32'29"S, 28°44'44"E about 10 km west of the town of Mthatha, Eastern Cape. The experiment was conducted during the 2010/11 growing season. The average annual rainfall for this region is 617 mm and the average minimum temperature is 15^{o} C while the average maximum temperature is 27^{o} C during summer season. The trial was planted towards the end of November 2010.

2.2.2.2 Lusikisiki

Lusikisiki is geographically located between 31°19'47"S, 29°44'59"E about 20 km east of the town of Lusikisiki, Eastern Cape. The average annual rainfall for this region is >1000 mm and the average minimum temperature is 14^{o} C while the average maximum temperature is 24^{o} C during summer season. The trial was conducted in 2011/12 growing season.

2.2.3 Soil conditions for Mthatha and Lusikisiki

The soil at Mthatha site was classified as Oakleaf with a good structure. This soil is loamy sand to sandy loam with an effective rooting depth of 1000 mm on the slope of between 2 and 4%. Soil samples were taken from the site at depth of 0-15cm and sent to the laboratory for nutrient analysis. Nitrogen (N) required was 20 kg ha^{-1} while phosphorus required was 60 kg ha^{-1} with zero

potassium needed, according to soil analysis results. Lime was not required nor was calcium as Ca level was high (Table 1).

The soil at Lusikisiki site was classified to be Avalon with a good soil structure (Table 1). Soil is sand loamy to sandy clay down the profile with an effective rooting depth of more than 800mm on the slope of between 2 and 3%. Soil samples were taken from the site at depth of 0-15cm and sent to the laboratory. Nitrogen (N) required was 20 kg ha^{-1} Phosphorus required was 60 kg ha^{-1} and potassium was 0 kg ha^{-1} required. Lime was not required and the amount of calcium tested was 1011 mg l^{-1} therefore there was no need to supplement with calcium before flowering.

Table1. The chemical characteristics of Oakleaf and Avalon soil forms used in Mthatha and Lusikisiki.

Location	**Mthatha**	**Lusikisiki**
Properties	**Composition**	
Phosphorus	0 mg/L	6 mg/L
Potassium	297 mg/L	224 mg/L
Calcium	871 mg/L	1011 mg/L
Magnesium	89 mg/L	185 mg/L
Zinc	1.6 mg/L	5.2 mg/L
Manganese	0 mg/L	0 mg/L
Copper	0.0mg/L	0.0mg/L
pH (KCL)	5.00	4.17
Exchange acidity	1 cmol/L	1.65 cmol/L
Acid saturation	15%	19%
Total cations	6.84mol/L	8.79 cmol/L

2.2.4 Experimental design and statistical analysis

The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. All data were subjected to statistical analysis using Genstat® Version 14. Means were separated using Fisher's unprotected testing least significant differences at 5% level when ANOVA showed significant ($P < 0.05$) difference between treatments. The study was a location x genotype.

2.2.5 Yield determination

Climatic data (temperature and rainfall) were collected monthly from the nearby Agricultural Research Council weather station. Three plant samples from each plot, across all replications, were harvested from an area of 0.135m^2 and taken to the laboratory for determination of above ground dry mass at flowering. Leaves and stems were oven-dried at 60 ºC until constant mass and ground (Jansen van Rensburg *et al.,* 2010). Plant nutrient analysis for calcium (Ca), nitrogen (N), phosphorus (P) and potassium (K), regarded as most important in groundnut production, was performed (Upadyaya *et al.,* 2006; Martin and Leornad, 1952). At maturity, five plants were randomly harvested per 1.35 m^2 to determine from each plot: number of seeds per pod in five plants (to determine pod filling), average number of seeds per pod, fresh and dry seed mass (kg), pop formation (%), number of pods per plant (in five plants). Seed yield was harvested in an area of 8.1m^2 in each plot. Fresh mass and dry mass for seed yield and pod yield, and 100-seed weight were calculated from harvested bulk (Phakamas *et al.,* 2008).

2.2.6 Seed oil determination

Oil contents of the samples were determined according to Meyer and Terry (2008). The recovered oil was weighed and the percentage oil content [% (w/w)] was calculated.

2.2.7 Seed protein determination

The Bradford micro assay was used to determine the protein contents of the samples. After the addition of reagent, the samples were read spectrophotometrically at 595 nm and protein concentrations were determined by comparing the results with a standard curve based on bovine serum albumin (Tesfay *et a*l., 2010).

2.3 Results

2.3.1 Climatic data

2.3.1.1 Rainfall of Mthatha

The climatic data were collected from the nearby Agricultural Research Council weather station monthly. Highest rainfall (between 78 and 174 mm) was received during the summer months (October, November, December) of 2010 which was at the commencement of the study in Mthatha. In 2011, the highest rainfall (176 mm) was recorded in January while February and March received slightly lower rainfall of 37 and 73 mm, respectively. The trial was harvested in April and the rainfall recorded for that month was the lowest at 3 mm (Figure 1).

2.3.1.2 Rainfall of Lusikisiki

The rainfall during growing season was moderately good though the first rainfall occurred in November instead of September therefore pushing the planting to be done in November (Figure 2). There was a low rainfall received during the flowering and pegging stage at the end of December and January. The relationship between the rainfall and temperatures was critical at this stage for the yield. High rainfall occurred also during the maturity stage just before the plants could be lifted.

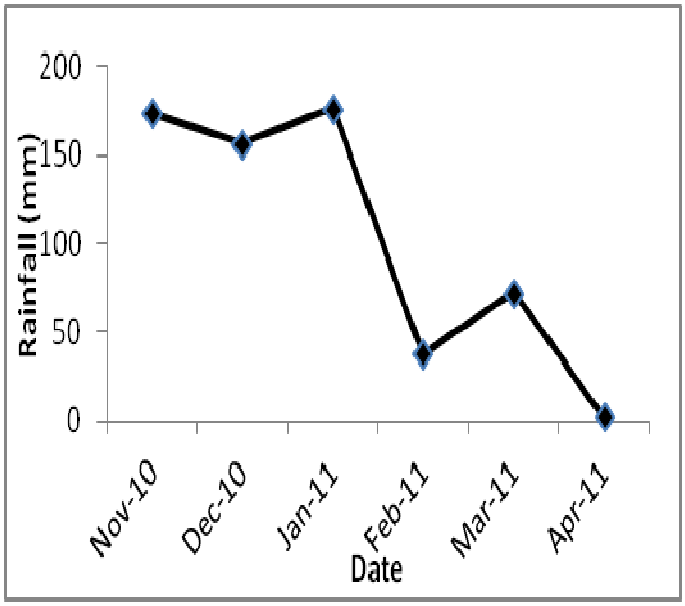

Figure 1 Monthly rainfall in Mthatha.

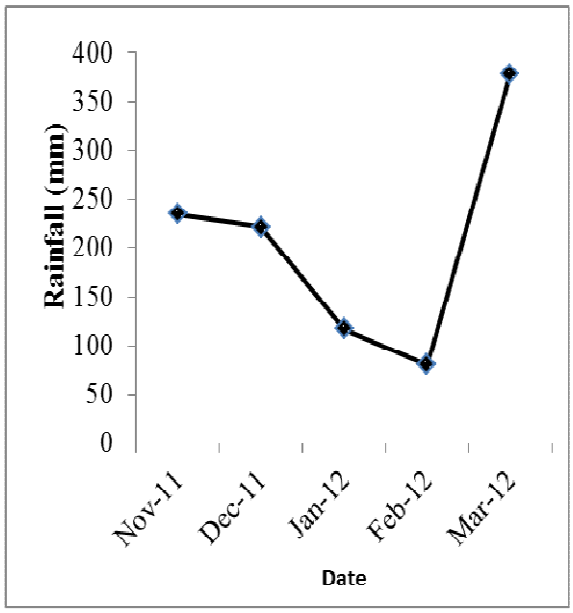

Figure 2 Monthly rainfall in Lusikisiki.

2.3.1.3 Temperatures of Mthatha

Average monthly temperatures during the growing season ranged between 23.76 and 28.44º C and the highest average temperature was recorded in February (28.44ºC) while the lowest (23.76 ° C) was recorded in April (Figure 3).

2.3.1.4 Temperatures of Lusikisiki

Average monthly temperatures during the growing season ranged between 23 and 28 ºC and the highest average temperature was recorded in January (28ºC) while the lowest was recorded in November (23ºC) (Figure 4).

