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Evaluating agronomic performance of new short season groundnut (*Arachis hypogea*) varieties under rain fed conditions.

Zhuwao Sandra
B1441318

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Author : SANDRA ZHUWAO

Reg Number : B1441318

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Submitted in partial fulfillment of the Bachelor of Agriculture Honours Degree in Crop Science

Name of supervisor:

Signed ……………………………………………………….

Date ………………………...

Declaration

Student declaration:

I Zhuwao Sandra (B1441318) vow that this dissertation has not been submitted to any University or Academic institution and that it is my own work conducted under the supervision of Doctor R. Mandumbu and Doctor C. Parwada. All the assistance towards the completion of this work and all the academic sources used have been duly accredited.

Zhuwao Sandra …………………………. Date 21 MAY 2018

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I have supervised this research project of the above mentioned student and I am convinced that the research project can be submitted.

Doctor R. Mandumbu (Supervisor)…………………………………………….

Date 21 May 2018

(Supervisor)

Doctor R. Mandumbu (Supervisor)……………………………………………

Date 21 May 2018

I certify that I have checked this Research Project and I am satisfied that it conforms to The Department of Crop Science Guidelines for Project Preparation and Presentation. I therefore, authorize the student to submit this dissertation for marking.

……………………………….. Date………………………………………

(Quality Controller)

Dedication

To my parents Mr and Mrs Zhuwao.

Acknowledgements

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Abstract

There have been continued low yields obtained by farmers in groundnut production. The objective of the study was to evaluate the performance of the new short season varieties and compare with the performance of the check varieties Nyanda, Illanda and Tern. The experiment was carried out in the 2016-2017 cropping season at the Department of research and specialist services in Harare. The experiment was laid in a randomised complete block design (RCBD) and replicated three times. The groundnut varieties were evaluated on the days to 50% emergence, 50% flowering, days to physiological maturity, pod and seed yield as well as the shelling percentage. The results showed that there was no significant difference in the days to 50% emergence among all the groundnut varieties. The new variety Jl11 had the shortest days to flowering whereas the check cultivar Illanda had the longest days to 50% flowering. The new variety Chitala and Jl11 took 91 days to reach physiological maturity whilst the check cultivar Tern took 120 days to reach physiological maturity. Chitala had the highest pod yield of 4635kg/ha and seed yield 3804kg/ha, whilst the check cultivar Tern had the lowest pod yield of 3020kg/ha and seed yield of 2169kg/ha. New variety Jl11 had highest shelling percentage of 83%, the check cultivar Nyanda and Illanda and had lowest shelling percentage of 68%. The new short season groundnut varieties proved to be better performing and better yielding, hence can improve groundnut yield obtained by farmers.

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List of abbreviations

Kg……………….... Kilograms

t/ha………………..Tonnes per hectare

^{o}C…………………Degrees Celsius

ANOVA ………… Analysis of variance

N…………………. Nitrogen

P…………………..Phosphorus

K…………………. Potassium

Ca………………… Calcium

S………………….. Sulphur

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Groundnut (*Arachis hypogaea)* is a self-pollinating annual legume that originated from South America in Bolivia (Kumar *et al.,* 2018). Groundnuts is divided into two subspecies which are *Arachis hypogea* subspecies *hypogea* and *Arachis hypogea* subspecies *fastigiata* (Kumar *et al.*, 2018). The subspecies *hypogea* are long season, they reach physiological maturity in 120-150 days. Subspecies *fastigiata* are the short season varieties which reach physiological maturity in 90-120 days.

Groundnut is an economically important crop in subsistence farming (Sabine *et al.*, 2015). It plays a significant role in the diet of people providing proteins, carbohydrates and mineral elements (Oteng *et al*., 2017). Groundnuts can be consumed raw or roasted as snacks or can be ground into peanut butter which can be used as a spread on bread. Groundnuts is an important oil crop with uses in industrial oil extraction as well as soap making. The plant stalk, haulms and shells make a good livestock feed (Kumar *et al.*, 2018). Groundnut crop has the ability to fix atmospheric nitrogen into available nitrogen for plant uptake. Hence, rotation with groundnut improves soil fertility (Waddington and Karigwindi, 2001). Groundnut is an important cash crop that can be sold as shelled or unshelled to generate income, thereby improving the farmer's income (Murray, 2016).

Production of groundnut is done in the tropics and subtropics. The highest groundnut producing countries are China, India, USA and Nigeria. In Africa, the highest groundnut producing country is Nigeria with an average yield of 1.720t/ha (FAOSTAT, 2015). In Zimbabwe, groundnut production is done in natural regions 2 and 3 under rain fed conditions. Little production is done in natural region 4 under irrigation (Sabine *et al*., 2015). Most of the groundnut production about 75% is done by small holder farmers, with women dominating. Groundnut as a crop is second after maize in Zimbabwe in terms of area coverage (Sabine *et al*., 2015). This makes groundnut an important crop in the country as an income generator to improve livelihoods of people. It is also a potential foreign currency earner through export (Sabine *et al.,* 2015).

