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Effects of Plant Density and Planting Pattern on Growth and Seed Yield of Groundnuts [*Arachis hypogaea* (l.)] in the Wet Middleveld of Eswatini

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Authors' contributions

This work was carried out in collaboration among all authors. Author NM designed the study, performed the statistical analysis and wrote the protocol. Author MPM managed the analyses of the study and wrote the first draft of the manuscript. Author NZ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The most appropriate plant density and planting pattern to use for optimum growth and yield of groundnuts (*Arachis hypogaea* L.) in Eswatini among those currently used is not known, as the patterns are highly influenced by environmental conditions in specific regions. A field trial was conducted with the objective of determining the optimum plant density and planting pattern for groundnut in the Wet Middleveld of Eswatini. The experiment was conducted at the University of Eswatini, Luyengo Campus during the 2018/2019 cropping. The treatments consisted of three planting densities (*i.e*. 88,889 plants/ha, 44,444 plants/ha, and 29,630 plants/ha) and two planting patterns (*i.e*. Ridges and Raisedbeds) in a split plot arrangement. Results showed that all the measured parameters including seed yield were not significantly different in all treatments. However, the highest seed yield was obtained at low plant density which was 71.4 kg/ha followed by 568 kg/ha at medium and the least was 434 kg/ha at high plant density. The high plant density (88889

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plants/ha) obtained the highest value of dry biomass (13018 kg/ha) at ridges which was higher than 3859 kg/ha obtained at the low plant density (29630 plants/ha) at raised beds at R6 growth stage. The ridges at the intermediate plant density (44444 plants per hectare) obtained the highest shelling percentage of 59.67% while the lowest (56%) shelling percentage was obtained at raised beds at 88889 plants per hectare. It is concluded that groundnuts at raised beds with low plant density yielded higher than those at ridges with high plant density. It is therefore, recommended that groundnuts be planted at raised beds with low plant density to increase groundnut production and for ease of harvesting.

Keywords: Groundnut; plant density; planting pattern; split plot design.

1. INTRODUCTION

Groundnut or peanut is a legume crop belonging to the *Fabaceae* family. It is an important subsistent and cash crop in Eswatini grown mostly by smallholder farmers in pure stand and/or crop mixtures for its high protein content. Groundnut is also an economically major oilseed crop in tropics and sub-tropical parts of the world. The seed contains 25 to 32% protein (average of 25% digestible protein) and 42 to 52% oil [1,2,3,4]. According to Gulluoglu et al. [4], groundnut is the fourth major oilseed crop of the world next to soybean, rapeseed and cotton. The crop has various industrial uses including products such as food, feed, paints, lubricants and insecticides. Mvumi, et al. [3] reported that all parts of the crop can be used. The seed provides up to 65% oil and up to 35% proteins, while the rest of the plant parts provide livestock fodder. Furthermore, groundnut is an ideal crop in rotational systems to improve soil fertility due to the roots having nodules and their natural ability to fix atmospheric nitrogen [2].

However, production levels of groundnut in Eswatini as well as most of the developing countries have remained low. In most regions, the low yields have been reported to be due to improper agronomic practices and included are; technological knowhow and improper planting methods used in specific locations [3]. Eswatini is not even counted amongst the producers of groundnut [5], with the world highest producers being China, India and USA respectively. In the United States of America groundnut yield is as high as 3000 kg ha^{-1}, while the average yield in tropical Africa is about 800 kg ha^{-1}, which is traceable to planting density amongst other factors [6]. Groundnuts can be planted using a number of methods which include planting on flat ground (FG), raised beds (RB) and ridges (R). Nevertheless, planting simply on FG is the most common method practised in smallholder sectors. Farmers consider making R or RB to be laborious and time consuming. Onat, et al. [7] defined plant density as the number of main stems within a unit area of land. These researchers indicated that as the number of plants per unit area increased, competition for growth resources such as nutrients, water and light also increased. Sreelatha, et al. [8] and Onat, et al. [7] reported that crop yield is determined by the efficiency with which plant population uses available environmental resources for growth. The relationship between planting pattern, plant densities and yield; two approaches are used commonly. First, if the plant produces enough leaf area to maximize isolation interception during reproductive growth, maximum yield can be obtained. Secondly, equidistant spacing between plants will provide maximum yield since it will minimize inter plant competition.

Plant density and planting pattern are efficient management tools for maximizing crop yield by optimizing resources utilization such as light, nutrients and water and reduce soil surface evaporation [9,10]. The response of groundnut to plant density and planting pattern has been investigated in many areas of the world; however, such information is scanty and not well-studied in Eswatini. It is therefore, important to gain an improved understanding of the effects of plant density and planting pattern on the crop's development and variability in yield and yield components to help develop efficient production options for groundnut. Thus the objective of the study was to determine the influence of different plant densities and planting patterns on phenological development, rate of development and yield of groundnut grown under rainfed conditions.

2. MATERIALS AND METHODS

2.1 Experimental Site and Treatments

The study location falls within the Wet Middleveld agro-ecological zone of Eswatini at point Latitude and Longitude 26°32′ S and 31°14′ E, Crop

Production Department experiment farm, Faculty of Agriculture, University of Eswatini between November 2018 and May 2019. Soils of the experimental site are the M-set soils (Deep-red soils) [11], with mean annual temperature and rainfall of 18ºC and 980 mm [12]. The experiment was laid out in a split-plot design with six treatments replicated three times (Table 1). The main plots were the planting patterns while sub-plots comprised of three plant densities. Each plot comprised of four rows and was also 4 m long.

