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THE EFFECT OF PLANT DENSITY ON POD YIELD AND SOME AGRONOMIC CHARACTERISTICS OF DIFFERENT GROWTHTYPE PEANUT VARIETIES (*Arachis hypogaea* L.) GROWN AS A MAIN CROP*

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ABSTRACT

This study was conducted at the University of Cukurova, Faculty of Agriculture research area in 2018 and 2019 in Adana, Turkey. The objective of this study was to determine the effect of plant density on pod yield and some agronomic characteristics of different growth type peanut varieties (Halisbey and NC-7) in main crop growing condition. In this research; five different intra-row spacing (5, 10, 15. 20 and 25 cm) were used in single row planting pattern. The experimental design was a split plot with three replications. Pod number and pod weight per plant, 100 seed weight, shelling percentage, oil and protein content, pod and kernel yield per hectare characteristics of varieties were investigated.
As a result; pod number and weight per plant and 100 seed weight values were decreased when the plant density was increased, but shelling percentage, pod and kernel yield and protein percentage values were increased. The oil content was not affected by the plant density. The highest pod yield (6652 kg ha^{-1}) was obtained when the seeds planted at 5 cm inter-row spacing (28.5 plants m^{-2} plant density). The highest pod yield was obtained from Halisbey variety.

Keywords: Peanut, Plant density, Peanut variety, Pod yield and Agronomic characteristic

INTRODUCTION

Peanut is an excellent source of plant nutrients contains 45-50% oil, 27-33% protein as well as essential minerals and vitamins (El Naim et al., 2011). For these reasons, peanut seed is an important source of edible oil and protein for human nutrition. The annual peanut production is around 41.9 million tons and it contributes 7.3% of the total oil seeds production in the world in 2018 (FAO, 2018). Peanut seeds commonly utilize for vegetable oil production and other products such as snack food and peanut butter in developed countries (Caliskan et al, 2008). Peanut production was 173.800 ton in Turkey in 2018 and all of them are used roasted peanut for the human nutrition (FAO, 2018).

Rasekh et al. (2010), indicated that peanut seed yield depends on the magnitude of management variability and practices, especially those which concerned with plant spacing, even between and/or within plants. The number of plant per unit area is one of the most important yield determinants of field crops. So that planting density is one of the main factors that have an important role on growth, yield and quality of peanut. It is important to accommodate the most appropriate number of plants per unit area to be obtained better yield (Gulluoglu et al., 2016). Onat et al. (2017) reported that plant density is defined as the number of main stems within a unit area of land and it is an important factor for growth and pod production rate, pod and kernel yield in peanut. Awal and Aktar (2015) indicated that among the various factors that influence the yield of peanut, plantation with proper row spacing is very important.

Optimum plant population density in peanut varies between environments, cultivars and management practices (Gabisa et al., 2017). Planting density of peanut is often low in farmers' field (Annadurai et al., 2009) and especially when the crop is not grown in rows resulting in low yields. Plant density are efficient management tool for maximizing crop yield by optimizing resources utilization such as light, nutrients and water and reduce soil surface evaporation (Dapaah et al., 2014 and Gabisa et al., 2017). It is important to gain an improved understanding of the effects of plant density on the crop's development and variability in yield and yield components to help develop efficient production options for peanut.

Egli (1988) and Rasekh et al. (2010) indicated that determination of the optimum plant population density necessary for optimal yield is a major agronomic goal. Two general concepts are frequently used to explain the relationship between row spacing, plant densities and yield. First, maximum yield can be obtained only if the plant community produces enough leaf area to provide maximum isolation interception during reproductive growth. Secondary, equidistant spacing between plants will maximize yield because it minimizes inter plant competition.

Zhao et al. (2017) reported that appropriate cultivation methods and density are needed to fully utilize the peanut's genetic potential for better yield. Planting density not only determines competition for light and nutrients, but also controls the distribution of dried materials between the organs and ultimately increased pod yield.