However production of groundnut has remained low in the country with an average of less than 0.5t/ha due to a number of challenges faced by farmers (Sabine *et al.*, 2015). The constraints contributing to the continued low yields include occurrence of frequent droughts which reduces pod yield. High incidence of diseases such as early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Cercospora personaium*) which causes leaf discolouration and stunted growth thereby reducing pod yield in groundnuts (Oteng *et al*., 2017). Poor weed management and poor soil fertility contribute to the continued low yields. According to Taruvinga *et al.*,(2015) weeds reduce yield through competition with the crop in the early vegetative stage for soil nutrients ,water and light. In addition farmers have poor access to quality seed which has resulted in over use of retained seed which over time lose plant vigour hence low yields (Konlan *et al.*, 2013). Lack of improved groundnut varieties which are well adapted to the changing climatic conditions has contributed to the low yields obtained by farmers. However there has been release of new short season groundnut varieties which are Nsinjiro, Chitala and Jl11. These new varieties may be able to improve groundnut yield.

1.2 Problem statement

Zimbabwe's groundnut production is characterised by low yields. Productivity has been fluctuating between 0.4t/ha – 0.6t/ha since 2008. In the 2011/2012 season yield dropped to a low of 0.36t/ha (GoZ, 2012). The continued low yields obtained by farmers in Zimbabwe affect the food security of the country as well as the livelihoods of the farmers. The low yields have increased importation of groundnuts from neighbouring countries such as Zambia and Malawi (USAID, 2010). The groundnut varieties that are in cultivation have long been used. The last variety that was released was Illanda, which was released in year 2006. There has been no introduction of new short season groundnut varieties despite the prevailing climate change (Personal communication with government groundnut breeder). The varieties that are in cultivation are no longer well adapted to the changing climate. Hence, the low yields in groundnut production being obtained by farmers. The varieties that are in cultivation for instance Nyanda, Illanda and Tern are susceptible to drought stress which is relatively reducing yield of the varieties.

1.3 Justification

The new short season groundnut varieties Nsinjiro, Chitala and Jl11 may have the ability to improve the groundnut yield in Zimbabwe. These new varieties may have been bred to adapt to the changing climatic conditions. These new groundnut varieties may be able to enhance yield even when farmers cannot afford costly external inputs such as fertilisers (personal communication with government groundnut agronomist). Improving groundnut production is important among small holder farmers because it is an important crop in the diet of people as a rich source of oil and protein. Groundnuts are a high value crop that requires low cost inputs relative to other crops such as maize and tobacco (Makuvaro *et al.*, 2014). Thus, groundnuts are important for generation of income among the rural farmers especially women who are the main producers (SNV, 2009). Increasing groundnut production will reduce imports of the crop thereby improving the country's economy. In addition, increased groundnut production will improve livestock feed and raw materials for industries which manufacture products derived from groundnuts. Export of groundnut from surplus can gain Zimbabwe foreign currency.

1.4 Main objective

- To evaluate the agronomic performance of new short season groundnut varieties under rain fed conditions.

1.4.1 Specific objectives

- To determine the days to 50% flowering of the new short season groundnut varieties Chitala, Nsinjiro and Jl11 against check cultivars, Nyanda, Illanda and Tern.
- To determine the days to physiological maturity of the new short season varieties Chitala, Nsinjiro and Jl11 against check cultivars Nyanda, Illanda and Tern.
- To determine yield of the new short season groundnut varieties Chitala, Nsinjiro and Jl11 against check cultivars, Nyanda, Tern and Illanda.

1.4.2 Alternative Hypothesis

- H_1: There is a significant difference in the days to 50% flowering between the new short season groundnut varieties Chitala, Nsinjiro and Jl11 and the check cultivars Nyanda, Illanda and Tern.
- H_1: There is a significant difference in the days to physiological maturity between the new short season groundnut varieties Chitala, Nsinjiro and Jl11 and the check cultivars Nyanda, Illanda and Tern.
- H_1: There is a significant yield difference between the new short season groundnut varieties Chitala, Nsinjiro and Jl11 and check cultivars Nyanda, Illanda and Tern.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and botany of groundnut

Groundnut originated from South America. The occurrence of groundnut in South America is widely distributed in Argentina, Bolivia, Paraguay and Uruguay (Kumar *et al.*, 2018). Groundnut is subdivided into *Arachis hypogea hypogea* and *Arachis hypogea fastigiata* (Kumar *et al*, 2018). *Arachis hypogea* subspecies *hypogea* show dormancy whilst *Arachis hypogea fastigiata* does not show dormancy.

2.2 Nutritional and economic importance of groundnut in Zimbabwe

Groundnut is an important subsistence crop throughout Zimbabwe (Sabine *et al*., 2015). It is grown for its edible seeds. Groundnut is a highly nutritious crop rich in oils, proteins, carbohydrates as well as vitamin B and E. On average groundnut seed has an oil content of about 48-50% and protein content of 26-28% making it an important crop in people's diets (DR&SS, 2015).

Groundnut can be used in many different forms, which include roasted or salted and consumed as a snack. They can also be consumed as boiled or raw. The groundnut seed can be grind into a paste known as peanut butter (figure 2.1) which is widely used as a spread on bread or can be added to relish (GoZ, 2012).

In industries, the seed of groundnut can be used for oil extraction (figure 2.1). The vegetable oil from groundnut can be used in margarine production. Groundnut is also utilised in pharmaceutical and cosmetic products. Furthermore, lubricants and emulsions for insecticides can be derived from groundnut (SNV, 2009).