2.2 Soil Characterization and Planting

Composite soil samples (0–20 cm) were randomly collected in the field, taken to the lab and air-dried, crushed to pass through a 2 mm sieves and then analysed for physicochemical properties (Table 2). Particle size analysis was determined by the hydrometer method after [13], soil pH after the method of Mclean [14], the ammonium molybdate blue method was used for available P [1] and exchangeable K was determined using standard method.

After physicochemical analyses, planting of seeds was done on the 17th of December 2018, where two seeds/planting station were placed at a depth of 5 cm and later thinned to one seedling after emergence. Gap filling was done a week after emergence to achieve a good crop stand. Weeds were controlled manually using hoes whenever there was weed infestation. Cut worm bait was applied to the soil using the banding method as the problem of cut worm was observed.

2.3 Canopy Width (cm)

Canopy width was taken from three randomly selected plants within the net plot at R1, R3 and R6 growth stages. At R1, the first flower opens at any node and pod formation begins where one peg with swollen ovary is twice the weight of the peg at R3 stage. At R6, One pod with cavity apparently filled by the seed when fresh. A graduated metre stick was used to measure the canopy width which was taken from the widest portion of the canopy.

2.4 Plant Height (cm)

Plant height was measured from the ground level (at the base of the plant) to the top of the highest point including the terminal leaflet using a graduated metre stick. It was recorded from three randomly selected plants within the net plot at R1, R3 and R6 growth stages.

2.5 Number of Leaves per Plant

Number of leaves per plant were counted directly from the three selected plants and recorded. Number of leaves was recorded at R1, R3 and R6 growth stages.

2.6 Number of Branches per Plant

Number of branches per plant was obtained by direct counting of branches from three randomly selected plants in each plot. It was taken from R1 to R6 growth stage.

2.7 Dry Biomass (kg/ha)

Dry mass of plants per plot was obtained after oven drying plants at 65ºC for 72 hours. It was recorded throughout the growth stage.

2.8 Number of Pods per Plant

After harvesting, pods were counted directly from ten plants of the harvestable row of each plot and an average was calculated.

Table 1. Treatment codes and descriptions of the experiment

Treatment code	Treatment description		
	Planting pattern	**Plant spacing (cm)**	**Plant density (p/ha)**
1	Raisedbeds	15	88889
2	Raisedbeds	30	44444
3	Raisedbeds	45	29629
4	Ridges	15	44444
5	Ridges	30	88889
6	Ridges	45	29629

Table 2. Physicochemical properties of the soil before planting

Soil pH ($CaCl_2$)	Soil texture	Available P (mg kg $^{-1}$)	Exchangeable K (cmol kg $^{-1}$)
5.65	Sandy loam	0.35	1.70

2.9 Mass of Haulm (kg/ha)

After harvesting, plants from the harvested row were placed in the green house for about two weeks for drying. All pods were removed and plants were weighed using a balance scale and mass of haulm was recorded.

2.10 Harvest Index

After pods were plucked off the plants, they were shelled and weighed. After that seed harvest index was calculated as follows:

$$\text{Harvest Index} = \frac{Seed\ mass}{Total\ biomass\ above\ ground}$$

Seed harvest index = seed mass/Total biomass above ground

2.11 Shelling Percentage (%)

Mass of unshelled pods and mass of shelled seeds were taken and used to determine the shelling percentage. Shelling percentage was calculated as follows:

$$\text{Shelling Percentage} = \frac{Mass\ of\ shelled\ seeds\ (g)}{Mass\ of\ unshelled\ seeds\ (g)} x\ 100$$

2.12 Seed Yield (kg/ha)

Seed yield is the mass of seeds in kilograms that will be produced per hectare. Seed yield was determined from the middle row using the formula:

$$\text{Seed yield} = \frac{Mass\ of\ seeds\ in\ net\ plot\ (g) x\ 10x\ Dry\ mass\ of\ seeds}{Dry\ mass\ at\ 8\%\ M.C\ x\ Net\ plot}$$

2.13 Statistical Analysis

Data collected were subjected to excel and subsequently analyses using GENSTAT statistical package 15th edition. Significantly different treatment means were separated using the Least Significant Difference (LSD) at 5% level of probability [15].

3. RESULTS AND DISCUSSION

Results presented in Table 2 showed that the soil texture was sandy loam, with pH – $CaCl_2$ (5.65), available P (0.35 mg kg^{-1}) and exchangeable K was 1.70 cmol kg^{-1} and is acceptable to grow crops like groundnuts. The results also show that phosphorus availability was low in the soil and potassium was within the range required by groundnuts. No soil amendment was applied to the soil before and at planting (Table 2).