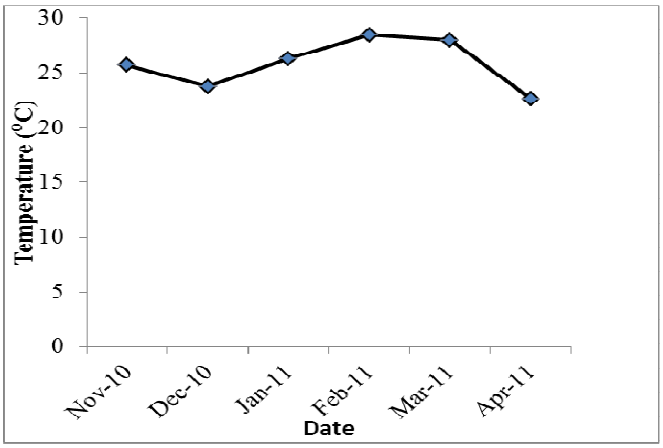

Figure 3 Monthly temperatures in Mthatha.

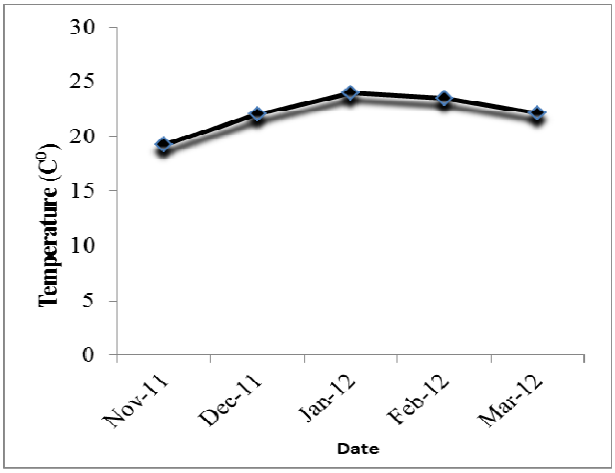

Figure 4 Monthly temperatures in Lusikisiki.

2.3.1.5 Nutrient concentrations at flowering stage

Calcium concentrations levels were significantly different between cultivars (P<0.05) (Table 2). High significant differences for calcium concentration levels were observed in Mthatha experimental site in all genotypes compared to Lusikisiki. For example, Nyanda had a concentration of 5.05% in Mthatha compared to Nyanda in Lusikisiki with the concentration of 1.7% and ICGV-SM 95714 had a concentration of 5.03% in Mthatha compared to ICGV-SM 95714 in Lusikisiki with concentration of 1.79% (Table 2). The lowest values for Ca were recorded in Kwarts for both sites (3.35 and 1.38%) respectively (Table 2). Phosphorus concentration levels were significantly different (P<0.05). For example, high concentration levels were observed in Mthatha for Kwarts were 0.49% compared to Lusikisiki with P concentration levels of 0.24%. The lowest concentration levels were observed in Nyanda for both sites (0.41 and 1.19%), respectively.

Nitrogen concentration levels were significantly different in genotypes evaluated (P<0.05) (Table3). Genotypes in Mthatha had high concentration levels of N compared to Lusikisiki experimental site. For example, ICGV-SM 90087 had a concentration level of 4.54% in Mthatha compared to 2.30% in Lusikisiki (Table2). Genotypes showed a significant difference in

potassium concentration levels (P<0.05) (Table 3). Notably, Kwarts had a highly significant K level of 5.58% compared to 3.30% absorbed in Lusikisiki (Table 2).

Table 2 Comparison of nutrient concentration levels in plants above ground for nine genotypes at flowering stage at two locations.

Concentration	Ca (%)		P (%)		N (%)		K (%)	
Genotype	MTA	LSK	MTA	LSK	MTA	LSK	MTA	LSK
Nyanda	5.05a	1.70f	0.41ab	0.19c	4.10a	2.11bc	3.86bcd	1.89f
ICGV-SM 95714	5.023a	1.79f	0.45a	0.20c	4.00a	1.80c	3.94bcd	2.79def
ICGV-SM 90087	4.81ab	1.62f	0.44a	0.31bc	4.54a	2.30bc	4.75a	3.21cde
SA Juweel	4.61abc	1.88f	0.48a	0.24c	4.15a	2.07bc	4.42abc	2.33ef
Anel	4.59abc	1.64f	0.41ab	0.22c	4.16a	2.06bc	4.32abc	3.27cde
Mwenje	4.50bc	1.70f	0.43a	0.20c	4.29a	1.89bc	3.62bcde	2.40ef
Akwa	4.28cd	1.61f	0.42ab	0.20c	4.08a	1.95bc	4.74ab	2.41ef
Harts	3.94d	1.51f	0.43a	0.20c	4.23a	1.20bc	5.36a	3.18cde
Kwarts	3.35e	1.38f	0.49a	0.24c	4.21a	2.51b	5.58a	3.30cde
CV %	8.3	6.6	14.9	29.3	5.5	16.1	17.7	8.3
LSD $_{0.05}$	0.64	0.19	0.11	0.11	0.40	0.58	1.38	0.40
Across sites								
CV%	8.8		19.4		11.1		18.8	
LSD $_{0.05}$	0.45		0.107		0.58		1.13	

Means in a column followed by the same letters are not significantly different (P>0.05), using Duncan's multiple range test. MTA= Mthatha, LSK= Lusikisiki

2.3.1.6 Above-ground biomass, pod mass and pods number

The nine groundnut cultivars were significantly different in vegetative mass and pod mass (P<0.05) (Table 3). For example genotype ICGV-SM- 90087 produced high biomass of 0.26 kg plant^{-1} in Mthatha compared to 0.046 kg plant^{-1} in Lusikisiki. The lowest biomass production was observed in SA Juweel for both sites (0.040 and 0.014 kg plant^{-1}), respectively.

Dry pod mass was significantly different to all genotypes (P<0.05). The highest significant difference was observed in ICGV-SM 90087 (0.25 kg plant^{-1}) for Mthatha compared to 0.048 kg

plant^{-1} for Lusikisiki (Table 3). There were no significant differences within genotypes in Lusikisiki in pod mass (P>0.05). Genotypes were significantly different in the number of pods produced per plant (P>0.05). The highest significant difference observed in Kwarts with73 for Mthatha compared to 43 in Lusikisiki (Table 3).

Table 3 Comparison of dry mass per plant, dry pods mass per plant and pod number per plant at harvesting at two locations

Parameters	Dry mass (kg plant^{-1})		Dry pods mass (kg plant^{-1})		No. of pods plant^{-1}	
Genotype	MTA	LSK	MTA	LSK	MTA	LSK
SA Juweel	0.040ef	0.014f	0.12b	0.024c	27fg	28efg
Harts	0.085d	0.020ef	0.23a	0.022c	53bc	23.g
Kwarts	0.15c	0.020ef	0.21a	0.037c	73a	43cde
Anel	0.21b	0.019f	0.15b	0.032c	35defg	32efg
Nyanda	0.21b	0.025ef	0.25a	0.029c	64ab	29efg
ICGV-SM-95714	0.13c	0.030ef	0.25a	0.054c	70a	42cde
Mwenje	0.14c	0.026ef	0.14b	0.027c	41cdef	25g
Akwa	0.081d	0.027ef	0.24a	0.026c	41cdef	24g
ICGV-SM-90087	0.26a	0.046e	0.25a	0.048c	66ab	48cd
CV%	64.7	36.6	42.8	28.6	52.8	27.5
LSD $_{0.05}$	0.038	0.017	0.030	0.016	46.8	15.56
Across sites						
CV%	15.7		29.5		18.0	
LSD $_{0.05}$	0.023		0.060		13.10	

Means in a column followed by the same letters are not significantly different (P>0.05), using Duncan's multiple range test. MTA= Mthatha, LSK= Lusikisiki

2.3.1.7 Podding and seed dry mass

Yield components such as number of seeds per pod, pop formation percentage and seed dry mass per plant were also used to determine the performance of the planted cultivars in both sites. There were no significant differences between genotypes for seed number produced per pod ($P>0.05$). The highest seeds produced per pod were observed for Nyanda closely followed by SA Juweel in Mthatha (Table 4). The lowest number of seeds produced per pod was observed for genotype ICGV-SM 90087 also in Mthatha (Table 4). Genotypes had a significant difference in pop formation (number of empty pods) ($P<0.05$). The highest percentage was observed in ICGV-SM 90087 (23.11%) (Table 4). The lowest percentage was observed in SA Juweel (3.31%) at Mthatha and 6.60% at Lusikisiki.