Figure 2.1 products of processed groundnuts, oil (left) and peanut butter (right). (www.google groundnut products pictures)

In cropping systems, groundnuts are grown as cover crops in intercropping systems with cereal crops such as maize and sorghum (Konlan *et al*., 2013). This results in reduced soil erosion in the fields due to its soil binding ability. Groundnut is also grown in rotation with cereal crops such as maize, sorghum and millet. This is because groundnut is a leguminous crop with the ability to fix atmospheric nitrogen. Groundnuts harbour symbiotic bacteria known as rhizobia in its nodules. The rhizobia assist in fixing atmospheric nitrogen into nitrogen available to the plants thereby improving soil fertility (Tarfa *et al*, 2017).

The plant stalk of the crop can be used as livestock feed. In addition the haulms are also highly palatable to livestock (Oteng *et al*., 2017). The haulms are relatively rich in proteins. Furthermore, the groundnut shells can be crushed to make livestock cake which can be fed to cattle. The residue from groundnut oil extraction is also utilised in livestock feed as protein supplements. It contains on average 40-50% protein, making it a good protein supplement to livestock (Murray *et al*., 2016).

Groundnuts crop can be used to facilitate increase in rural income. Shelled groundnut per metric tonne at private buyers such as Reapers is sold at US$900 (AMA, 2018). Most commonly, the groundnut are sold in pods at markets such as Mbare musika (Makuvaro *et al*., 2014). A 20 litre bucket of unshelled groundnut is sold at US$22 (AMA, 2018). There can be value addition to groundnuts to raise income generation. This is largely done by women who grind the nuts into peanut butter which is packed in different bottle sizes for sale (Kagoro and Chatiza, 2012).

2.3 Ecology of groundnuts

Groundnuts are well adapted to tropics, sub-tropics and warm temperate regions (Bolaji *et al.*, 2015). The average annual rainfall requirements for groundnut production is 450mm-700mm that is evenly distributed (FAO, 2014). Best yield results of groundnuts are obtained from deep, well drained soils, which include sandy loam soils. The best pH for growth ranges from 5.3-6.5 ($CaCl_2$) (N2 Africa, 2014).

2.4 Growth and development of short-season groundnut varieties

The short-season groundnut varieties are always erect and the pods are concentrated around the central axis (Pagadala *et al*., 2000). The seeds of the short-season varieties do not show dormancy. Physiological maturity is reached in 90-120 days (DR&SS, 2015).

In groundnuts, seed germination initiates in 3-5 days after sowing depending on soil moisture. Emergence of groundnuts from the soil is observed in 8-10 days after sowing as observed by Canavar (2016). The optimum temperature for seed germination and seedling emergence is 25-30^{0}C. In the early development stage, the seedling is mainly concerned with main stem elongation and leaf production.

The economic yield of groundnut is dependent on flowering of the crop (Craufurd *et al.*, 2000). Flowering in groundnut initiates in 30-40 days after sowing. Each node develops several flowers. The petals are folded when the flower first emerges. Unfolding of the flower usually takes place early in the morning. Soon after unfolding of the flowers, pollen is shed and fertilization follows in 3-6 hours (Prasad, 2011).

The flower withers after fertilization activating the growth and elongation of an intercalary meristem (Prasad, 2011). This is found at the base of the ovary. The intercalary meristematic structure is known as the peg or gynophore. The gynophores are geotropic, they grow towards the soil. This process is highly dependent on soil moisture for the pegs to exert a force to penetrate the soil. The gynophore holds the ovary with the fertilised ovule at its tips (Kaba *et al.,* 2014).

Once the peg penetrates the soil to a depth of about 5cm, the ovary at the tip of the peg begins to swell. The tip aligns itself horizontally away from the base of the plant and the pod develops (Prasad, 2011). The pod will continue to expand increasing its size until it reaches dimensions characteristic of the cultivar.

2.5 Production of groundnuts in Zimbabwe

2.5.1 Areas of production

In Zimbabwe, groundnuts is grown in natural farming regions 2 and 3 under rain fed conditions and is grown under irrigation in natural farming region 4 and 5 (Waddington and Karigwindi, 2001). Manicaland and Mashonaland east provinces are the highest producers of groundnuts in Zimbabwe. Groundnuts are also grown in some parts of Mashonaland central and Mashonaland west provinces (GoZ, 2012).

Production of groundnut in Zimbabwe is mainly done by small holder farmers. Groundnut crop is second after maize in Zimbabwe in terms of area coverage, 354.636 ha is under groundnut production (Sabine *et al*., 2015). The average yield obtained by farmers in Zimbabwe is 0.5t/ha.

2.5.2 Varieties grown

The groundnut varieties grown in Zimbabwe include the long season varieties such as Flamingo and short season varieties such as Nyanda, Illanda and Tern. The variety Nyanda was released in year 2000. It has an average pod yield of 3550kg/ha and seed yield of 2414kg/ha. On average Nyanda has a shelling percentage of 68%. Nyanda takes about 120 days to maturity (Seed Co, 2015).

Tern was released in year 2005. It has an average of 3917kg/ha pod yield. The average seed yield is 2685kg/ha. Shelling percentage of tern on average is 68%. The variety tern takes about 125-130 days to maturity (DR&SS, 2015).

The groundnut variety Illanda was released in the year 2006. On average, it has a pod yield of 4000kg/ha and seed yield of 2880kg/ha. The shelling percentage of Illanda on average is 72%. It takes about 85-100 days to maturity. Illanda lacks dormancy, hence it is highly susceptible to sprouting if harvesting is delayed (DR&SS, 2015).

2.6 Importance of short season groundnut varieties in agricultural production

The short season groundnut varieties reach physiological maturity in 90-120 days (DR&SS, 2015). Hence these varieties are able to circumvent abiotic and biotic stress faced during the growth period. Thus early maturing varieties have the ability to yield high in the face of natural stress.