All the plant densities (*i.e.* 88,889 plants/ha [High], 44,444 plants/ha [Medium], and 29,630 plants/ha [Low]) and planting patterns (i.e. raised beds and ridges) tested did not have significant effect on plant height. This outcome could be a result of homogeneity of the soil fertility of the experimental site [3]. Ridges at 88889 plants ha^{-1} recorded the tallest plants with a mean of 44.9 cm $plant^{-1}$ at R6, while shorter plants were also recorded where groundnut were grown in ridges (29630 plants ha^{-1}) and had an average of 17.1 cm at R1 growth stage (Table 3). In a similar study by Mvumi, et al. [3], they found no significant effect of planting methods on plant height. There were also no significant differences among the treatment means. However, these researchers also found that planting on ridges, had a noteworthy (36.46 cm) plant height. The potential to obtain increased plant height on ridges may be expected because ridges have loose soil, more aeration and drainage which is less compacted and have been found to be effective in enhancing maize seed emergence inducing vigour to plant growth [16]. Chassot and Richner [17] mentioned that ridges have loose soil which promotes root penetration or growth of crops. These researchers further found that good performance after planting on ridges was reported to be due to deeper penetration of water and suppression of evaporation losses.

There were no significant difference in the number of leaves/plant in response to the interaction of plant density and planting pattern (Table 4). However, data trends showed that the highest number of leaves/plant (165.30) was recorded at 29630 plants ha^{-1} at raised beds (R6) and the lowest (40.0) at 88, 889 plants ha^{-1} where groundnuts were grown in ridges, but at R1 growth stage. Mvumi [3] found significant increase in the number of leaves/plant on ridges, which corresponds with the findings of other researchers. However, contrary to the results obtained in the present study, Gabisa [9] reported that the interaction effects of variety and plant density on number of leaves/plant was significant. These researchers found that the highest number of leaves/plant recorded was 485.7 from the lowest plant density (142, 857 plants ha^{-1}), while the lowest number of leaves/plant recorded was 247.0 from the highest plant density (333,333 plants ha^{-1}). Leaves of groundnuts can increase proportionately with increase in soil fertility and other favourable environmental conditions. Differences in number of leaves/plant might be attributed to difference in growth habit amongst planting patterns and the lowest number of leaves/plant at the highest plant density might be attributed to more competition for growth resources at higher plant density.

The data on the number of branches/plant at different plant densities and planting pattern is presented in Table 5. Statistical analysis for plant density and planting pattern interaction showed no significant effect on the number of branches/plant. Number of branches/plant varied from 6.60 to 17.70 (both 88889 plants ha^{-1}), where groundnuts were grown on ridges and raised beds respectively. In a similar study on soybeans, Güllüoğlu, et al. [4] found that the branch number varied from 2.10 to 2.98 in a two-year average. These researchers further reported that soybean produced more branches/plant at low plant densities (31.60 plant m^{-1}) compared with the high plant densities

Table 3. Effects of plant population and planting pattern on the plant height of groundnuts at R1, R3 and R6 growth stages

Treatments	Plant height (cm/plant)		
	R1	R3	R6
Interaction (Raised x Density)			
15 cm	20.37	34.4	43.9
30 cm	20.30	32.4	37.6
45 cm	18.60	32.6	43.1
Interaction (Ridges x Density)			
15 cm	19.07	31.5	44.9
30 cm	16.43	32.5	38.8
45 cm	17.10	30.4	37.5
SE±	1.95	4.04	3.97
Pattern (Raised x Ridges)			
Raised	19.76	33.2	41.5
Ridges	17.53	31.5	40.4
SE±	1.13	2.33	2.29
Significance	ns	ns	ns

ns – non-significant at P = 0.05; Means in columns followed by different letters are significantly different to each other at P = 0.05 according to Least Significant Difference (LSD) test

Table 4. Effects of plant population and planting pattern on the number of leaves/plant of groundnuts at R1, R3 and R6 growth stages

Treatments	Plant height (number of leaves/plant)		
	R1	R3	R6
Interaction (Raised x Density)			
15 cm	41.0	80.7	151.7
30 cm	42.0	94.7	160.3
45 cm	37.3	85.3	165.3
Interaction (Ridges x Density)			
15 cm	40.0	76.0	132.7
30 cm	41.0	88.3	139.3
45 cm	42.3	70.3	125.7
SE±	3.22	11.35	27.34
Pattern (Raised x Ridges)			
Raised	40.1	86.9	159.1
Ridges	41.1	78.2	132.6
SE±	1.86	6.55	15.78
Significance	ns	ns	ns

ns – non-significant at P = 0.05; Means in columns followed by different letters are significantly different to each other at P = 0.05 according to Least Significant Difference (LSD) test

Table 5. Effects of plant population and planting pattern on the number of branches/plant of groundnuts at R1, R3 and R6

Treatments	Plant height (number of branches/plant)		
	R1	**R3**	**R6**
Interaction (Raised x Density)			
15 cm	9.0	9.7	17.7
30 cm	8.0	11.7	14.7
45 cm	6.7	11.7	15.7
Interaction (Ridges x Density)			
15 cm	6.7	8.3	12.7
30 cm	7.0	10.3	15.7
45 cm	6.7	9.3	15.7
SE±	1.02	1.41	3.57
Pattern (Raised x Ridges)			
Raised	7.9	11.0	16.0
Ridges	6.8	9.3	14.7
SE±	0.59	0.81	2.06
Significance	ns	ns	ns

ns – non-significant at P = 0.05; Means in columns followed by different letters are significantly different to each other at P = 0.05 according to Least Significant Difference (LSD) test

Table 6. Effects of plant population and planting pattern on dry biomass of groundnuts at R1, R3 and R6