Genotypes had a significant difference in seed dry mass ($P<0.05$) (Table 4). For example, in Mthatha ICGV-SM 95714 (0.19 kg plant^{-1}) was significantly higher than ICGV-SM 95714 (0.034 kg plant^{-1}) in Lusikisiki. Seed dry mass was significantly different to all genotypes ($P<0.05$). For example, ICGV-SM 95714 in Mthatha had a high significant difference of 0.19 kg plant^{-1} in seed dry mass compared to 0.034 kg plant^{-1} in Lusikisiki. The lowest seed dry weight was observed in SA Juweel at both sites (0.063 and 0.014 kg plant^{-1}), respectively.

Table 4 Comparison of number of seeds per pod, pod formation and seed dry mass at two locations.

Parameters	**No. of seed pod^{-1}**		**Pod formation (%)**		**Seed dry mass (kg plant^{-1})**	
Genotype	**MTA**	**LSK**	**MTA**	**LSK**	**MTA**	**LSK**
ICGV-SM 90087	0.92b	1.22ab	23.11a	21.62ab	0.11d	0.025ef
Mwenje	1.18ab	1.20ab	11.22cdef	22.05ab	0.10d	0.019f
Harts	1.24ab	1.18ab	17.78abc	10.49cdef	0.15bc	0.013f
Anel	1.20ab	1.13ab	16.21abc	17.97abc	0.13cd	0.019f
Kwarts	1.31ab	1.33ab	12.35cde	13.88bcde	0.13bcd	0.027ef
ICGV-SM 95714	1.41a	1.20ab	6.17ef	17.56abc	0.19a	0.034ef
Akwa	1.45a	1.31ab	15.01abcd	14.77abcd	0.17ab	0.037ef
SA Juweel	1.50a	1.29ab	3.31f	6.60df	0.063e	0.014f
Nyanda	1.53a	1.36ab	10.05cdef	10.99cdef	0.12cd	0.031ef
CV%	16	59.6	59.6	8	33	62.5
LSD $_{0.05}$	0.38	17.30	17.30	0.021	0.071	21.61
Across sites						
CV%		19.1		30.7		26.1
LSD $_{0.05}$		0.41		7.34		0.034

Means in a column followed by the same letters are not significantly different (P>0.05), using Duncan's multiple range test. MTA= Mthatha, LSK= Lusikisiki

2.3.1.8 Seed yield and 100-seed weight

Seed yield was generally low due to heavy rainfall experienced just before harvesting for both sites. During harvesting some of the seeds were rotten and some could not be lifted together with the plants since the pegs were broken due to wet conditions. Genotypes were significantly different in seed yield (P<0.05). For example, in Mthatha Kwarts produced significantly higher seed yield of 1155 kg ha^{-1} compared to seed yield of Kwarts (630 kg ha^{-1}) in Lusikisiki (Table 5) The highest seed yield in Lusikisiki was observed in Anel (930 kg ha^{-1}) compared to Anel (692 kg

ha^{-1}) in Mthatha. The lowest seed yield for both Mthatha and Lusikisiki was recorded in SA Juweel (545 and 518 kg ha^{-1}) respectively. The results for 100-seed weight revealed that there were significant differences between cultivars ($P< 0.05$). For example, in Lusikisiki 100-seed weight for Anel (0.055 kg $plot^{-1}$) was significantly higher than Anel (0.045 kg ha^{-1}) in Mthatha (Table 5). ICGV-SM 90087 was not significantly different ($P>0.05$).

Table 5 Comparison of seed yield and 100-Seed weight for nine genotypes at two locations.

Parameters	**Seed Yield (kg ha^{-1})**		**100-seed weight (kg $plot^{-1}$)**	
Genotype	**MTA**	**LSK**	**MTA**	**LSK**
Kwarts	1155a	630bc	0.051bcde	0.050bcde
Anel	692bc	936ab	0.045ef	0.055abcd
Nyanda	895abc	890abc	0.042f	0.049cdef
ICGV-SM 95714	878abc	642bc	0.042f	0.051bcde
Mwenje	817abc	625bc	0.041f	0.047def
Akwa	806abc	723bc	0.055abcd	0.0533abcd
ICGV-SM 90087	666bc	789abc	0.058ab	0.058ab
Harts	779bc	781bc	0.056abc	0.059a
SA Juweel	545c	518c	0.042f	0.053abcde
CV%	21.0	21.4	7.9	8.5
$LSD_{0.05}$	425.4	328.5	0.0065	0.0078
Across sites				
CV%	25.2		8.5	
$LSD_{0.05}$	376.75		0.0071	

Means in a column followed by the same letters are not significantly different ($P>0.05$), using Duncan's multiple range test. MTA= Mthatha, LSK= Lusikisiki

2.3.1.9 Oil content

There were significant differences ($p<0.05$) between cultivars in Mthatha. Three cultivars, Kwarts, Harts and ICGV-SM 95714 had high oil content 52.7, 47.4 and 40.03%, respectively, while the others had lower levels between 28 and 35% (Figure 9). The total oil content in Lusikisiki between genotypes was not significantly different ($P>0.05$). The highest oil content in Lusikisiki was observed in Mwenje (30.94%) and the lowest oil content was observed in Kwarts (25.02 %).

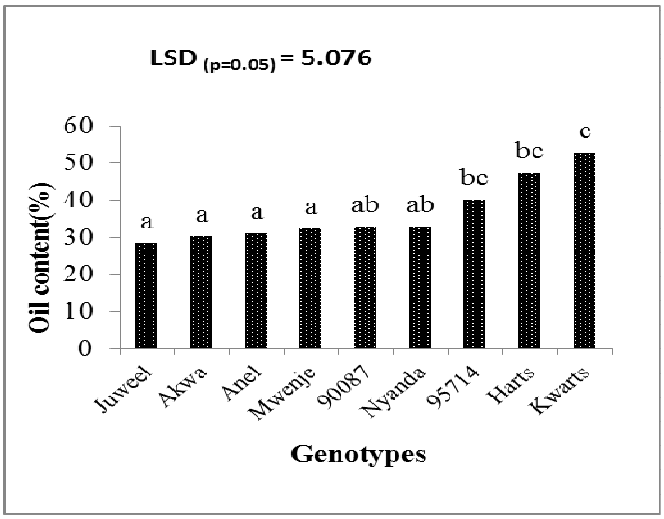

Figure 5 Total oil content in Mthatha

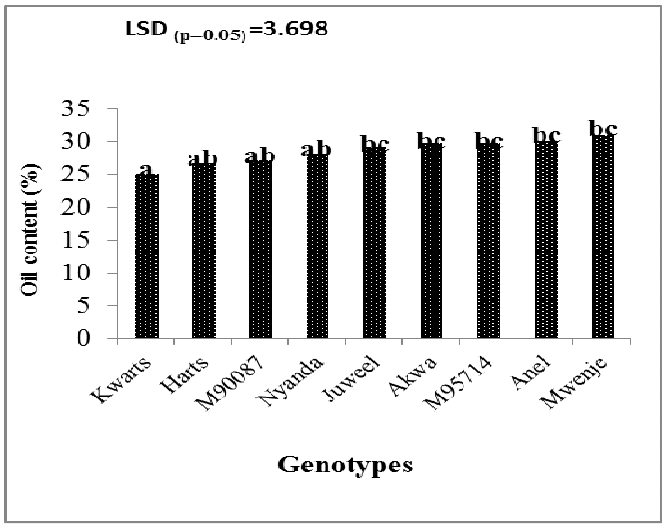

Figure 6 Total oil content in Lusikisiki

2.3.1.10 Protein content

No significant differences were observed between the nine cultivars with respect to total protein content in Mthatha ($p>0.05$). Protein content ranged between 10.80 and 11.85 $m.g^{-1}$ (Figure 6). Genotypes showed significant differences ($p<0.05$) in protein content among each other in Lusikisiki. SA Juweel was significantly higher than all genotypes with protein content of 14.18 mg g^{-1} followed by ICGV-SM 95714 (13.3 mg g^{-1}), Mwenje (12 mg g^{-1}) and Kwarts (12.81 mg g^{-}

^{1}). The lowest values were associated with Akwa and ICGV-SM 90087 (9.6 and 10.36 mg g^{-1}) (Figures 7 and 8).