Konlan et al. (2013) indicated that several workers have reported higher yields in close spaced compared to wide spaced peanut systems, usually attributed to higher plant population densities that effectively utilize water, nutrient and perhaps more importantly light. It is known that yield increases in these systems are closely linked to increased light interception that occurs in close spaced compared to wide spaced systems. Onat et al. (2017) indicated that as the number of plants per unit area increased, competition for growth resources such as nutrient, water and light also increased. According to Nakagawa (1983), the plant's population is one of the main factors that can limit the yield potential of peanuts. Due to this fact the row spacing and population density needs to be explored.

Among cultural practices, many authors have emphasized the importance of plant density, cultivar selection, planting date and fungicide application and their integration (Naab et al., 2009). Determination of the optimum plant population density necessary for optimal yield is a major agronomic goal. Plant density varies according to location, sowing time and varieties in peanut farming. The objective of this study was to determine the effect of intra-row spacing (plant density) on pod yield and some agronomic characteristics of peanut varieties grown as a main crop in Adana-Turkey.

MATERIALS AND METHODS

Materials

Field experiments were conducted at Research Farm of Cukurova University (Southern Turkey, 36^{o}59^l N, 35^{o}18^1 E and 23 m elevation) as a main crop in 2018 and 2019. Two different growth type peanut varieties such as Halisbey (semi-spreading) and NC-7 (spreading), peanut varieties belonging to Virginia market types were used as a plant material in this research.

The soil texture was clay loam. The soil tests indicated that pH of 7.7 with high concentrations of K_2O (705 kgha^{-1}) and low concentrations of P_2O_5 (28 kgha^{-1}). In addition, the organic matter (1.4%) and nitrogen content of the soil were very low. The lime content was 22.1% in the soil.

This study was conducted in Adana province in Turkey and in this region, winters are mild and rainy, whereas summers are dry and warm, which is a typical of a Mediterranean climate. The climate data such as temperature, precipitation and relative humidity during the 2018 and 2019 growing period and long term (LT) average (1929-2019) in Adana was shown in Table 1.

Table 1. The climate conditions during the 2018-2019 growing period and long term (LT) average (1929-2019)

Months	Average Temperature (°C)			Precipitation (mm)			Relative Humidity (%)		
	2018	2019	L.T.	2018	2019	L.T.	2018	2019	L.T.
April	20.1	17.0	17.5	33.0	61.4	51.1	61.2	67.0	60.1
May	24.4	24.1	21.7	25.6	2.6	47.1	62.8	57.6	63.2
June	26.4	27.1	25.6	27.0	13.8	20.5	70.2	68.7	70.2
July	29.1	28.4	28.2	0.0	28.0	6.2	69.8	68.8	67.5
August	29.7	29.6	28.7	0.0	0.0	5.5	68.8	68.0	68.5
September	27.9	27.3	26.1	1.2	0.0	17.6	63.6	62.1	65.4

The average monthly air temperature during the research period (April-September) was varied between 20.1 and 29.7 ^{o}C in 2018, whereas it was 17.0 and 29.6 ^{o}C in 2019. The average air temperature was the higher during the research period in both years than long term average temperature. The total rainfall was 86.8 mm and 105.8 mm during the growing period in 2018 and 2019, respectively. The average relative humidity was ranged from 61.2% to 70.2% in 2018 and 57.6% to 68.8% in 2019. The differences between the years and long term for the climate data were not found very significant (Table 1).

Methods

The experiment was designed as a split plot design (varieties as main plots and intra-row spacing as subplots) with three replications. 300 kg ha^{-1} of Di-ammonium phosphate (54 kg ha^{-1} N, 138 kg ha^{-1} P_2O_5) fertilizer was applied and incorporated to soil before planting. Urea (46%N) at the rates of 400 kg ha^{-1} was applied two times; before first (beginning of flowering) and third (pod formation) irrigation (200 kg ha^{-1} + 200 kg ha^{-1}) in each years. Individual plots consisted of 4 rows 5.0 m long and 70 cm apart. The seeds were sown by hand at the first week of April in each year. Five different (5, 10, 15, 20 and 25 cm) intra-row spacing and plant densities were established (Table 2). During the growing period, recommended pesticides and fungicides were applied to control insects and diseases. The remaining cultural practices were applied during the growing period. The plants were harvested by hand after sowing 150 days at the beginning of September in 2018 and 2019.