Treatments	Dry biomass per plot (kg/ha)		
	R1	**R3**	**R6**
Interaction (Raised x Density)			
15 cm	2219	5128	9073
30 cm	938	2765	6025
45 cm	526	2369	3859
Interaction (Ridges x Density)			
15 cm	1726	4734	13018
30 cm	765	2370	6617
45 cm	526	1843	4936
SE±	384.3	534.9	1442.1
Pattern (Raised x Ridges)			
Raised	1228	3421	6319
Ridges	1006	2982	8190
SE±	221.9	308.8	832.6
Significance	ns	ns	ns

ns – non-significant at P = 0.05; Means in columns followed by different letters are significantly different to each other at P = 0.05 according to Least Significant Difference (LSD) test

(69.90 plant m^{-1}). When planting density is high, the branching of each plant is depressed and the number of the lateral stem decrease. Contrary to the current findings, Dapaah, et al. [9] found that at 50 days after planting, the low and medium sowing densities had slightly higher number of branches/plant than the control and high sowing densities. However, Dapaah, et al. [9] found that branching in groundnuts may impact positively on yield since the branches bear the leaves and also determine the canopy spread and closure and solar radiation interception and utilization. Giayetto, et al. [18] reported that the numbers of branches/plant are reduced proportionally with an increase in plant density. At low plant density, existing plants developed more branches and pegs because of reduced in competition. Moreover, Donald [19] found that as the number of plants per unit area increased competition for growth resources such as nutrients, water and light also increased. Similar results were reported by others researches [20,21,22,23].

Dry mass was not significantly different among treatments in response to the interaction of plant density and planting pattern. Gabisa, et al. [9]

reported a highly significant (P<0.05) interaction effect of variety and plant density on the aboveground dry biomass of groundnut. The high plant density (88889 plants/ha) obtained the highest value of dry biomass (13018 kg/ha) at ridges which is higher than 3859 kg/ha obtained at the low plant density (29630 plants/ha) at raised beds at R6 growth stage (Table 6). Similar results were obtained by Gabisa, et al. [9] where they were investigating the effects of planting density on yield components and yield of groundnut varieties at Southern Ethiopia. Differences in dry mass might be due to the reason that, at higher plant densities crop growth resources are efficiently used and resulted in higher dry matter accumulation at optimum plant densities. Mckenzie, et al. [24] and Bell, et al. [25] reported that the amount of solar radiation intercepted in to the canopy depends on plant density where the higher plant population density speeds up canopy closure and increases interception of photosynthetically active radiation (PAR) needed for carbohydrate production and higher biomass in the plants. However, according to Olanyika and Etejere [1], variation in dry matter accumulation could be due to differences in the leaf area production and leaf area index (LAI). Moreover, Lakshmaiah and Reddy [26] found that under field conditions high biomass production might reflect high water use efficiency (WUE).

The number of pods/plant was not significant in response to the interaction of plant density and planting pattern. The ridges at low plant density (29630 plants per hectare) obtained higher number of pods, 42.30 which is higher than 28 obtained on ridges at high plant density (88889 plants per hectare) (Fig. 1). Güllüoğlu, et al. [4] conducted a similar study and found that there was a statistically significant (P<0.05) difference in pod number/plant between plant densities in different planting pattern in both years. These researchers reported that the pod number/plant values varied between 45.40 and 67.40 in 2013, and from 46.0-69.0 in 2014.

Differences in number of pods/plant may be attributed to the fact that decreasing plant density leads to more peanut pegs penetration of each plant to soil [7]. In a study conducted by Ahmed, et al. [22] it was gathered that number of pods/plant increase with increasing plant spacing which is similar with the observation of this study. Onat, et al. [7] also stated that when the plant density increases, the plants produce fewer pods and most of them are mature. Gulluoglu, et al. [4] found that the pod number increase in the low plant density was a result of extra branching. At low density, existing plants developed more branches and pods because of reduced in competition. These researchers found that the number of pods/plant tended to decrease with increased population density, which is contrary to the findings of this experiment where a high plant population yielded less pods/plant.

Mass of unshelled pods was not significantly different at the interaction of plant density and planting pattern (Fig. 2). Highest mass of unshelled pods was obtained at low plant density of 29630 plants/ha with a value of 434 g, whilst the lowest mass was obtained at high plant density of 88889 plants/ha with a value of 197 g where groundnuts were grown in raised beds. Data trends as shown in Fig. 2 showed that decreasing the plant population for both planting methods lead to an increase in mass of unshelled pods.

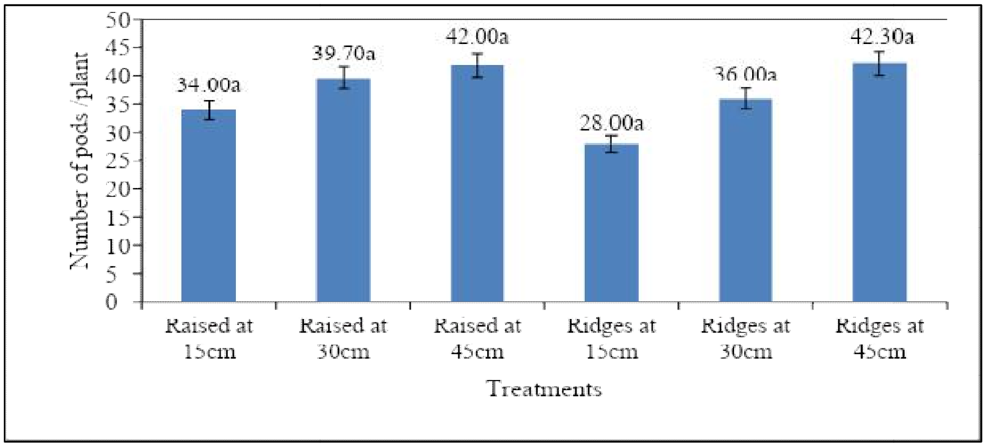

Fig. 1. Effects of plant population and planting pattern on the number of pods of groundnuts

