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The effects of planting methods on growth and yield of groundnut (*Arachis hypogaea*) cultivar natal common in Africa South of the Sahara

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Abstract

The most appropriate planting method to use for optimum growth and yield of groundnuts (*Arachis hypogaea*) in Africa South of the Sahara (ASS) among those currently used is not known, as the methods are highly influenced by environmental conditions in specific regions. Investigations of the effects of planting methods on growth and yield of a groundnut cultivar (cv.) (NTC), under rainfed conditions were carried out. Treatments used were planting on flat ground (FG), earthing up after planting on flat ground (EFG) and planting on ridges (R). Flat ground was considered as the standard (control). The parameters measured for growth were plant height, stem width and number of leaves, while those for yield were grain yield, pod yield and number of pods plant^{-1}. Results showed that the planting methods used significantly ($P<0.001$) increased number of leaves plant^{-1}of NTC. All treatment means were significantly ($P<0.05$) different, and R had the greatest mean number of leaves. Treatments did not significantly ($P= 0.533$) increase grain yield; only the R mean grain yield was significantly ($P<0.05$) greater, compared to the other two methods. Panting on ridges (R), followed by EFG, had higher number of leaves, number of pods plant^{-1} and increased grain yield, which, thus outweighing FT. Increase in the number of leaves, which are important for growth, and pod yield plant^{-1}, are thought to be responsible for the ultimate increase grain yield. It is recommended that groundnuts should be planted on R in SSA in order to cherish the highest production benefits of NTC groundnut.

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Introduction

Peanut or groundnut (*Arachis hypogaea* L.) is an economically important oilseed, feed, and food crop is widely cultivated in tropical and subtropical regions of the world (Variath and Janila, 2017). All parts of the plant can be used. The seed provides 50 to 65% oil (Linnemann, 1990; Boye-Goni *et al.*, 1990) and 25 to 35% proteins (Knauft and Ozias-Akins, 1995), while the rest of the plant parts provide livestock fodder. The roots have nodules which provide nitrogen to soil, thus improves soil fertility.

However, the productivity levels of groundnut in most of the developing countries have remained low (Naab *et al.,* 2005; Breisinger *et al.*, 2010). In most regions, including Africa South of the Sahara (ASS), such low yields have been reported to be due to improper agronomic practices which include technological knowhow (Variath and Janila, 2017) and improper planting methods used in specific locations. Groundnuts can be planted using a number of methods which include planting on flat ground (FG), earthing up after plant on flat ground (EFG), planting on raised bed (RB) and planting on R (Bhol *et al.*, 1993; Olayinka *et al.*, 2015). Earthing up is the raising of the soil around the plant in order to cover the pegs, depending on the cultivar (Mhungu and Chiteka, 2010). Nevertheless, planting simply on FG is the most common method practised in smallholder sectors. Farmers consider EFG, making R or RB to be laborious and time consuming.

The factors affecting yields are mainly agronomic practices, which are influenced by environmental factors, such as biotic and abiotic (Singh and Joshi, 1993; Narayanan *et al.*, 1981). For example, most farmers in Makoni District, Manicaland, Zimbabwe yearn to cherish the various uses of groundnuts, but they are thwarted by the groundnut grain yield they get. They plant groundnut cv natal common (NTC) on FG, in light textured sandy to sandy loam soils in regions of medium to high rainfall. This has been thought to cause problems like waterlogging in few parts having loam soil, since it is a medium to high rainfall area. These conditions cause poor root respiration of the cultivar and low microbial activity as well as diseases, mainly fungal. Poor pegging ability on flat ground where there is no good drainage also affect the yields. There is therefore need for a research to determine the best method to use for groundnut production in Makoni District, as part of Africa South of the Sahara (ASS). Investigations on the effect of growing groundnuts on FG, RB and R have been done (Shrinivasa *et al.*, 2017) using other groundnut varieties which do not exist in Zimbabwe, but not much work has been done in ASS to determine, among the commonly used planting methods, the one which is the most influential in effecting growth and yield of the local groundnut varieties in the soil types prevailing in specific locations.