2.6.1. Short season groundnut varieties and moisture stress

Early maturing varieties are well adapted to regions where erratic rainfall patterns are experienced. The moisture critical stages which are flowering, pegging and pod development coincide with adequate moisture required to initiate these stages (Ricardo *et al*., 2010). This enables optimum flowering to occur. More so, pegging initiates when there is adequate soil moisture allowing the crop to exert enough force to overcome soil resistance and penetrate the soil, thereby initializing pod formation (Kaba *et al* ., 2014). Early maturing varieties are highly preferable when experiencing drought conditions in order to obtain better yield due to their ability to mature early and escape stress.

2.6.2. Short season groundnut varieties and heat stress.

The short season groundnut varieties can overcome heat stress during the growing period which compromises yield. The optimum temperatures for the growth and development of groundnut is 25-30^{0}C, temperature exceeding this will induce stress in the crop (Hamidou *et al*., 2012). Heat stress especially during flowering, pegging and pod development will directly reduce yield (Pagadala *et al*., 2000). This is because heat stress reduces pollen viability and pollen production, thereby reducing peg number which initiates pod development. Heat stress during pod development also reduces pod expansion resulting in smaller pods (Hamidou *et al.*, 2012). The early maturing varieties synchronises the heat sensitive stages with optimum temperatures. Therefore short season groundnut varieties can escape heat stress.

2.6.3. Short season groundnut varieties and aflatoxin contamination

The short season groundnut varieties reach physiological maturity before the end of season drought sets, thus can overcome problems of aflatoxins (Oteng *et al*., 2017). Drought stress in the late season is favourable to aflatoxin contamination which is a major challenge in groundnut production. Aflatoxins limit groundnut trade and also limit groundnut producers from accessing big markets for their produce (Guchi, 2015). In addition, aflatoxins have serious effects on human health, therefore aflatoxin contamination should be avoided in groundnuts. The short season varieties due to their early maturity are harvested earlier before extreme drought is experienced, hence can escape in field aflatoxin contamination.

2.7 Constraints to groundnuts production in Zimbabwe

Production of groundnuts in Africa at large is very low with an average yield of less than 900kg/ha as compared to the world's average yield of 1500kg/ha (FAO, 2014). In Zimbabwe the average yield is even lower at less than 0.5t/ha (Sabine *et al*., 2015). Both abiotic and biotic factors are constraining groundnuts production. Furthermore social factors are contributing to the challenges being faced in groundnut production.

2.7.1 Abiotic stress

Abiotic factors such as erratic rainfall patterns leading to drought occurrences as well as heat stress affect groundnut production. Moisture stress and heat stress mainly affect the critical development stages of the crop which determine output yield. The critical stages affected are flowering stage, pegging stage as well as the pod formation stage.

Extreme high temperatures above 36^{0}C significantly reduces yield. These extreme high temperatures especially during the reproductive stage reduces flowering (Kumar *et al*., 2018). The flowers produce pegs which penetrate the soil to form the groundnut pods. High temperature which compromise flowering will directly affect yield of groundnuts.

Drought stress causes at least 90% yield variation in groundnuts (Ricardo *et al*., 2010). During the flowering stage, drought stress decreases the number of flowers per plant. In addition, the moisture stress reduces or stops pegging as well as pod development (Hamidou *et al*., 2012). This is because the pegs are not able penetrate the hard soil in order to initiate pod development.

2.7.2. Biotic stress

Biotic factors such as pests and diseases are a major challenge faced in the production of groundnuts. The major pests of groundnut include aphids (*Aphis craccivora*). The aphids suck sap from the growing plant causing stunted growth. The leaf eating pests such as the bollworm (*Helicoverpa armigera)* feed on foliage causing holes and cuttings, hence reducing the surface area for photosynthesis (Biswas, 2014).

Groundnut is highly susceptible to losses incited by pathogens (Oteng *et al*., 2017). Soil borne pathogens such as *Aspegillus* can easily attack the crop due to the close association of the pods and the soil. *Aspegillus* causes seed rot in soil. Early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Cercospora personaium*) also contribute to low yields. Early and late leaf spot cause elongate brown spots on leaves, stems, petioles and pegs which result in premature ageing of the crop. Rust (*Puccinia arachidis*) produces orange pustules on the lower leaflet surface and may also show on the upper surface. The leaves become necrotic, curl and desiccate leading to premature drop of the plant (Oteng *et al*., 2017).

Weeds are a major problem especially in the early vegetative stage. This is because groundnut shows slow growth in the early vegetative stage, thus highly susceptible to weed infestation (Bolaji *et al*., 2015). According to Taruvinga *et al.*, (2015), weeds compete with the crop for the above ground and below ground resources. Below ground, the weeds compete with the crop for soil moisture and soil nutrients. Above the ground the weeds compete for sunlight with the groundnut crop.

2.7.3 Social constraints

The social constraints being faced by farmers in groundnut production include poor agronomic practices. These challenges include poor planting dates such as delayed planting. A research carried out by Canavar (2016) showed that planting dates have a major influence on yield in groundnuts. Early planting with the first effective rains show 20%-50% greater pod yield than late planting. This is because early planting maximises the growing period for yield advantage. With late planting the crop is likely to suffer end of season drought and heat stress. Significant increase in potential yield is related to early planting.