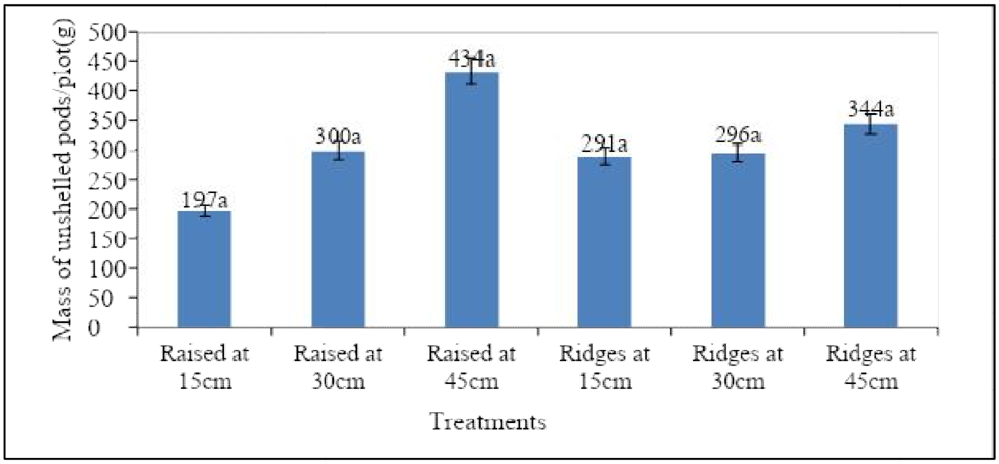

Fig. 2. Mass of unshelled pods per plot of groundnuts in response to plant density and planting pattern

Onat, et al. [7] conducted a similar study on groundnuts and found that decreasing the plant density significantly (P<0.05) increased pod weight per plant considerable. These could potentially be explained by decreasing plant density provides higher photosynthesis per plant. Similar findings are supported by Shiwlong and Tehming [27] and Sternitzke, et al. [21].

The data belonging to dry mass of 100 seeds at different planting densities and planting patterns are presented in Fig. 3. Data showed that there were no significant differences in the interaction of plant density and planting pattern with regard dry mass of 100 seeds and this coincides with the findings of Onat, et al. [7]. The highest mass was observed at raised beds to be 42.10 g at low plant density (29630 plants per hectare) while the lowest mass of 35.10 g was observed at ridges with high density (88889 plants per hectare). Güllüoğlu, et al. [4] found that the average 100 seed weight in two seasons varied between 13.89 g-14.20 g and no significant difference was observed in a soybean study. In contrast to the present findings, Gabisa, et al. [9] found significant (P<0.05) effects of the interaction of variety and plant density on hundred seed weight. Their results stated that with increased plant density, 100 seed weight decreased, the highest 100 seed weight (86.67 g) was recorded at the lowest plant density of 142,857 plants per ha, whereas, the lowest (67 g) was recorded at the highest plant density of 333, 333 plant per ha. This might be because of the wider spaced plants, that improved the supply of assimilates to be stored in the seed, hence, the weight of 100 seeds increased. According to Onat, et al. [7], spacing differences regarding 100 seed weight might be due to the competition for light, water and other essential requirements among the plants. Ahmad, et al. [22] and Konlan, et al. [23] reported that 100 seed weight decreased with increasing plant density in peanut.

The response of harvest index at the interaction of plant density and planting pattern was not significantly different. This agrees with Gabisa, et al. [9], who found that the interaction effect of variety and plant density was found significant (P<0.05) on the harvest index of groundnut. However, ridges with low plant population (29630 plants per hectare) had the highest harvest index while raised beds at high plant density (88889 plants per hectare) obtained the lowest harvest index of 0.10 (Fig. 4). Gabisa, et al. [9] also reported that harvest index increased from 15.17% to 36.5% as the plant population increased from 142,857 to 250,000 plants ha^{-1} and then decreased to (18.67) when plant density increased from 250,000 to 333,333 plants ha^{-1}. A decrease in plant density favours huge vegetative growth and thereby results in lower percent of productive pegs, pods, seed per pod and finally lower harvest index when beyond optimum plant density. This could be attributed to the rapid development of seed yield in higher plant density by optimizing utilization of growth factors, once the reproductive phase started, so that the process of maturation proceeds quickly and lead to harvestable crop while weather conditions are good.

Yaser, et al. [28] wrote that differences in harvest index might be due to difference in efficient partitioning of assimilates into the seed rather than the pod in the recommended plant density and more luxurious growth in the highest plant density favoured more pod formation than seed yield.

According to Gabisa, et al. [9], shelling percentage is the indication of pod filling efficiency and high shelling percentage values indicate effective pod filling. In the present study, there was no significant difference in shelling percentage in response to the interaction of plant density and planting pattern.