Olayinka *et al.* (2015) investigated the effects of FG, RB and R on growth, yield and proximate composition of groundnuts on loamy sand soil, with very high carbon (2.16%) and organic matter (3.74%). However, there is not much literature linking these planting methods with growth and yield of groundnuts cultivars such as NTC grown in SSA, including Zimbabwe. Moreover, no work has been reported considering EFG relative to the other planting methods like planting on FG.

The current research explores the effect of planting groundnut cv. NTC on flat ground (FG), earthing up after planting on flat ground (EFG) and planting on ridges (R) on growth and yield performance of the crop in Makoni District.

Materials and methods

Experimental site

The experiment was conducted in ward 7 of Makoni District, Village 23 in Manicaland Province about 42km from Rusape along Harare-Mutare road which lies within *18° 32*' 6.9072'' S and 32° 8' 5.5140'' E coordinates. It is located in agro-ecological region II b, which receives approximately 700-900 mm annum^{-1} with temperatures ranging from 18-30 °C. The soil was light textured sandy to sandy loam, and 5.6 pH. The research study was carried out under rain-fed conditions in 2015/2016 and 2016/2017 cropping seasons.

Experimental material

Certified seed of natal common (NTC), specified as Anel, was obtained from Farm Supplies (Harare), and authenticated by Agricultural Management Department, Zimbabwe Open University. Compound D (8:14:7) was applied at 150 kg ha^{-1}. At flowering, gypsum was applied once, using broadcasting method, at 200 kg ha^{-1}as top dressing fertilizer.

Land preparation

Ploughing was done to the whole experimental field using an ox-drawn plough. Depth of ploughing was 30 cm. Hoes were then used to break large clods. Levelling was further done using a rake to bring soil to a fine tilth, which facilitates easy germination. Hoes were used to configure the soil to the three planting methods. Ridges were constructed up to 40 cm high. A tape measure was used to measure the required space. Standard pegs and strings were used to demarcate and align the plots.

Planting

Planting was done on the 25^{th} September during the 2015/2016 and 3 October 2016/2017 growing seasons after effective rains of 30mm and 33mm respectively. The planting depth used was 5 cm furrows of 5 cm depth were opened up for FG. Compound D was drilled first at an average of 150 kg ha^{-1}. Planting was done in the furrows. A thin film of soil was first used to cover, to avoid fertiliser–seed contact. The furrows were later fully closed up to obtain a FG.

Treatments and experimental design

Three methods of planting NTC were the treatments used in the current study. In the field, there were 3 blocks in which the treatments were randomized.

The blocking factors were slope and soil fertility. T1 was planting on flat ground (FG) (acting as the standard or control), T2 was earthing up after planting on flat ground (EFG), and T3 was planting on ridges (R). Earthing up was done at 2 and 7 weeks after sowing (Ouedraogo *et al.*, 2012). Flat ground is the most commonly used method by smallholder farmers in ASS (Dapaah *et al.*, 2014). Therefore, FG was used as the standard. The experiment was laid out in randomized complete block design (RCBD), replicated 3 times. The plot sizes were 4 x 1.8 m. There were 4 rows, which were 3 metres long with an inter-row spacing of 45 cm. Plants used for measurements were from the middle rows of the plots (net rows). In-row plant spacing was 5 cm. The experiment was repeated two times.

Measurements were done on five plants randomly taken from the net rows in each plot, to determine the following:

Plant height (cm)

The height of randomly selected five plants was measured from ground level to the tip of the last fully opened leaf after every 14 days from 30 days post planting. Five plants were tagged at random in each of the net lines and then measured and averaging the height of the stems.

Stem width (cm)

Stem width was measured from the tagged five plants using tags and measuring tape at 42 days after planting. This was done by measuring the width of five randomly chosen plants from the net lines per treatment.