The lack of input investment in groundnut production is another challenge being faced (Waddington and Karigwindi, 2001). The majority of the farmers who produce groundnuts do not apply fertilisers to the groundnut crop in areas of poor soil fertility. This is due to inability to afford fertilisers and lack of technical knowledge on the fertiliser requirements (Sabine *et al*., 2015). Furthermore farmers do not apply gypsum (Ca 22.3%: S18.6%) to their crop during the flowering stage. Gypsum improves number of pods and pod filling thereby improving pod yield in the crop (SNV, 2009).

Moreover there is lack of extension services to provide information on groundnut production practices that enhance yield. Farmers in groundnut production do not have adequate technical knowhow on agronomic practices to improve yield (Waddington and Karigwindi, 2001).

Lack of improved seed is a major challenge in groundnut production contributing to the continued low yields obtained by farmers. Improved seed enhances yield even when the farmers cannot afford to invest in costly inputs such as fertilizers (personal communication with government groundnut agronomist). Most farmers in the smallholder sector use retained seed (Sabine *et al.,* 2015). Groundnut seed can be retained for at least three seasons and continue to give better yields. However if the seed is retained for many years plant vigour is lost hence leading to poor plants which are very low yielding.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study site

The trial was carried out in the 2016-2017 cropping season at the Department of Research and Specialist Services (DR&SS) in Harare. DR&SS is in natural region 2a, it receives an average rainfall of 750-1000mm per annum and an average of 16^{0}C in winter and 26^{O}C in the summer season. DR&SS is located at an altitude of 1506m above sea level, longitude of 31'^{0}03'E and 17O48'S latitude. It is characterised by red loamy soils.

3.2. Experimental design

The trial was laid in a Randomised Complete Block Design (RCBD). The blocking factor was slope. The experiment had six treatments. The treatments were three new short season groundnut varieties which are Chitala, Nsinjiro, Jl11 and three check cultivars which are Nyanda, Illanda and Tern. The treatments were replicated three times.

3.2.1 Field layout

Table 3.1: Field layout

Rep 1

1	2	3	4	5	6
1	**2**	**3**	**4**	**5**	**6**

0.5 m between plots   6 m long rows   2.25m in width

Rep 2

7	8	9	10	11	12
5	**3**	**6**	**1**	**2**	**4**

Rep 3

13	14	15	16	17	18
6	**4**	**2**	**3**	**1**	**5**

KEY

Top number – plot number

Bottom number - treatment number

Table 3:2 Treatments

Treatment number	Variety
1	Nyanda
2	Illanda
3	Tern
4	Nsinjiro
5	Chitala
6	Jl11

3.2.2 Source of planting material

The seed for the new short season groundnut varieties Chitala, Nsinjiro and Jl11 as well as the seed for the check cultivars Nyanda, Illanda and Tern were obtained from the Agronomy Research Institute.

3.3 Experimental procedure

3.3.1 Land preparation and trial setup

The land was disc ploughed using a tractor drawn disc plough with a disc harrow to establish fine tilth to loosen the soil. Setting-up of the trial site was done using field pegs, thread and tape-measures. The plots were labelled by placing tags in each plot. Rows were created using row markers.

3.3.2 Planting and fertiliser application

Groundnut seed for planting was dressed with a fungicide, Thiram. Planting was done by hand at a seed rate of 100kg/ha with an interrow spacing of 45cm and inrow spacing of 7.5cm. Compound D (N 7%: P_2O_5 14%: K_2O 7%) was applied in rows at planting at 150kg/ha.

At flowering stage calcium sulphate (gypsum) (Ca 22.3%: S 18.6%) was applied. The calcium sulphate was split applied, 100kg/ha was applied at day 33 after sowing. Another 100kg/ha was applied at day 47 after sowing. The calcium sulphate was applied at the base of the plants to enhance pod development.

3.3.3 Weeding

Weeding was done at day 15 and day 42 after sowing. Hoe weeding was done at day 15 and at day 42 hand pulling of weeds was carefully done in order not to interfere with the flowers.

3.3.4 Harvesting

Harvesting was manually done by pulling the groundnuts from the soil. Each plot was harvested separately. The groundnuts were naturally sun dried in the field. After drying, the pods were plucked and packed in ventilated pockets. In each pocket a tag was put, in order not to mix the different varieties.

3.4 Data collection

3.4.1 Days to 50% emergence

The groundnut seedling starts by cracking the soil before fully emerging from the soil. Constant checks were done in the morning and late afternoon for emergence of the seedlings from the crop. Days to 50% emergence were determined as the number of days after sowing when 50% of the plants emerged from the soil.

3.4.2 Days to 50% flowering

The number of days after sowing when 50% of the plants bear at least one flower each was recorded as the date to 50% flowering.

3.4.3 Days to physiological maturity

Five plants were selected randomly from the discard row and pulled out. When the pods were observed to have reached normal size with characteristic veins, they were break open to determine seed size and colour. When the internal pod had turned to a darker colour, seed turned into the characteristic seed colour to variety and when the seed were fully developed the crop was considered to have reached physiological maturity. The date was then recorded as the day to physiological maturity.