Table 2. Average plant density and seeding rate for Halisbey and NC-7 peanut varieties

Varieties	Intra-row spacing (cm)	Plant density (plants m^{-2})	Seeding rate (kg ha^{-1})
Halisbey	5	28.5	356.3
	10	14.2	177.5
	15	9.5	118.8
	20	7.1	88.8
	25	5.7	71.3
NC-7	5	28.5	327.8
	10	14.2	163.3
	15	9.5	109.3
	20	7.1	81.7
	25	5.7	65.6

***Data collection and analysis**:* The data belonging to agronomic and quality characteristics such as pod number and pod weight per plant, shelling percentage, 100-seed weight, pod and kernel yield per hectare, oil and protein content were collected according to Arioglu et al. (2018)'s method. The collected data on different parameters were statistically analyzed to obtain the level of significance using JMP 8.1.0 package program with split plot design. The means differences were compared with the Least Significant Differences (LSD, 5%) Test.

RESULTS AND DISCUSSION

Pod number per plant

The data belonging to pod number per plant at different plant density and peanut varieties has been presented in Table 3. As it can be seen in this table, pod number per plant varied between 28.8 and 31.3 pods plant^{-1} in a two year average. The differences between the varieties for the pod number were not statistically significant. According to a two year average, pod number per plant value was found higher in Halisbey than NC-7. The variation in the number of pods per plant observed was probably largely attributable to the genotypes of the peanut varieties. Similar results were reported by others researchers (Ahmad et al., 2007; Konlan et al., 2013; Gabisa et al., 2017 and Yousif and Hussain, 2019).

Table 3. Pod number (pods plant^{-1}), pod weight per plant (g plant^{-1}), shelling percentage (%) and 100 seed weight (g) as means of two years.

Treatments	Pod number (pods plant^{-1})	Pod weight (g plant^{-1})	Shelling percentage (%)	100 Seed weight (g)
Varieties (A)				
Halisbey	31.3	71.3 a	68.9 b	125.8 a
NC-7	28.8	64.1 b	73.0 a	117.9 b
LSD(5%A)	N.S.	3.86	1.06	3.07
Plant density(B) (plants m^{-2})				
28.5	14.4 e	32.1 e	71.4 a	118.9 d
14.2	22.5 d	53.5 d	71.2 ab	120.0 cd
9.5	27.5 c	66.1 c	71.0 b	121.1 c
7.1	39.1 b	87.7 b	70.6 c	123.5 b
5.7	46.8 a	99.2 a	70.5 c	125.5 a
LSD (5% $_B$)	2.73	3.79	0.36	1.69
LSD(5% $_{AB}$)	N.S.	5.37	0.51	N.S.

The differences between the plant densities were statistically significant for the pod number per plant in a two year average. Pod number per plant values varied between 14.4 and 46.8 pods plant^{-1} in a two year average. According to a two year average, increasing the plant density from 5.7 plants m^{-2} to 28.5 plants m^{-2}, pod number per plant was decreased from 46.8 pods plant^{-1} to 14.4 pods plant^{-1}. Planting density is important factor for growth and pod production in peanut. The highest pod number per plant was obtained from 5.7 plants m^{-2} planting density due to less competition among the plants to get enough space for their growth and development (Table 3). This result can be attributed to the greater branching of the plants as the free space for development increases and the competition for nutrients, water and light decreases. Statistical analysis for plant density and variety interaction showed no significant effect on the pod number of per plant (Table 3). Giayetto et al. (1998) reported that the number of branching per plant was reduced with the increase of plant density. At low plant density, existing plants developed more branches and pegs because of reduced in competition. Onat et al. (2017) indicated that as the number of plants per unit area increased, competition for growth resources such as nutrient, water and light also increased. Virk et al. (2005) and Abdullah et al. (2007) also reported that, increased plant density decreased number of pods per plant and as plant density decreased, number of pods per plant increased. These results are in agreement with the findings of Awal and Aktar (2015), Gabisa et al. (2017), Onat et al. (2017), Kurt et al. (2017), Yousif and Hussain (2019) and Magagula et al. (2019).