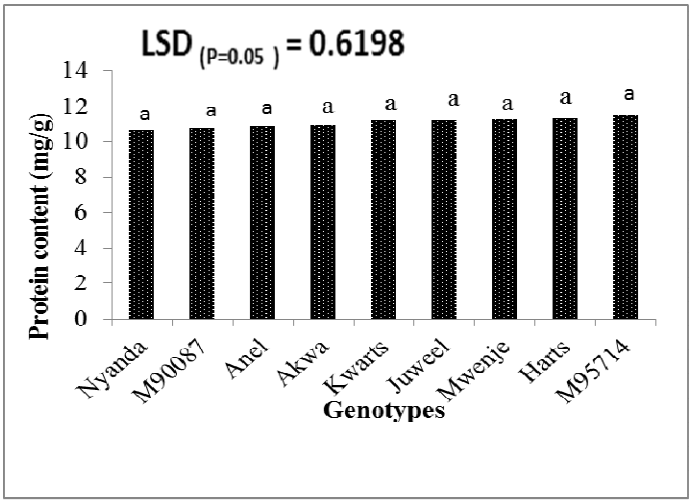

Figure 7 Total protein content in Mthatha.

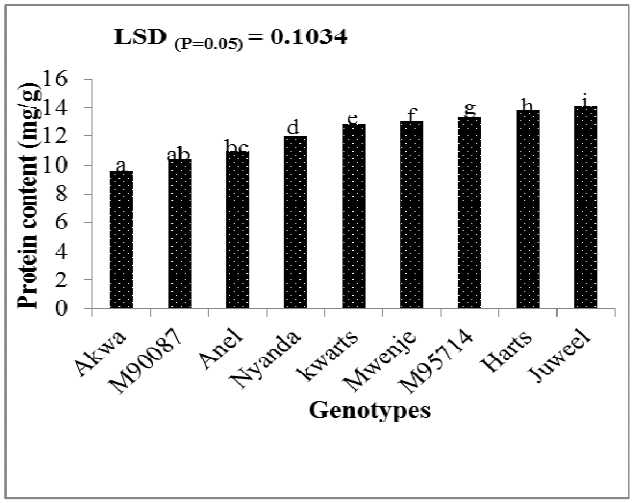

Figure 8 Total protein content in Lusikisiki.

2.4 Discussion

Generally the results in the current study for macro-nutrients were not different from those of Hochmuth *et al.* (2010) who reported groundnut sufficiency levels for macro-nutrients as N (2 to 5%), P (0.25 to 0.6%), K (1.5%), and Ca (0.6 to 5%) . However, potassium concentration levels for all genotypes in both sites in the current study were above the sufficiency levels reported in the literature. N concentration levels for ICGV-SM 95714, Mwenje, Akwa, Harts and Kwarts were slightly below the sufficiency levels for Lusikisiki location.

The above-ground biomass showed significant differences in genotypes. For example, ICGV-SM 90087 had significantly high dry mass in Mthatha when compared to dry mass in Lusikisiki. The current study agrees with the findings of Mekontchou *et al.* (2006) who stated that groundnut genotypes do not respond similarly under varying climatic conditions. There was positive relationship between dry mass above ground and dry pod mass for ICGV-SM 90087 for Mthatha.

Basu *et al.* (2008) reported that balancing the nutrients in the soil lead to increased dry matter production and yield. The current study has shown that dry matter production depends on genotype grown in that location when all other factors remain favourable. The number of pods produced per plant was significantly different in genotypes. Genotypes ability to produce pods does not always depend on the dry matter produced but also genetic ability. For example, Kwarts produced low dry matter above ground in Mthatha compared to ICGV-SM 90087 at the same location but Kwarts had high number of dry pods.

Kamara (2010) reported that genotypes significantly influenced the seeds per pod. This is in agreement with the results of the current study where out of nine genotypes two genotypes, Nyanda and SA Juweel, displayed a significantly high number of seeds produced per pod. ICGV-SM 90087 produced fewer seeds per pod compared to all other genotypes in Mthatha despite its good performance in dry matter and pods per plant. The poor performance of ICGV-SM 90087 with regard to seed yield could be due to low calcium available near pod zone (Kamara 2010) or its ability to absorb nutrients during the pod filling (Kamara 2010). It had huge percentage of empty pods compared to SA Juweel and Nyanda. The behaviour of this genotype might be that it strongly needs more calcium supplementation at flowering stage (Murata 2003). SA Juweel was the least performing genotype when compared to ICGV-SM 90087 with respect to dry matter and pods produced, but it did well during pod filling.

Mekontchou *et al*. (2006) reported that differences exist among genotypes in their response to changes in an environment and different locations. In the current study the results were not different from the reported by (Mekontchou *et al*., 2006). The highest yield in Mthatha was

recorded in Kwarts whilst in Lusikisiki it was Anel. SA Juweel and Akwa have been reported to produce low yield under dry land conditions (Pretorius *et al.,* 2010). This was evident to the current study for SA Juweel and Akwa since they produced low yield in both experimental sites. The seed yield in this study was not different from the range reported by Mekontchou *et al*. (2006) of 1303 kg ha^{-1} and 873 kg ha^{-1} from both locations. Seed yield was at par with results of Kamara (2010) who reported an average seed yield of 1378 kg ha^{-1}. The highest yielding genotypes in both locations also had a high 100seed weight compared to when their seed yields were low according to their location. The seed yields of the current study in both locations were slightly above the findings of Mathew*, et al.* (2007) in the study of new groundnut varieties for smallholder farmers in Mpumalanga province of South Africa.

The results of the current study for Kwarts, ICGV-SM 95714 planted in Mthatha agree with those of Mohamed-son (1984) and Ee and Dunford, (2009) who have reported that the oil content of groundnut range from 45.7 to 48.7% and 44 to 53%, respectively. However, genotypes in Lusikisiki produced low oil content when compared to the range reported by the workers above. The results of the current study agree with findings of Singkham *et al.* (2012) and Ajay (2006) who have reported that groundnut oil content was higher during the dry season compared to rainy season. Nutritional quality (oil and protein content and amino acids) of the seed is strongly influenced by production location, genotype and season, with respect to soil moisture and temperature during crop growth and seed maturation and seed size (Dwivedi *et al*., 1996). The genotypes Lusikisiki mostly in the current study which produced low oil content confirm the above mentioned statement. SA Juweel and Akwa share a similar genetic makeup. Although SA Juweel has high oleic acid in nature, both of them were the least performing genotypes with

respect to oil content (ARC, Grain Crop Institute). The low oil content of these genotypes is probably due to their poor performance in seed yield under dry land.

Groundnut is known as an excellent source of protein. In the current study protein content showed no significant differences among genotypes. It is not understood what would be the reason for genotypes' behaviour on protein content. Gashti *et al.* (2012) reported that using calcium and potassium fertilizers interfered in oil synthesis pathway and probably most of fixed carbon in the plant may be used to synthesize the oil during the protein synthesis in the kernels. Gashti *et al.* (2012) further stated that groundnut is an oil and protein crop and there is a mutual relationship between oil and protein production. Protein components such as amino acids are synthesized first and then the plant uses these substances in order to synthesize the oil and therefore its content enhances. Protein content in groundnuts is not affected by drought towards the end of the season instead it increases (Dwivedi *et al*., 1996). This statement was in agreement with the results of Lusikisiki location.

2.5 Conclusion

Genotypes were significantly different in terms of nutrient concentration levels. Genotypes showed significant differences in seed yield, 100-seed weight and seed dry mass per plant in the across locations. Genotype x environment was observed in Kwarts which was the best performing genotype in Mthatha in terms of seed yield and oil content whilst in Lusikisiki it was Anel for both parameters. Oil content among genotypes was significantly affected by climatic conditions in different locations. Genotypes showed no significant differences in protein content. Depending on genetic variations protein content showed an increase in Lusikisiki location. The productivity of groundnut is high at pH range of 5.3 to 7. However, in Lusikisiki the pH was 4.17 while at

Mthatha it was 5.0. At current state Mthatha is more suitable for groundnut production than Lusikisiki which needs liming prior to groundnut growing. High percentage of empty pods to other genotypes is a result of calcium deficiency. This strongly supports the need for soil nutrient analysis before planting the groundnut.