The ridges at the intermediate plant density (44444 plants per hectare) obtained the highest shelling percentage of 59.67% while the lowest (56%) shelling percentage was obtained at raised beds at 88889 plants per hectare (Fig. 5).

Differences in shelling percentage of groundnuts might be due to that efficient partitioning of assimilates into the seed rather than the pod in the higher plant densities and more luxurious growth in the lower plant densities favoured more pod formation than seed yield. Likewise, El Naim, et al. [29] reported that plant density had no significant effect on shelling percentage in cowpea. Moreover, according to Rasekh, et al. [30], it was gathered that plant density significantly (P<0.05) affected shelling percentage of groundnuts with those planted on the least plant density having the highest shelling percentage while those sown on highest plant density had low shelling percentage which concurs with results obtained in this study.

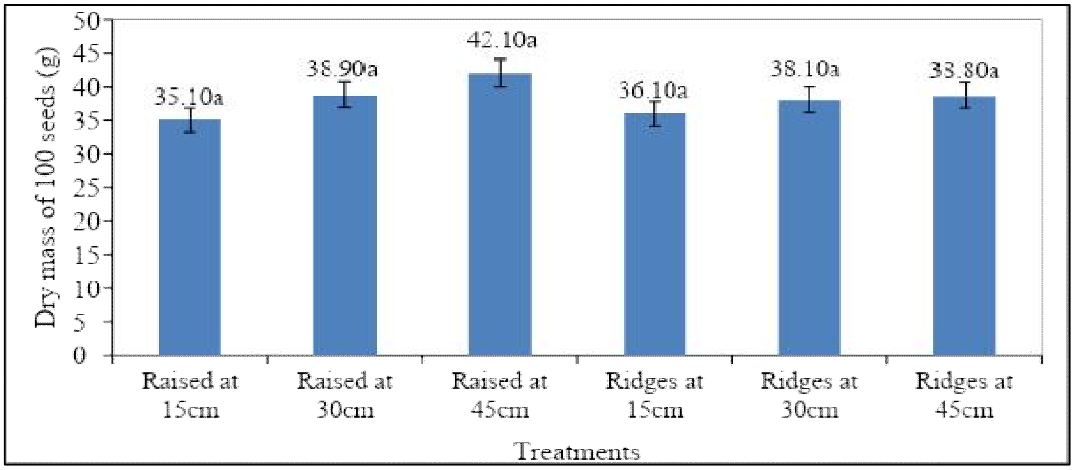

Fig. 3. Dry mass of 100 seeds (g) of groundnuts in response to plant density and planting pattern

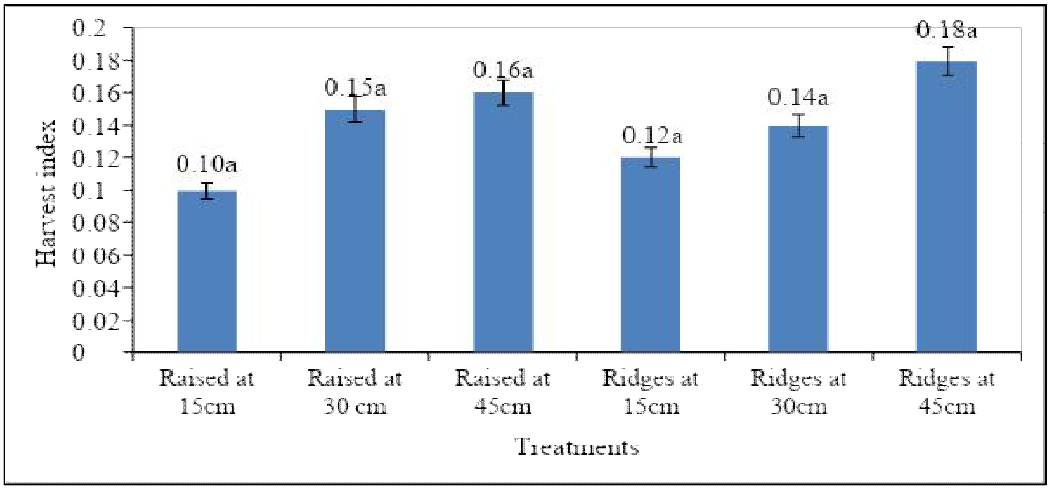

Fig. 4. Harvest index of groundnuts at the interaction of plant density and planting pattern