3.4.4 Pod yield (kg/ha)

Plants from each plot were harvested and sun dried. After sun drying the pods were plucked from the main plants and weighed. Pod yield was calculated using the formula:

$$\text{Pod yield} = \frac{\text{pod weight (kg)}}{\text{area harvested (m)2}} \times 10\ 000$$

3.4.5 Seed yield (kg/ha)

The pods from each plot were unshelled manually by hand. Seed yield was calculated using the formula:

$$\text{Seed yield} = \frac{\text{seed weight (kg)}}{\text{area harvested (m)2}} \times 10\,000$$

3.4.6 Shelling percentage

Shelling percentage was calculated using the formula:

$$\text{Shelling percentage} = \frac{\text{weight of shelled seed(kg)}}{\text{total pod weight(kg)}} \times 100$$

3.5 Data analysis

Data were analysed using Genstat version 14 and where treatment means were different they were separated using the least significant difference at 0.05 probability level.

CHAPTER FOUR: RESULTS

4.1: Effect of groundnut variety on days to 50% emergence

There was no significant difference ($p>0.05$) in the days to 50% emergence between the new short season varieties and the check cultivars. The six groundnut varieties emerged between day 9-10 after sowing (Figure 4.1).

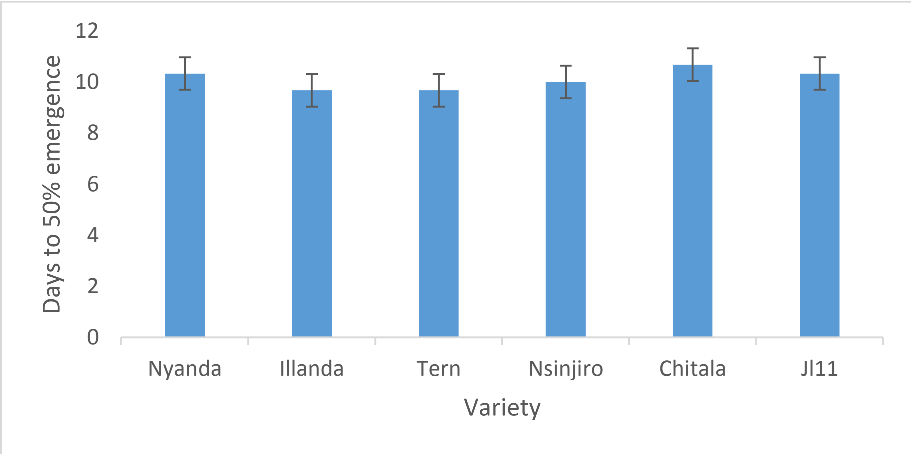

Figure 4.1: Effect of groundnut variety on days to 50% emergence

4.2: Effect of groundnut variety on days to 50% flowering

There was a significant difference ($p<0.05$) among the six short season groundnut varieties on days to 50% flowering. The new short season variety Jl11 had the shortest days to 50% flowering, it took 33 days. The check cultivar Illanda had the longest days to 50% flowering, it took 37 days (Figure 4.2).

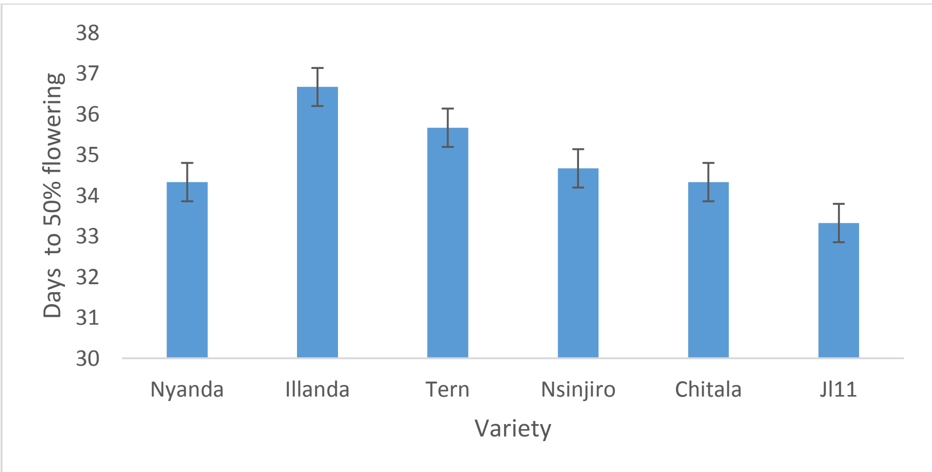

Figure 4.2: Effect of groundnut variety on days to 50% flowering

4.3. Effect of groundnut variety on days to physiological maturity

There was a significant difference ($p<0.05$) in the days to physiological maturity among the six short season groundnut varieties. The new varieties Nsinjiro, Chitala and Jl11 had the shortest days to physiological maturity, they took 91 days. The check cultivar Tern had the longest days to physiological maturity, it took 120 days (Figure 4.3).