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3 THE RESPONSE OF FOUR GENOTYPES TO CALCIUM SUPPLEMENTATION AT FLOWERING STAGE IN MTHATHA

3.1 Introduction

Groundnut (*Arachis hypogaea L.*) after soybean is one of the most important oil seed crops in tropical and subtropical regions and is often planted for its richness in oil and protein (Gashti *et al.,* 2012). Increasing global demand for food from one side and production of by-products from the other side determine the economic importance of this crop (Gashti, *et al.,* 2012). Environment and biotic factors are not the only limiting factors: calcium is also a yield limiting nutrient in groundnut production. It is needed for both good vegetative growth of the crop and healthy fruit (pod and seed) development (Cheema *et al.,* 1991; Gashti *et al.,* 2012).

Sufficient calcium content in the soil around the peanut pods leads to increased yield, oil content and protein content of the kernel. It decreases the number decayed pod and other detrimental elements from the soil (Gashti *et al.,* 2012). For vegetative growth, calcium deficiency is manifested as localized pitted lesions on the lower surface of the leaves, which then develop to brown necrotic spots (Cheema *et al.,* 1991). Shortage of calcium and low pH in the soil are the important limiting factors in peanut growth and production (Gashti *et al.,* 2012). Calcium shortage in the soil can also be expressed as blackened plumule inside the seed halves (black heart) while its minor shortages may result into poor germination or weak and deformed seedlings (Cheema *et al.,* 1991). Low levels of calcium result in production of immature pods and black embryo in seeds. It increases the production of potential aflatoxin, especially in soils that are conducive for the growth and development of fungus such as *Aspergillus flavus* (Gashti *et al.,* 2012).

Correct levels of calcium in the soil increase the growth and survival of symbiotic bacteria in peanut, especially in acidic soil, therefore this has a positive effect on nitrogen fixation. Adequate calcium in the soil can help prevent black hallow, cracked pods and decreases pod decay (Gashti *et al.,* 2012). Calcium is absorbed from the soil by roots and transmitted to aerial parts of the plant and it is not transmitted from plant to the pegs. Therefore this incomplete flow of calcium makes it necessary for the soil to have enough levels of calcium around the pegging zone for pod filling. Calcium is available in different sources but it is important to choose the most appropriate source. Gypsum ($CaSO_4$) and calcitic lime ($CaSO_3$) are sources of calcium. However, gypsum easily dissolves and may leach out of pegging zone if 150 mm of rainfall accumulate (Florence, 2011). Gypsum should be applied at early flowering to avoid leaching around pegging zone this will ensure that gypsum is available through pod development. Applications of gypsum may reduce the availability of potassium and magnesium in the pegging zone. This may lead to potassium and magnesium deficiencies in the seed, which reduces their quality, or to the vegetative plant, which reduces plant health and growth. Gypsum does not increase soil pH as compared to calcitic lime.

The objective of the study was to evaluate the response of four genotypes to calcium supplementation selected as best performing in the region of Mthatha.

3.2 Materials and methods

3.2.1 Genotypes

Four different groundnut genotypes, Kwarts, Mwenje, ICGV-SM 95714 and Nyanda were selected from the nine cultivars used in the previous season. The genotypes were selected based on their performance with regard to seed yield.

3.2.2 Experimental site

The experiment was conducted at Mthatha, geographically located between 31°32'29"S, 28°44'44"E about 10km west of the town of Mthatha, Eastern Cape. The average annual rainfall for this region is 617 mm and the average minimum temperature is 15^{o} C while the average maximum temperature is 27^{o} C during summer season.

3.2.3 Soil conditions

The soil at the site was classified to be Oakleaf with a good soil structure (Table 6). Soil is loamy sand to sandy loam with an effective rooting depth of 1000mm on the slope of between 2 and 4%. Soil samples were taken from the site at depth of 0-15cm and sent to the laboratory. Nitrogen (N) required was 20 kg ha^{-1} Phosphorus (P) required was 85 kg ha^{-1} and potassium (K) was 0 kg ha^{-1} required. Lime required was 1000 kg ha^{-1}calcitic lime. The soil pH tested was 4.06 below the required pH of 5 to 6.5 for groundnuts so liming was done (Table 6).

Table 6 The chemical characteristics of Oakleaf soil form used in the study.

Properties	Composition
Phosphorus	0 mg/L
Potassium	187 mg/L
Calcium	218 mg/L
Magnesium	52 mg/L
Zinc	6.6 mg/L
Manganese	0 mg/L
Copper	0.0mg/L
pH (KCL)	4.06
Exchange acidity	0.65 cmol/L
Acid saturation	25%
Total cations	2.64 cmol/L

3.2.4 Planting material

All plots were treated equally at planting; at flowering out of 24 plots only 12 plots in each cultivar were supplemented with calcitic lime ($CaCO_3$) (0.432 kg/plot). The other 12 plots were not supplemented with calcium. Calcitic lime was used in the absence of gypsum ($CaSO_4$), which is the best source of calcium as compared to liming the soil. The plot size was 4 x 3.6 m (14.4 m^2) and the row spacing was 90cm and intra row was 7cm.

3.2.5 Yield determination

At harvesting, dry mass for seed yield and pod yield and 100-seed weight were calculated from harvested bulk (Phakamas *et al.,* 2008). Pods were harvested from the 8.1m^2 and dried in a room temperature for a week. Pods were then weighed to get the pod yield over harvested area and converted to kg/ha. Seed dry mass from the pods was weighed and then converted to kg/ha. Shelling percentage was calculated using a formula of (Sigh and Oswalt, 1995) as follow:

$$\text{Shelling \%} = \frac{\text{Seed dry mass}}{\text{Pod dry mass}} \times 100$$

3.2.6 Seed protein determination

The Bradford micro assay was used to determine the protein contents of the samples. After the addition of reagent, the samples were read spectrophotometrically at 595 nm and protein concentrations were determined by comparing the results with a standard curve based on bovine serum albumin (Tesfay *et a*l., 2010).

3.2.7 Seed oil determination

Oil contents of the samples were determined according to Meyer and Terry (2008). The recovered oil was weighed and the percentage oil content [% (w/w)] was calculated.

3.2.8 Experimental design and statistical analysis

The experiment was arranged in a Randomized Complete Design (RCD). All data were subjected to statistical analysis using Genstat® Version 14. Means were separated using Fisher's unprotected testing least significant differences at 5% level when ANOVA showed significant.

3.3 Results

3.3.1 Climatic data

3.3.1.1 Temperatures

Temperatures were collected on a nearby Agricultural Research Council (ARC) weather station.Temperatures during the growing season were moderately high but decreased towards winter season (Figure 9). This occurred as crop was reaching maturity, however maximum temperatures remained above 20º C until harvest. The critical time of the growing season was between February and March during the flowering and pegging stage.

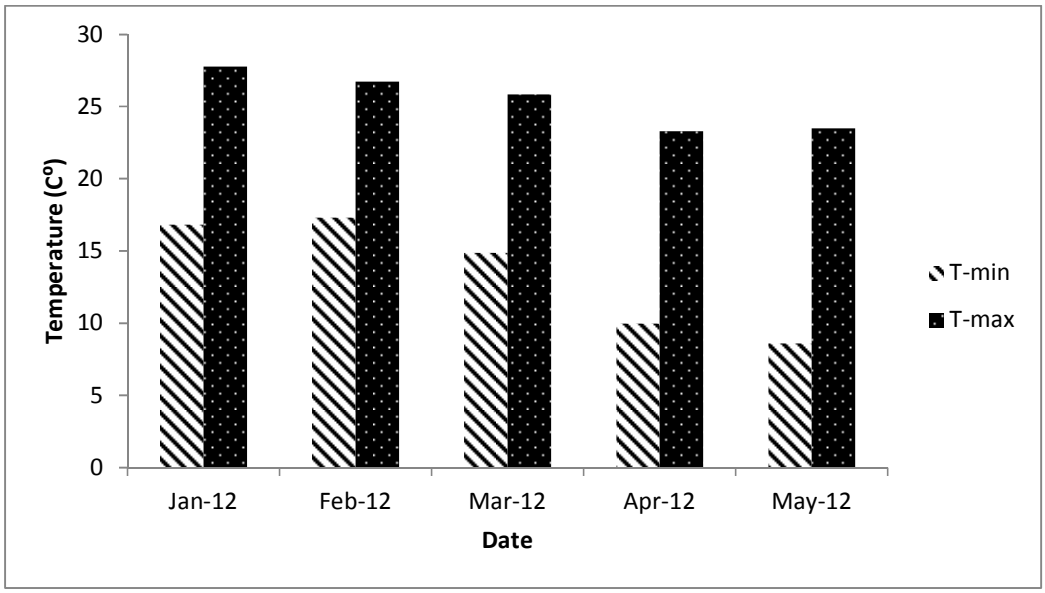

Figure 9 Minimum and maximum temperatures for 2011/12 growing season in Mthatha.