Pod weight per plant

As shown in table 3, pod weight per plant varied between 64.1 and 71.3 g plant^{-1} in a two year average. There were significant differences in pod weight per plant between the peanut varieties in a two year average. According to a two year average, the highest pod weight per plant (73.1 g plant-1) was obtained for the variety Halisbey with semi-spreading growth habit and the lowest pod weight per plant (64.1 g plant^{-1}) was obtained for variety NC-7 with spreading type growth habit. Hassan et al. (2005) reported that significant differences for pod number per plant among peanut cultivars were attributed due to variation of the genotypes. Gulluoglu et al. (2017) reported that the pod weight per plant of the peanut varieties was varied between 40.40-95.55 g plant^{-1} in main cropped conditions.

As it can be seen in Table 3, the differences between the plant densities were statistically significant for the pod weight per plant. Pod weight was significantly affected by planting density. Pod weight values varied between 32.1 and 99.2 g plant^{-1} in a two year average. Pod weight per plant was increased from 32.1 g plant^{-1} to 99.2 g plant^{-1} when the plant density decreased from 28.5 plants m^{-2} to 5.7 plants m^{-2} (Table 3). The pod weight per plant was negatively correlated with planting density. According to a two year average, the largest pod weight per plant was found in the lower plant density due to less competition among the plants to get enough space for their growth and development. Onat et al. (2017) and Kurt et al. (2017) indicated that as the number of plants per unit area increased, competition for growth resources such as nutrient, water and light also increased. As it can be seen in Table 3, pod number per plant was the higher at the lower plant density. For these reason, pod weight was found higher at the lower plant density. Statistical analysis for plant density and variety interaction showed significant effect on the pod weight per plant in a two year average (Figure 1). According to a two year average, the highest pod weight was obtained from Halisbey variety at 5.7 plants m^{-2} planting density and the lowest from NC-7 at 28.5 plants m^{-2} planting density. These results are in agreement with the findings of Konlan et al. (2013), Dapaah et al. (2014), Kurt et al. (2017) and Onat et al. (2017).

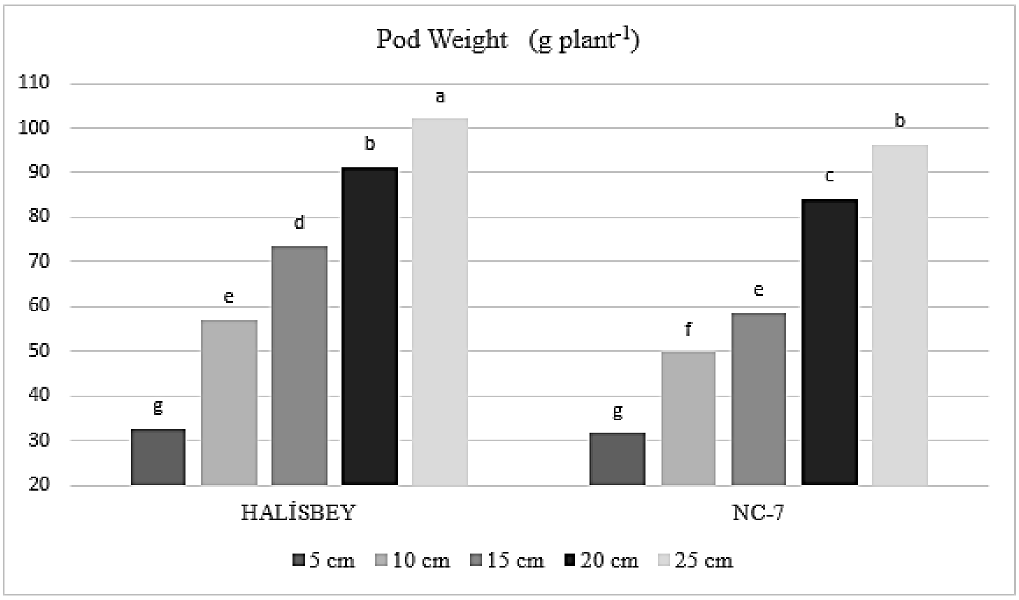

Figure 1. Interaction between the variety and plant density for the pod weight per plant

Shelling percentage

Shelling percentage is the indication of pod filling efficiency and high shelling percentage values indicate effective pod filling. The shelling percentage of the peanut varieties varied between 68.9 and 73.0% in a two year average (Table 3). The differences between the Halisbey and NC-7 for the shelling percentage were significant. The shelling percentage was found higher in NC-7 than Halisbey. According to a two year average, the shelling percentage was 68.9% in Halisbey and 73.0% in NC-7 peanut variety. The reason of these differences between the varieties for the shelling percentage originated from their genotypic background. Similar results were reported by Rasekh et al. (2010) and Konlan et al. (2013).