Number of leaves

Fully opened leavers were counted from selected the randomly tagged five plants at 42days after planting. That was done by counting the number of leaves per plant and averaging it.

Number of pods plant^{-1}

Number of pods per each treatment were collected and weighed. The total pod weight from the net plots of each treatment was divided by the number of plants in the plots to get mean weight which was expressed in kg ha^{-1}.

Pod yield

After harvesting, the total weight sample of pods the tagged plants in net lines of each treatment was recorded and averaged.

Grain yield

The total grain weight from the net lines was divided by the grain weight from the number of plants $plot^{-1}$ to get mean weight which was expressed in t ha^{-1}.

Statistical analysis

Statistical analysis of the data of both growth characteristics and yields was done using ANOVA GLM SAS 2003; using the following model:

Yij = μ + Ti + Dj + eij,

Where μ= overall mean,

Ti =treatment effect (i; 1, 2, 3),

Dj = effect of time in days (j; 42 ……)

Eij =error term

Means will be separated using Tukey's HSD test (*P*< 0.05).

Results

Growth parameters measured

Plant height

There was no significant (P=0.239) effect of all the three planting methods on plant height. There were also no significant (P>0.05) differences among the treatment means. However, planting on R (T3), had a noteworthy (36.46 cm) plant height (Table 1).

Table 1. Means for plant height, stem width and number of leaves of groundnuts (*Arachis hypogaea*)grown using three different planting methods (flat ground, earthing up after planting on flat ground and on ridges) as treatments.

	Treatments			P value
Parameter measured	FG	EFG	R	
Plant height (cm)	36.30	36.02	36.46	0.239
Stem width (cm)	3.07	3.15	3.02	0.595
Number of leaves	37^b	39^a	39^a	0.001

^{ab} Mean values with different superscripts are significant at P< 0.05.

Stem width

There was no significant (P=0.595) effect of methods of planting on stem width (Table 1). The effects of all planting methods on stem width were statistically similar, with T1 = 3.07; T2 = 3.15 and T3 = 3.02 cm respectively. This means there were no significant (P>0.05) differences among all means**.**

Number of leaves

There was highly significant (P<0.001) effect of planting methods on number of leaves (Table 1). However, number of leaves between T2 and T3 showed no significant mean difference (P>0.05).

The height of the two treatments (T1 and T2) were significantly (P<0.05) greater than T1.

Yield parameters measured

Pod yield and grain yield

Planting methods tested did not significantly (P=0.165) and (P=0.533) increased pod yield and grain yield, respectively (Table 2).

Table 2. Effects of planting methods (Flat ground, earthing after planting on flat ground, and on ridges) on the yield attributes of groundnuts (*Arachis hypogaea*).

	Treatments			Se	P value
Parameter measured	FG	EFG	R		
Pod yield (t ha^{-1})	0.191^a	0.147^a	0.186^a	0.017	0.165
Grain yield (t ha^{-1})	0.100^b	0.11^b	0.94^a	0.100	0.533
Number of pods $plant^{-1}$	53.80^c	60.6^b	63.8^a	0.990	0.001

^{ab} Mean values with different superscripts are significant at P< 0.05.

Nevertheless, planting on R showed a significantly ($P<0.05$) higher mean grain yield when compared to FL and EFG planting methods. There were no significant ($P>0.05$) differences among pod yield treatment means of FG, EFG and R. There was also no significant ($P= 0.533$) effect of planting methods of FL and EFG on grain yield. Flat ground and EFG showed no significant ($P<0.05$) difference in the grain yield produced. However, R showed a significant difference between the FG and EFG methods.

Number of pods plant^{-1}

The three planting methods tested highly significantly $P<0.001$) increased the number of pods plant^{-1}(Table 3). All the treatment means were significantly different from each other, and R had the greatest mean number of pods plant^{-1}, while planting on the FG treatment had the least mean.