3.9.1.2 Rainfall

The rainfall data was collected on a nearby ARC weather station. The rainfall was received throughout the growing time of the crop. However there was low rainfall between the month of February and March and this was the flowering and pegging stages of the crop (Figure 10). The interactions of both rainfall and temperature would then be of determining factor for yield in this

area. Large amount of rainfall was received (186 mm) in the month of April which the pod formation and maturity stage of the crop.

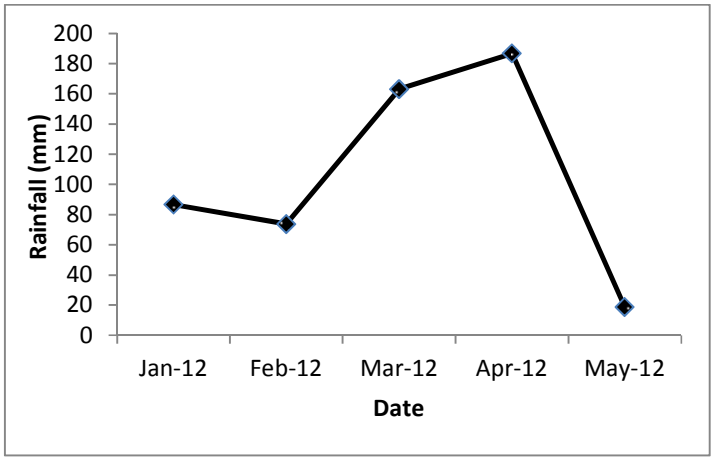

Figure 10 Total rainfall received during growing season in Mthatha.

3.9.2 Pod and seed yield at different levels of calcium

The yield results were very low for 2011/12 season in Mthatha region (Table 7). The experiment was planted in the third week of December 2011 instead of October due to drought prevalence. The germination was poor due to bird damage and replanting was done in second week of January 2012 covered with net wire for two weeks to control birds. At the flowering stage there was severe drought and though the crop managed to flower but most of the pegs could not reach the soil. There was significant difference ($P<0.05$) between genotypes in pod yield (Table 7). Nyanda not supplemented with Ca had the highest pod yield of 545 kg ha^{-1} followed by Nyanda supplemented with 300 kg ha^{-1} of Ca which produced 452 kg ha^{-1} pod yield, ICGV-SM 95714 not supplemented with Ca had high pod yield of 321 kg ha^{-1} . Whilst the same genotype supplemented with 300 kg ha^{-1} of Ca had pod yield of 275 kg ha^{-1} and Kwarts supplemented with 300 kg ha^{-1} of Ca produced pod yield of 312 kg ha^{-1} (Table 7). The lowest pod yields were recorded in Kwarts not supplemented with Ca which had a pod yield of 176 kg ha^{-1}, Mwenje with no supplementation of

Ca produced pod yield of 186 kg ha^{-1} and Mwenje supplemented with 300 kg ha^{-1} of Ca had a pod yield of 191 kg ha^{-1}(Table 7).

Genotypes showed a significant difference ($P<0.05$) in seed yield (Table 7). The highest seed yield was obtained in cultivar Nyanda treated with 300 kg ha^{-1} of Ca had seed yield of 153 kg ha^{-1} followed by Kwarts supplemented with 300 kg ha^{-1} of Ca produced seed yield of 150 kg ha^{-1} and Nyanda not supplemented had seed yield of 140 kg ha^{-1} more than Mwenje supplemented with 300 kg ha^{-1} of Ca which had seed yield of 110 kg ha^{-1} (Table 7). The high seed yield of Nyanda not supplemented with Ca may be probably attributed to its ability to absorb other nutrients that are responsible for seed development like sulfur. The lowest seed yield was recorded in Mwenje not supplemented with Ca with a seed yield of 40 kg ha^{-1}, ICGV-SM 95714 supplemented with 300 kg ha^{-1} of Ca, had seed yield of 53 kg ha^{-1} whilst the same genotype not supplemented with Ca produced seed yield of 95 kg ha^{-1} and Kwarts not supplemented with Ca produced seed yield of 63 kg ha^{-1} (Table 7).

Table 7 The response of four genotypes to different levels of calcium.

Cultivar	Calcium levels kg ha^{-1}	Pod yield kg ha^{-1}	Seed yield kg ha^{-1}
Kwarts	0	176 a	63 ab
Mwenje	0	186 ab	40 a
Mwenje	300	191 abc	110 cd
ICGV-SM- 7514	300	275 abc	53 ab
Kwarts	300	312 bc	150 d
ICGV-SM-7514	0	321 cd	95 bc
Nyanda	300	452 de	153 d
Nyanda	0	545 e	140 cd
CV %		24.7	26.2
$LSD_{0.05}$		131.6	45.68

3.9.3 Shelling percentage

The shelling percentage was significantly different ($P<0.05$) between genotypes (Figure 11). The highest percentage was observed in genotype Mwenje (58.29%) supplemented with 300 kg ha^{-1} of Ca followed by Kwarts (49.29%) supplemented with 300 kg ha^{-1} of Ca, Kwarts (34.64) not supplemented and Nyanda (34.10) supplemented with 300 kg ha^{-1} of Ca. The lowest shelling percentage was observed in ICGV-SM 95714 (19.18%) supplemented with 300 kg ha^{-1} of Ca, ICGV-SM 95714 (21.88%) not supplemented with Ca, Mwenje (22.16%) not supplemented with Ca and Nyanda (25.62%) not supplemented with Ca (Figure 11).

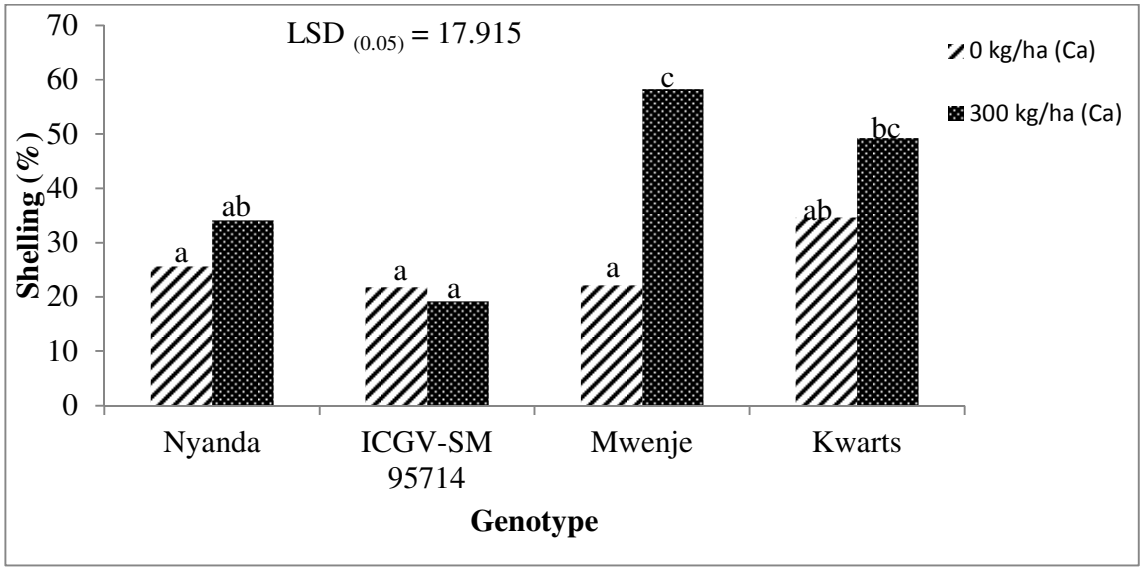

Figure 11 The effect of calcium on shelling percentage.