The differences between the planting densities for the shelling percentage were significant. The shelling percentage values varied between 70.5 and 71.4% in a two year average (Table 3). The shelling percentage was affected by plant density. Shelling percentage increased with increasing plant population density up to 28.5 plants m^{-2}. According to a two year average, shelling percentage was the highest (71.4%) in higher plant density (28.5 plants m^{-2}) and it was lowest in lower plant density (5.7 plants m^{-2}). Onat et al. (2017) and Kurt et al. (2017) reported that the shelling percentage of the peanut varieties was varied between 64.20 and 67.34% at different plant densities. The similar results were found by Rasekh et al. (2010), Konlan et al. (2013), Zhao et al. (2017) and Gabisa et al. (2017). According to a two year average, the interaction effect of variety and plant density was significant on shelling percentage (Figure 2). According to a two year average, the highest shelling percentage (73.3%) recorded for NC-7 variety at 9.5 plants m^{-2} planting density, while the lowest shelling (68.3%) percentage recorded for Halisbey at 28.5 plants m^{-2} planting density.

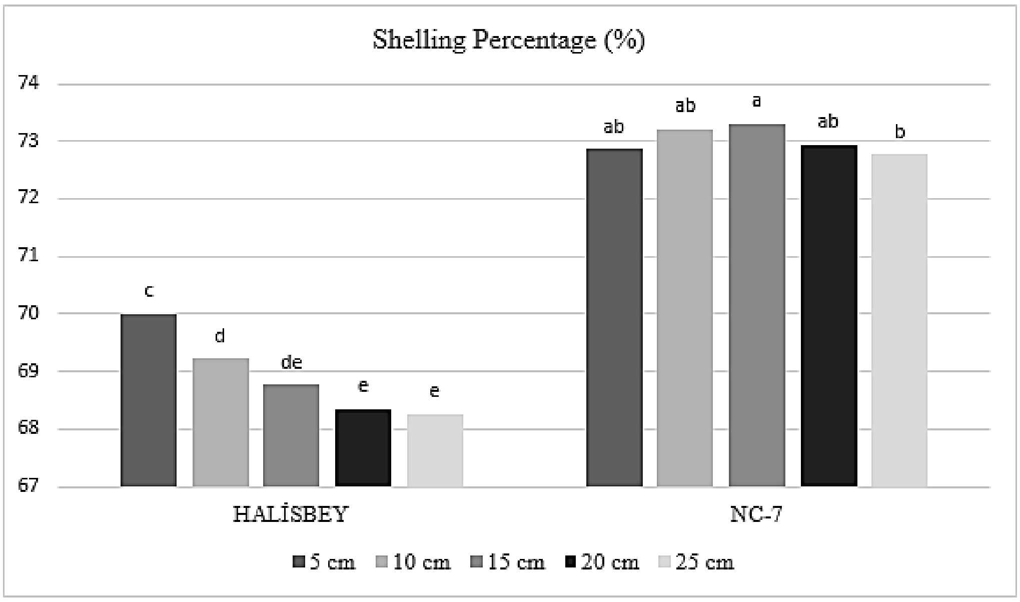

Figure 2. Interaction between the variety and plant density for the shelling percentage

Hundred seed weight

As can be observed in Table 3, the 100 seed weight of the peanut varieties varied between 117.9 and 125.8 g in a two year average. The differences between the varieties for the 100 seed weight were found significant. According to a two year average, 100 seed weight was found higher in Halisbey (125.8 g) than in NC-7 (118.2 g) variety. The reason of these differences between the varieties for the 100 seed weight originated from their genotypic background. Gulluoglu et al. (2017) reported that 100 seed weight varies between 105-136 g in Virginia market type peanut varieties in main crop conditions.