Discussion

The effect of planting methods on the growth of NTC

All the three methods (FG, EFG and R) tested did not have a significant effect on plant height. This outcome could be a result of homogeneity of the soil fertility of the experimental site. However, measured height of plants on ridges (R) was observed to have slightly higher (36.46cm) than the other two methods. Natal common has potential to increase its height when grown under favourable conditions (Kuipar and Quilambo, 2000). The potential to obtain increased plant height on R may be expected because ridges have loose soil, more aeration and drainage which is less compacted, have been found to be effective in enhancing maize seed emergence inducing vigour to plant growth (Bakht *et al.*, 2011). Chassot and Richner (2002) mentioned that ridges have loose soil which promotes root penetration or growth of crops. Good performance after planting on R was reported to be due to deeper penetration of water and suppression of evaporation losses (Willis *et al.*, 1963). In case of small rain showers, ridges have been found to offer greater moisture availability to plants because it concentrates water in furrows. Different surface configurations like ridges were found to influence the surface water movement (Huibers, 1985). Ridges increase the total infiltration and depression storage and thus slow down the flow velocity of surface runoff. Venkateshwarlu (1987) indicated that the ridges results in uniform rain water recharge of the profile and increase moisture for extended times. Ridges therefore appear to overcome drought effects due to dry spells during the rainy season. Ridges increase the extractable soil moisture even from the deeper layers. The improved drainage characteristics resulting from the bed configurations cause the soil to be drier and warmer (Adams, 1967). There was no significant ($P=0.595$) effect on methods of planting on stem width.

Kumar and Gill (2009) compared flat ground and ridge method of planting NTC groundnuts variety during 2003-04 and 2004-05 on loamy sand soil of Ludhiana (Punjab) and found that the two planting methods did not influence stem width. This outcome may be due to genetic differences among groundnuts types, their varieties (Dapaah *et al.*, 2014) and homogeneity of the soil fertility at the experimental site. The stem width of NTC does not easily change despite increase in soil fertility. This can be due to the compensation by growth in form of height (Parkash (2014).

There as an increase in the number of leaves plant ^{1}. Kaur (2001) and Parkash (2014) reported that plant height, number of leaves plant^{-1}, tillers plant^{-1} as well as fresh and dry leaf weight were significantly more in R planted turmeric as compared to flat planting. The leaves of ridge planted crop remained photosynthetically active (i.e. green) for longer period than leaves of flat planted turmeric (Bhimjibhai, 2011). Zhaojiuzhou *et al.* (1995) recorded increased plant height, pod number plant $^{-1}$ and other variables measured in soyabean planted ridge and compared it with FG method of planting at Mishan (China) in albic soil. In a different study, Wiggins (1995) found that soybean grown on ridges gave the highest number of leaves and tillers, root length, plant height and fresh and dry weight. Thus, our results of significant increase in the number of leaves and pod number plant^{-1}, on R, corroborate the earlier findings of Wiggins (1995) and Kaur (2001).

Leaves of NTC can increase proportionately with increase in soil fertility and other favourable environmental conditions (Kaur, 2001).

The effect of planting methods on the yields of NTC

The greater grain yield was obtained from planting on R than the two other planting methods. This agrees with Haile and Keith (2017), who mention that ridges are recommended if water logging is a problem. Ridging is commonly practised and the indication is that it could increase grain yield (Haile and Keith, 2017). In an experiment conducted by Pathak *et al.* (1991) on the response of groundnut grain yields when grown on raised ridges, the oxygen content at depths 0-5, 5-10 and 10-15 cm soil in ridges and flat ground treatments differed only slightly between 19.94 to 21.32%. They observed that the oxygen content mentioned in the above depths was slightly higher on ridges than on flat ground throughout the cropping season. Air filled pores in the upper 15 cm layer of ridges was found to be significantly higher than for the flat system during wet spells (International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 1981). Drainage in certain soil portions with sand loams within the study area would help reduce any slight chances of water logging and disease occurrence in such conditions. This confirms the effectiveness of ridges in improving drainage in seed and root environment.