3.9.4 Oil content

Genotypes had significant difference (P<0.05) with respect to oil content composition (Figure 12). The differences were irrespective of calcium levels across the genotypes. The overall highest oil content was observed in Kwarts (29.96%) with no calcium supplement, followed by ICGV-SM 95714 in both levels (28.96 and 28.68) (Figure 12). The overall lowest value for oil content was observed in genotype Nyanda (20.7%). Mwenje showed clear response to calcium levels though the difference was not huge. Mwenje supplemented had 27.59% whilst Mwenje not supplemented had 25.87%. Nyanda also showed a good response to calcium supplementation a percentage of 27.28% for 300 kg ha^{-1} and Nyanda not supplemented had oil content of 20.7%. Kwarts unexpectedly gave the opposite results of oil content, Kwarts not supplemented had high oil content (29.96%) than Kwarts supplemented with 300 kg ha^{-1} of calcium. ICGV-SM 95714 showed no significant difference between the calcium levels 0 and 300 kg ha^{-1} with respect to oil conten (P<0.05) (Figure 12).

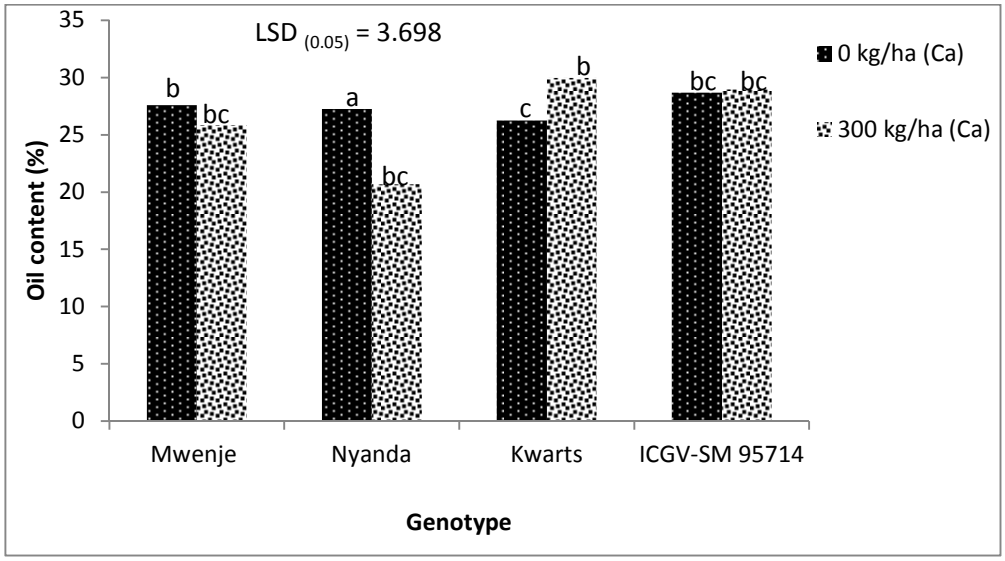

Figure 12 The effect of calcium on oil content in four genotypes.

3.9.5 Protein content

Genotypes showed significant difference (P<0.05) between genotypes in protein content, though difference could not be associated with calcium supplement (Figure 13). The highest protein content was observed in ICGV-SM 95714 with value of 16.63 mg g^{-1} followed by Nyanda (14.54 mg g^{-1}), notable in these genotypes the protein content is high where calcium was not supplemented. Mwenje showed no significant difference (P>0.05) in protein content at different levels of calcium. There is no significant difference (P>0.05) in genotype Kwarts to protein content though the supplement Kwarts had the highest percentage of 12.91% compared to 12.01%.

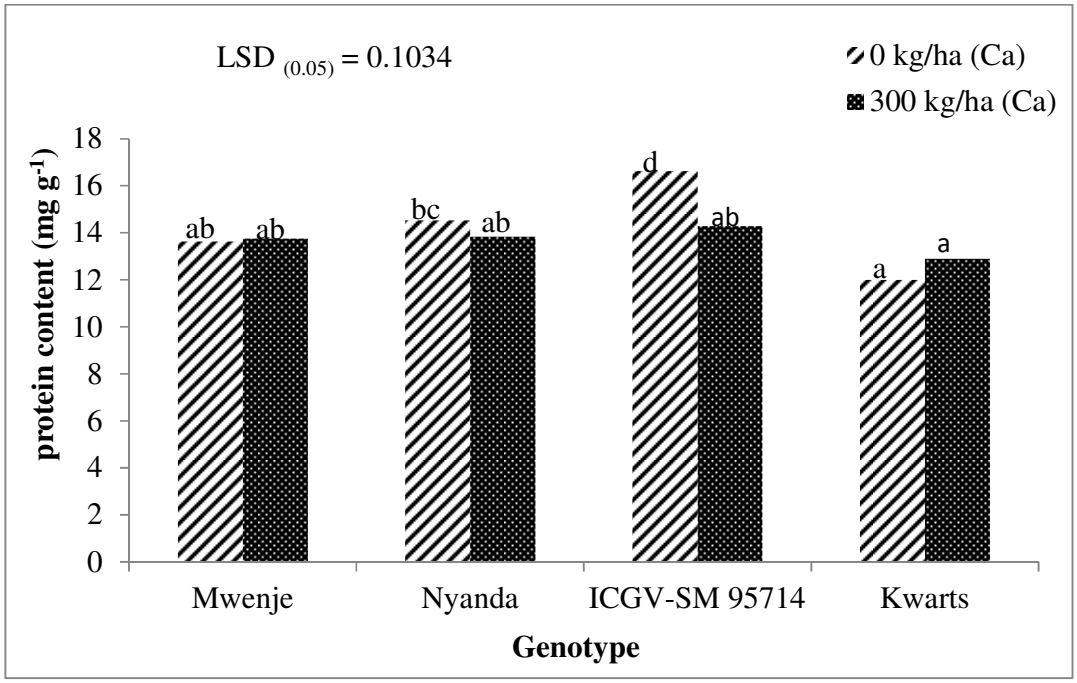

Figure 13 The effect of calcium on protein content in four genotypes.

3.10 Discussion

Calcium in groundnut production is a limiting nutrient; it is needed for both vegetative growth and health seed formation in the pods. Results in the current study were not different from those found by Kamara (2010) who reported that variety and application of calcium had significant effect on seed yield. In the current study the highest yield was recorded in Nyanda and Kwarts supplemented with calcium at flowering stage. Genetic variations were observed in Nyanda supplemented with 0 kg ha^{-1} of calcium producing the highest yield compared to Mwenje and ICGV-SM 95714 supplemented with 300 kg ha^{-1}. Pod yield result differed with the findings of Gashti (2012) who reported that calcium levels had an effect on pod yield increase. The differences were observed in Nyanda and ICGV 95714 with high pod yield produced at 0 kg ha^{-1} of calcium level. The other two genotypes agreed with findings of the worker. However, seed yield findings for all genotypes were not different from those of (Gashti, 2012) except for ICGV-

SM 95714 which had the high yield at 0 kg ha^{-1} of calcium than in 300 kg ha^{-1} of Ca. The behavior of ICGV-SM 95714 is not understood.

Gashti (2012) reported an increase in shelling percentage when high levels of calcium were applied at flowering stage. The percentage increase was perhaps due to the high 100seed-weight since according to the worker the shelling percentage had positive relationship with 100seed-weight. In the current study this increase was noticed in genotype Mwenje and Kwarts. Kamara, (2010) reported the highest shelling percentage of 63% at the rate of 200 kg ha^{-1} which was lower than 300 kg ha^{-1} in the current study. The difference between these two studies could be in the sources of calcium. In the current study calcitic lime ($CaCO_{3)}$ was used while Kamara (2010) used gypsum ($CaCO_4$) which is easily accessible from the soil in the pod zone. The shelling percentage of Nyanda supplemented with 300 kg ha^{-1} of Ca was equal to percentage of Kwarts treated with 0 kg ha^{-1} of Ca. This could be due to low ability of Nyanda to absorb calcium due to environmental conditions or genetic variation though this genotype produced high yield on shelling per it was out-classed by Mwenje and Kwarts. Hartmond (1996) stated that calcium deficiency causes groundnut pegs and pods to abort, resulting in decreased shelling percentages and yields. Environmental factors influencing calcium availability include soil Ca content and soil moisture. The response of ICGV-SM 95714 to calcium was not effective since the 300 kg ha^{-1} of Ca gave low shelling percentage and low yield than the 0 kg ha^{-1} of Ca.