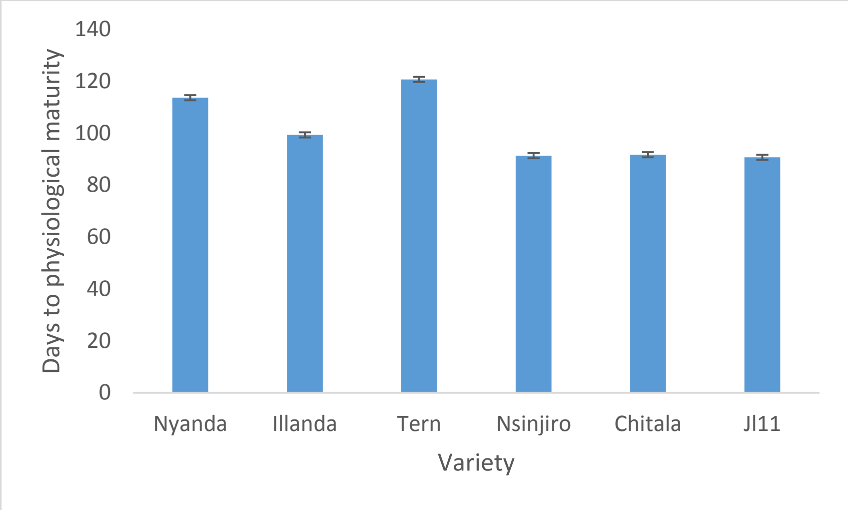

Figure 4.3: Effect of groundnut variety to days to physiological maturity

4.4: Effect of groundnut variety on yield

4.4.1: Effect of groundnut variety on pod yield

Pod yield differed significantly ($p<0.05$) among the short season groundnut varieties. The check cultivar Tern had the lowest pod yield of 3020kg/ha (figure 4.4). The new short season groundnut variety Chitala had the highest pod yield of 4635kg/ha.

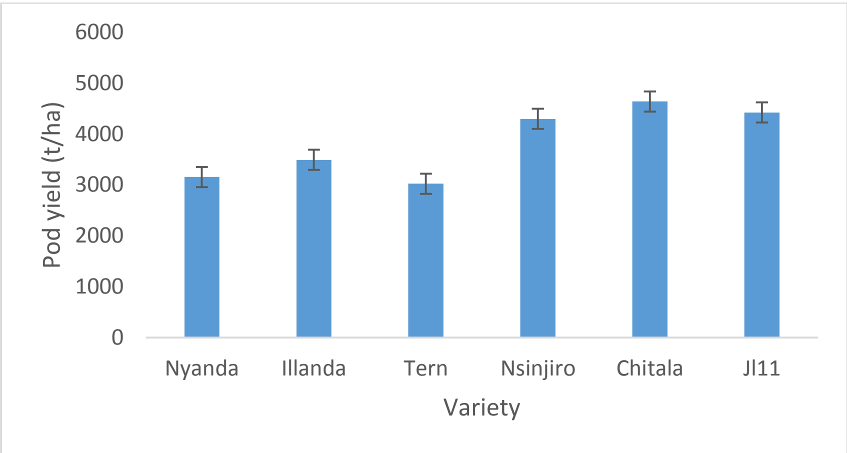

Figure 4.4: Effect of groundnut variety on pod yield (t/ha)

4.4.2: Effect of groundnut variety on seed yield

There was a significant seed yield difference ($p<0.05$) among the six short season groundnut varieties. The new short season variety Chitala had the highest seed yield of 3804kg/ha compared to the check cultivar Tern which had the lowest seed yield 2169kg/ha (figure 4.5).

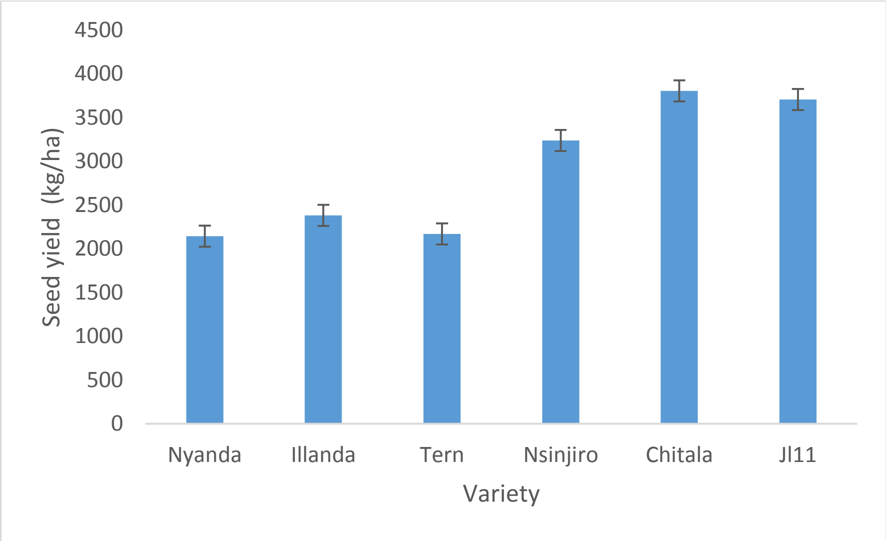

Figure 4.5: Effect of groundnut variety on seed yield (t/ha)

4.4.3: Effect of groundnut variety on shelling percentage

There was a significant difference ($p<0.05$) in the shelling percentage among the six short season groundnut varieties. The new short season groundnut variety Jl11 had the highest shelling percentage of 83% as compared to check cultivars Nyanda and Illanda which had the lowest shelling percentage 68% (figure 4.6).