There were no significant differences among pod yields of all the treatments used on all the three methods of planting used. In an experiment done by NARP (1981), sowing groundnut on the ridges was compared with sowing on the flat bed. It was found that planting the seed on the ridge gave higher pod yield (1,002 kg ha^{-1}) than the flat bed (638 kg ha^{-1}). Probably, due to higher bulk densities in flat ground, the pod yields were less than in ridges as a result of unfavourable conditions for peg penetration, pod setting and development in the surface soil layers of flat seed beds. In groundnuts, higher pod yield was recorded in R than FG technique of planting (Hadvani *et al.*, 1993). These variations could be caused by various factors.

The results of the studies done by Hadvani *et al.* (1993) above disagree with the results of the current experiment. Ahmad *et al.* (2015) also reported the increase in pod yield. This might have been to covering of stem above the soil surface with earthing up which ease up the process of pegs penetration. The impact of earthing up depends on the type of groundnut; it also varies from cultivar to cultivar. Earthing up later in the season normally does not lead to deformed plants (as in the previous instance) but does not lead to increased pod yield (Chivuraise, 2015). The results of Chivuraise (2015) are in agreement with our results, which showed an eventual effect on lack of increase in pod and grain yield for EFG treatment. The variation may also be due genetic characteristics of the variety (Dapaah *et al.*, 2014). NTC does not have a good trait of developing long or large pods because NTC develops small seeds (Kuipar and Quilambo, 2000) even if when grown in loose, fertile soils, but can develop many pods $plant^{-1}$ (Wiggins (1995). Natal common has a great deal of diversity of minor cultivars to select from, since four minor cultivars (Anel, Elna, Seleksie 5) and Natal Elite) were developed by selecting directly from NTC, and these behave differently (Cilliers and Swanevelder, 2003).

In our study, NTC (Anel) showed potential to form pods $plant^{-1}$and pegs in greater number after EFG and on R treatments than after planting on FG, but producing no significant difference or increase in the ultimate pod yield. The results are in agreement with Prasad and Muralidharudu(1991), Mkandawire and Sibuga (2002) and Ouedraogo *et al.* (2012).

Earthing up of groundnuts is not recommended, especially before flowering, as it does not increase yields (Chivuraise, 2015) such as pods $plant^{-1}$. Earthing up of groundnuts (where soil is piled up around the main stem of the peanut plant) is an important yield limiting factor as it influences poor pod growth on the lower highly productive nodes, and promotes disease development. Earthing up, especially in the early stage, has an influence on plant development leading to deformed plants with poor or no production at the lower nodes.

Flowers may not develop at the nodes, and thus no or less number of pods are formed. This results in an overall reduction in pod yield (Haile and Keith, 2017). Earthing up during flowering may also affect peg formation and development, which has influence on pod development due to damage to the plant's delicate flowers. Earthing up is an important agronomic practice which increases pods plant $^{-1}$ on EFG and on R methods when it is done during the pegging process, when flowering period has passed, compared to earthing up at flowering when using FG method. The pegs of NTC develop at flowering stage (Haile and Keith, 2017). The earthing up procedure and the soil mounds (ridges) makes the soil loose and enhance peg penetration (Ahmad *et al.*, 2015. The variations which exist with other studies done before may be attributed to differences in soil structure, varietal characteristics (Cilliers and Swanevelder, 2003) and prevailing agro-climatic conditions (Ahmad *et al.*, 2015).

Conclusion

Planting groundnuts on ridges showed higher plant height in comparison to FG and EFG. Planting methods had no significant effect on stem width and grain yield for NTC groundnut, although, exclusively, R had a significant effect on the grain yield. Panting on ridges (R) and EFG had higher number of leaves, number of pods plant^{-1}and increased grain yield, thus outweighing FT. It is recommended that groundnuts should be planted on R in SSA in order to cherish the highest production benefits of NTC groundnut.

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