Oil content has been reported to range between 33.6 to 56% in groundnut kernels (Ajay *et al.,* 2006; Gashti *et al.,* 2012; Kamara 2010; Ee and Dunford, 2009 and Shad *et al.,* 2009). The results in the current study showed low oil content than the range reported. This might be due to low temperatures that occurred during the growing season which have restricted the synthesis of oil.

Kamara (2010) reported that oil content of groundnut differ with growing season and growing conditions. In normal growing season calcium application increases the oil content of the groundnut seeds (Kamara 2010; Gashti *et al.,* 2012).

In the current study Nyanda and Mwenje are the only genotypes that showed clear response to calcium application. The response of other genotypes Kwarts and ICGV-SM 95714 is not understood where the same genotype treated with calcium at flowering will produce low or equal oil content when calcium was not applied. Gashti *et al.* (2012) reported high levels of potassium compared to calcium levels may compete in pod zone thus disturbing photosynthetic materials synthesis leading to low oil and protein content. Calcium application has no effect on protein content instead phosphorus is reported to increase protein content (Kamara, 2010). The results of the current study showed no significant difference between the calcium levels with respect to protein content. The highest protein content was observed in ICGV-SM 95714 with no calcium application.

3.11 Conclusion

Generally genotypes treated with calcium at flowering stage had high seed yield than when they were not supplemented. This means that calcium supplementation will always increase seed yield in groundnuts. Shelling percentage was higher in all genotypes supplemented with calcium than when they were not supplemented except for ICGV-SM 95714. Calcium application at flowering increased the oil content in genotype Nyanda and Mwenje. Genotypes did not differ with calcium application at flowering in protein content but differences were based on climatic conditions and the season though they were higher than results in chapter three in the same site.

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4 GENERAL DISSCUSION AND CONCLUSIONS

4.1 Discussion

Agro-ecological conditions vary widely in southern Africa and therefore there are a number of production constraints (Hildebrand and Subrahmanyam, 1994). The dominating factors include diseases, and the lack of suitable cultivars adapted to specific environments, particularly to areas where rainfall is unreliable. Lack of suitable varieties, adapted to many and varied agro-ecological conditions (Hildebrand *et al.,* 1994) with acceptability for various preferences and final uses, has long been considered a major constraint in southern Africa. Groundnut is of major importance to smallholder farmers in southern Africa. It is an important source of protein and oil, a food source that does not even need processing.

The main aim of the study was to find the suitable commercial cultivars for different agro-ecological zones of Eastern Cape Province of South Africa. Out of the nine genotypes planted at the first site (Mthatha) five genotypes, Kwarts, ICGV-SM 9571 4, Nyanda, Mwenje produced good yield under dryland conditions. Kwarts has been recommended under dry land conditions by the South African ARC, Grain Crop Institute as the best yielding genotype and it can be planted from late November to mid-December. This genotype is reliable to small scale farmers when unreliable rainfall is delayed. In the current study, Kwarts and Nyanda also gave lowest percentages of empty pods (pops) which is a good sign of calcium absorption during pod filling. SA Juweel produced low empty pods, but it also produced low yield, therefore it is not suitable under dry land conditions. However, Akwa is recommended together with Anel and Kwarts under high potential conditions (ARC, Grain Crop Institute).

The same genotypes studied in Mthatha were planted under different conditions with high rainfall in Lusikisiki. However, seed yield was generally lower when compared to Mthatha region irrespective of the genotype performance. Among the highest performing cultivars were Anel, Nyanda, ICGV-SM 90087, Akwa and Harts. The results in this region also confirmed the report by ARC, Grain Crop Institute that Anel can perform well under dryland conditions without irrigation. Notably, genotype Kwarts had highest yield in Mthatha, but it came last in Lusikisiki. However, the observations revealed that winter or late season rainfall just before harvesting can significantly reduce yield. This genotype matured early in all sites and, therefore, was severely affected by wet conditions particularly in Lusikisiki where it was wet and warm due to coastal influence. This genotype had the highest shelling percentage in all genotype despite its low yield and second last in low 100 seed-weight.

Harts, although among the best performing cultivars, it was also affected by the wet and warm conditions just before harvesting and is reported by ARC, Grain Crop Institute as the shortest growing season cultivar. Seed yield and shelling percentage of ICGV-SM 95714 confirmed results of Kamara (2010) who reported a positive relationship between the number of filled pods and shelling percentage. Notable, 100seed-weight for Harts did not change with the environment, although the yield was slightly lower in Mthatha region. Generally, the highest performing genotype in both environments in terms of seed yield also produced the highest oil content and lowest performing genotypes also produced lower oil content. Protein content in Lusikisiki was higher than Mthatha and the differences could be associated with the environment.

Environment and biotic factors are not the only limiting factors, calcium is also a yield limiting nutrient in groundnut production. It is needed for both good vegetative growth of crop and healthy

fruit development (Cheema *et al.,* 1991; Gashti *et al.,* 2012). Calcium is very important for seed development in groundnut. Groundnuts are particularly susceptible to a calcium deficiency in the soil. If groundnut is grown on low calcium soils (ARC, Grain Crop Institute) the producer will have a direct seed loss as well as indirect damage to the seed which is not always visible. Seed produced under such conditions is not suitable for planting.

In this study genotypes that produced high yield in Mthatha were further investigated for response to calcium supplementation levels. Genotypes, Nyanda, Kwarts and Mwenje showed good response to calcium application at flowering stage. These results suggest that for high yield to be achieved, adequate calcium levels are important around the pod zone. Kamara (2010) also reported a highest number of filled pods when 100 kg ha^{-1} was applied at flowering stage compared to 0 kg ha^{-1} of calcium. Shelling percentage increased when calcium was applied at flowering stage except for genotype ICGV-SM 95714. This study was in agreement with that of Kamara (2010) who reported an increase in shelling percentage at 100 to 200 kg ha^{-1}. Calcium application at flowering or enough calcium around pod zone does not only ensure high seed yield, but also an increase in oil content (Gashti *et al.,* 2012; Kamara, 2010). However, protein content was not affected by calcium application, which was still in line with the findings of the same workers. Protein content was reported to increase by the application of phosphorus (Kamara, 2010).

4.2 Conclusions and recommendations

In conclusion, the following recommendations are based on the study conducted at both sites and on the calcium supplementation study that followed.

a) Genotypes showed significant difference under different conditions. Kwarts, Nyanda Mwenje and ICGV-SM 95714 were found to be suitable in the climatic conditions of

Mthatha region. However the emphasis on the best genotype will be in Kwarts since it is highly recommended in dry land conditions.

b) Anel, Nyanda, Harts, ICGV-SM 90087 and Akwa were found suitable in the climatic conditions of Lusikisiki region. Anel and Harts would be recommended for smallholder farmers because of high performance under dryland conditions and Harts with the shortest growing season.

c) In both regions it is highly recommended for farmers to avoid late harvesting as these regions have a potential of winter or late season rainfall which can significantly reduce yield. Late harvesting affect the seed quality and high pod rot hence pods remaining in the soil.

d) The ability of SA Juweel to fill almost all pods produced per plant in both regions makes it necessary for future studies and breeding programme to develop this genotype for dryland conditions.

e) The relationship between seed yield and oil content needs further investigation in the highest performing genotypes.

f) Groundnut production in Lusikisiki would require extra effort of liming as the soil is more acidic due to high rainfall.

g) The two genotypes Kwarts and Anel that were adapted to agro-ecological zones of Mthatha and Lusikisiki absorbed less calcium in both locations at flowering. This behavior might have assisted these genotypes to save calcium for pod filling.

h) The behavior of Nyanda in response to Ca supplementation warrant further investigation especial the root characteristics.

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