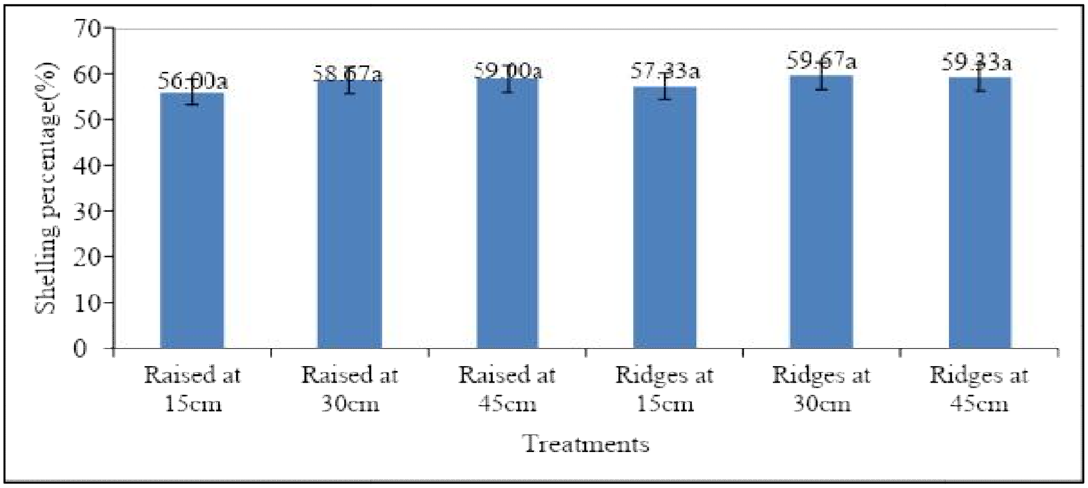

Fig. 5. Shelling percentage (%) of groundnuts in response to plant density and planting pattern

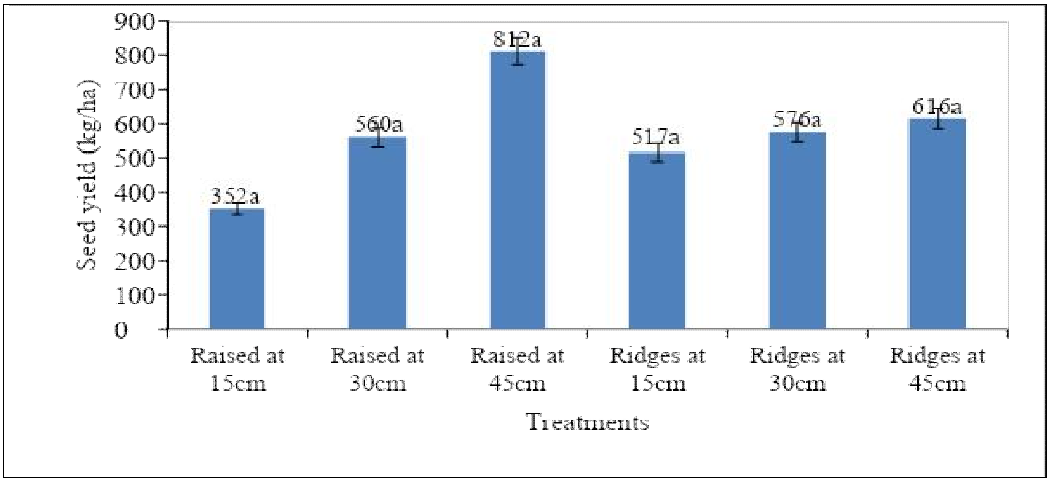

Fig. 6. Seed yield of groundnuts (kg/ha) at the interaction of plant density and planting pattern

The seed yield was not significantly different in response to the interaction of plant density and planting pattern. The raised beds at low plant density (29630 plants per hectare) obtained the highest seed yield of 812 kg/ha while the raised beds at high plant density (88889 plants per hectare) obtained the lowest seed yield of 352 kg/ha (Fig. 6). This might be attributed to its more number of seeds per pod, higher number of pods per plant, hundred seed weight and shelling percentage [29]. It may also be attributed to reduction to inter plant competition with assimilates and low pod yield and low plant density (29630 plant/ ha). In contrast, Kouassi and Zoro [31] reported that planting on ridges enhanced grain yield during the short rainy season where rainfalls were low. Mvumi, et al. [3] also stated that ridging is commonly practiced and the indication is that it could increase grain yield as 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.

4. CONCLUSION AND RECOMMENDATIONS

The interaction effects of plant density and planting pattern gave no significant differences with regard to all the measured parameters (plant height, number of leaves/plant, number of branches/plant, number of pods/plant, dry biomass, 100 seed weight, shelling percentage and seed yield). However, raised beds at a spacing 45 x 60 cm gave higher values of most of the measured agronomic characters and yield.