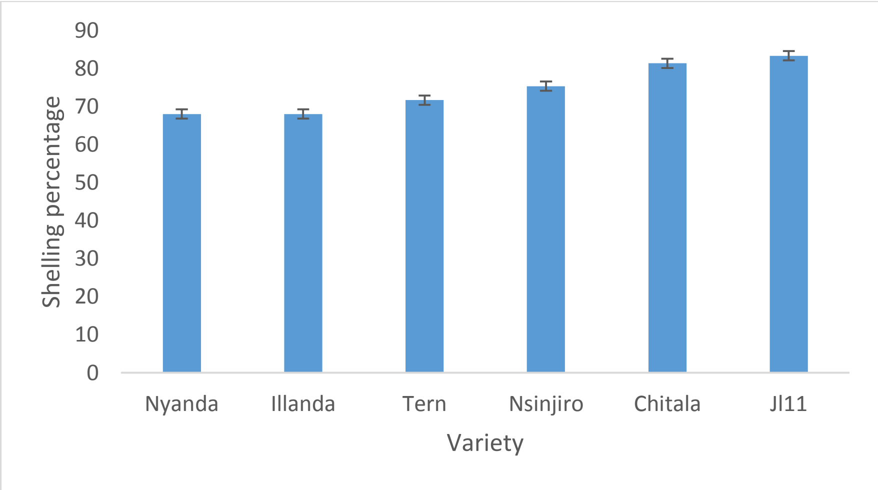

Figure 4.6: Effect of groundnut variety on shelling percentage

CHAPTER FIVE: DISCUSSION

The groundnut varieties emerged on day 9 and 10. This observation agrees with the work of Canavar (2016), who reported that groundnut seed takes 8-10 days after sowing to emerge. Uniform emergence could have also been as a result of the well prepared land which loosens the soil and allows the seedling to exert less force to crack the soil and emerge. Similarly SNV (2009) asserted that well prepared land allows good drainage which prevents water logging which prevents seed rotting in the soil, thus increasing the chances of uniform seed emergence.

Use of high quality seed attributes to uniform emergence. Thus, use of high quality seeds which are free from any physical damage may have also attributed to uniform emergence of the groundnut varieties. A previous study by Trivedi and Bhatt (2008) ascertained that uniform non-shrivelled seed results in uniform emergence in groundnut. As reported by N2 Africa (2014), fungicide use reduces seed bed losses and improves germination. The fungicide Thiram which was used as seed dressing protected the seed from attack by soil micro-organisms such as the *Aspergillus* which cause seed rot. This also explains the uniform emergence of the groundnut

The variations in days to flowering among the groundnut varieties could be attributed to the genotypic difference of the varieties (Oteng *et al*., 2017). The new short season varieties Nsinjiro, Chitala and Jl11 may have been bred to flower earlier than the check cultivars Nyanda, Illanda and Tern.

Earliness in maturity of the new short season groundnut varieties could have been attributed by the earliness in flowering by the new short season groundnut varieties. Early flowering as revealed by Harrison *et al.,* (2014) can lead to early physiological maturity. Early flowering results in early channelling of assimilates to the pods, thereby reaching full pod and seed development earlier (Kaba *et al.,* 2014).

The high pod yield of the new short season varieties could have been attributed by early flowering of the varieties. Pod yield is as a result of partitioning of assimilates during the reproductive stages as stated by Kaba *et al.,* (2010). Assimilates produced after flowering are channelled to pod and seed development. Thus the varieties which had early flowering had an earlier advantage to channel assimilates to pod and seed development. This supports the research previously done by Giayetto *et al.,* (2013). Early peg initiation and onset of rapid pod growth attributes to high pod yield.

The high pod yield could also have been attributed by high number of pods produced by the varieties. High pod number is correlated with high pod yield as revealed by Phakamas *et al.,* (2008). High pod number could be as a result of high number of flowers turning into pegs which develop into pods. Harrison *et al.,* (2014) reported that high yielding varieties produce more pegs, thus high conversion of pegs into mature pods.

The low yield of the check cultivars could have been induced by moisture and heat stress during the growing period. Research done by Pagadala *et al*., (2000) revealed that heat stress reduce pod yield. As observed by Hamidou *et al*., (2012) heat stress during pod development reduces pod expansion. The plants could also have suffered moisture stress which progressively inhibit pod yield due to insufficient plant turgor and lack of assimilates.

High seed yield could have been attributed by the high pod yield of the varieties. The variety Chitala which had the highest pod yield had the highest seed yield. High seed yield could be as a result of high pod filling. Thus the seeds were fully developed due to early pod development. Early pod development may be as a result of early pegging allowing partitioning of assimilates to the seed at an early stage as stated by Giayetto *et al* (2013).

The high shelling percentage in the new varieties could have been attributed to the high seed yield from the variety which is as a result of high seed weight (Oteng *et al.,* 2017). The seed obtained adequate assimilates for maximum seed development. The big seed is as a result of fully developed seed which is the most economic yield of the groundnut. The early flowering and pod establishment of the new varieties gave a seed yield advantage which contributes to the high shelling percentage. High shelling percentage show that there was high seed to shell ratio (Konlan *et al*., 2013)

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The new short season groundnut varieties Nsinjiro, Chitala and Jl11 have revealed to be better performing and better yielding. These new varieties have shown to have shorter days to flowering and physiological maturity as compared to the check cultivars. Hence are better able to escape drought stress as well as heat stress in the face of climate change. The new varieties have also shown to be high yielding. Thus they can improve groundnut yield among the small holder farmers. High yields will therefore improve the diets of people as well as livelihoods through increasing income generation from groundnuts. Improving yield will also result in reduction in groundnut import from neighbouring countries such as Malawi and Zambia.

6.2 Recommendations

The following recommendations can be made based on the results obtained from the research.

- Farmers are recommended to grow the new short season varieties Nsinjiro, Chitala and Jl11. These varieties have a shorter growing period thus can circumvent biotic and abiotic stress experienced during the growing period.
- Farmers are encouraged to grow the new varieties because they are high yielding and also have a higher shelling percentage.
- To obtain more reliable results, the experiment should be carried out for more than one season.
- The research should also be further carried out under small holder farmers' setup in different natural farming regions.

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