It is therefore recommended that groundnuts should be planted on raised beds in Eswatini in order to cherish the highest production benefits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Olsen SR, Sommers LE, Page AL. Methods of soil analysis. Part 2. Chemical and microbiological properties of phosphorus. ASA Monograph. 1982;9: 403–30.
2. Abady S, Shimelis H, Janila P, Mashilo J. Groundnut (*Arachis hypogaea* L.) improvement in sub-Saharan Africa: A review. Soil & Plant Science; 2019. DOI: 10.1080/09064710.2019.1601252
3. Mvumi C, Washaya S, Ruswa C. The effects of planting methods on growth and yield of groundnut (*Arachis hypogaea*) cultivar natal common in Africa South of the Sahara. International Journal of Agronomy and Agricultural Research. 2018;13(6):1-9.
4. Güllüoğlu L, Bakal H, Arioğlu H. The effects of twin-row plantin pattern and plant population on seed yield and yield components of soybean at late double cropped planting in Cukurova Region. Turkish Journal of Field Crops. 2016; 21(1):59-65.
5. FAO - Production Statistics August. 2014; Food Balance Sheets, World Bank - WDI; ADI 2013; 2014.
6. Akobundu IO. Weed science in tropics, principles and practices. New York: Wiley. and yield of cowpea (*Vigna unguiculata* L. Walp). Australian Journal of Basic and Applied Sciences. 1987;4(8):3148-3153.
7. Onat B, Bakal H, Gulluoglu L, Arioglu H. The effects of row spacing and plant density on yield and yield components of peanut grown as a double crop in mediterranean environment in Turkey. Turkish Journal of Field Crops. 2016;22(1): 71-80.
8. Sreelatha P, Sudhakar P, Umamahesh V, Subramanyam D, Vasanthi RP. Variability in growth and yield attributes among different growth habits of groundnut genotypes. International Journal of Current Microbiology and Applied Sciences. 2019; 8(6):1066-1071.
9. Gabisa M, Tana T, Urage E. Effect of planting density on yield components and yield of Groundnut (*Arachis hypogaea* L.) varieties at Abeya, Borena Zone Southern Ethiopia. International Journal of Scientific Engineering and Applied Science. 2017; 3(3):23-34.
10. Dapaah HK, Mohammed I, Awuah RT. Growth yield performance of groundnuts (*Arachis hypogaea* L.) in response to plant density. International Journal of Plant and Soil Science. 2014;3(9):1069-1082.
11. Murdoch GM. Soils and land capability in Swaziland. Swaziland Ministry of Agriculture. Mbabane, Swaziland; 1968.
12. Edje OT, Ossom EM. Crop science handbook, 2nd edition. BlueMoon Publishers, Manzini, Swaziland; 2016.
13. Bouyoucos GJ. Hydrometer method improved for making particle size analyses of soils. Agronomy Journal. 1962;54(5): 464–475.
14. McLean EO. Soil pH and lime requirement. In Methods of soil analysis. Part 2. Chemical and microbiological properties, eds. Page AL, Miller RH, Keeney DR. Madison, WI: American Society of Agronomy. 1982;199–224.
15. Rangaswamy R. A text book of agricultural statistics, 2nd Edition. New Age International publishers. New Delhi. India; 2010.
16. Bakht J, Shafi M, Rehman H, Uddin R, Anwar S. Effect of planting methods on growth, phenology and yield of maize varieties. Pakistan Journal of Botany. 2011;43(3):1629–1633.
17. Chassot A, Richner W. Root characteristics and phosphorus uptake of maize seedlings in a bilayered soil. Agronomy Journal. 2002;94(1):118–127.
18. Giayetto O, Cerioni GA, Asnal WE. Effect of Sowing Spacing on vegetative growth, dry matter production and peanut pod yield. Peanut Science. 1998;25:86-92.
19. Donald CM. Competition among crops and pasture plants. Advances in Agronomy. 1963;15(3):17-27.
20. Wright GC, Bell MJ. Plant population studies on peanut (*Arachis hypogaea* L.) in Subtropical Australia. 3. growth and water use during a termal drought stress. Australian Journal of Experimental Agriculture. 1992;32:197-203.
21. Sternitzke DA, Lamb MC, Davidson JI, Barron Jr RT, Bennet CT. Impact of plant

spacing and population on yield for single-row non irrigated peanuts (*Arachis hypogaea* L.). Peanut Science. 2000;27 (2):52-56.

22. Ahmad A, Rahim M, Khan U. Evaluation of different varieties, seed rates and row spacing of groundnut, planted under agro-ecological conditions of Malakand Division. Journal of Agronomy. 2007;6(2):385-387.
23. Konlan S, Sarkodie-addo J, Asareand E, Kombiok MJ. Groundnut (*Arachis hypogaea* L.) Varietal response to spacing in the Guinea Savanna Agro-Ecological Zone of Ghana. Growth and Yield*.* African Journal of Agriculture Research. 2013; 8(22):2769-2777.
24. Mckenzie BA, Andrews M, Ayalsew AZ, Stokes JR. Leaf growth and canopy-development in chickpea. Proceeding of Agronomy Society, New Zealand. 1992;22: 121-125.
25. Bell MJ, Muchow RC, Wilson JL. The effect of plant population on peanuts (*Arachis hypogaea* L.) in a monsoonal tropical environment. Field Crop Research. 1987;17:91-107.
26. Lakshmaiah B, Reddy PS, Reddy BM. Selection criteria for improving yield in groundnut *(Arachis hypogaea* L.). Peanut Science. 1983;38:607-611.
27. Shiwlong T, Tehming C. Effects of plant density on dry matters production and partitionning in groundnut. Bulletin of National Pingtung Polytechnic Instute Department of Plant Industry, National Pingtung Polytechnic Instute, Taiwan. 1996;5(1):1-8.
28. Yaser A, Hefny A, Asmaa A. Study the effect of phosphorus fertilizer rates and plant densities on the productivity and profitability of peanut in sandy soil. Asian Journal of Agricultural Science. 2017;48 (4):15-28.
29. El Naim AM, Jabereldar AA. Effect of Plant density and cultivar on growth and yield of cowpea (*Vigna unguiculata* L. Walp*).* Australian Journal of Basic and Applied Sciences. 2010;4(8):3148-3153.
30. Rasekh H, Asghari J, Safarzader MN, Wishkai, Massoumi SL, Zakkerinejad, R. Effect of planting pattern and plant density on physiological characteristics and yield of peanuts (*Arachis hypogaea* L.) In Iran. Research Journal of Biological Sciences. 2010;5(8):542-547.
31. Kouassi N, Zoro BI. Effect of sowing density and seedbed type on yield and yield components in bambara groundnut (*Vigna subterranea*) in woodland savannas of Cote d'ivoire. Experimental Agriculture. 2010;46(1):99-110.

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