100 seed weight values varied between 118.9 and 125.5 g in a two year average (Table 3). The differences between the plant densities were statistically significant for seed weight in a two year average. According to a two year average, the highest 100 seed weight (125.5 g) was recorded at the lowest plant density of 5.7 plants m^{-2} (25 cm intra row spacing) whereas the lowest (118.9 g) was recorded at the highest plant density of 28.5 plants m^{-2} (5 cm intra-row spacing). 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 hundred seeds increased. Onat et al. (2017) indicated that, intra-row spacing differences regarding 100 seed weight might by due to the competition for light, water and other essential requirement among the plants. Ahmad et al. (2007), El Naim et al. (2011), Konlan et al. (2013), Awal and Aktar (2015), Onat et al. (2017), Gabisa et al. (2017), Kurt et al. (2017), Zhao et al. (2017) and Yousif and Hussain (2019) reported that 100 seed weight decreased with increasing plant density in peanut. According to a two year average, interaction between the plant density and variety for hundred seed weight was not statistically significant.

Protein and Oil content

The data belonging to oil and protein content of peanut varieties at different plant densities has been presented in Table 4. According to a two year average oil and protein percent of peanut varieties varied between 45.62 and 48.25% and 24.74 and 27.34%, respectively. The differences between the varieties for the oil and protein content were statistically significant. The oil content was found higher in Halisbey (48.25%), whereas the protein content was higher in NC-7 (27.34%) variety. These two varieties belong to Virginia market type and the differences for oil and protein content among peanut cultivars were attributed due to variation of their genotypes. Hassan et al. (2005), Hassan and Ahmed (2012) and Yousif and Hussain (2019) reported that oil content of peanut varieties ranged between 49.83 and 53.06%, 46.1 and 52.9% and 49.83 and 53.06%, respectively. Arioglu et al. (2018) reported that Halisbey variety has the 49.00% oil and 24.58% protein content.

Table 4. Oil content (%), protein content (%), pod yield (kg ha^{-1}) and kernel yield (kg ha^{-1}) as means of two years.

Treatments	Oil content (%)	Protein content (%)	Pod yield (kg ha^{-1})	Kernel yield (kg ha^{-1})
Varieties (A)				
Halisbey	48.25 a	24.74 b	7160 a	4936 a
NC-7	45.62 b	27.34 a	5116 b	3737 b
LSD(5%A)	0.13	0.12	679.8	440.5
Plant density(B) (plants m^{-2})				
28.5	46.78	26.88 a	6652 a	4738 a
14.2	46.81	26.43 b	6400 ab	4540 a
9.5	47.00	25.97 c	6115 bc	4318 b
7.1	47.11	25.64 d	5834 cd	4097 c
5.7	47.27	25.29 e	5688 d	3989 c
LSD (5% $_B$)	N.S.	0.24	289.2	204.9
LSD(5% $_{AB}$)	N.S.	N.S.	N.S.	N.S.

As shown in table 4, there were no significant differences between plant densities for the oil content in a two-year average. According to a two-year average, oil percentage varied between 46.78 and 47.27%. The oil content was decreased when the planting density increased. The oil content was 46.78% while the planting density was 28.5 plants m^{-2}, it increased to 47.27% at 5.7 plants m^{-2} planting density in a two-year average. Oil content was not affected significantly by the planting density. Onat et al. (2017) reported that the oil percentage was increased up to 47.5% when the plant space increased from 5 cm to 25 cm in peanut seed grown as a double crop.

The protein percentage values varied between 25.29 and 26.88% in a two year average. The statistically significant differences were found between the plant densities for protein content. The protein percentage was 25.29% at the 5.7 plants m^{-2} planting density and it increased to 26.88% at the 28.5 plants m^{-2} planting density (Table 4). The protein content was increased when the planting density decreased. These results are in agreement with Onat et al. (2017) and Kurt at al. (2017). Interaction between the variety and plant density for the oil and protein content were not significant.

Pod yield

As it can be seen in Table 4, pod yield per hectare of the peanut varieties varied between 5116 and 7160 kg ha^{-1} in a two year average. The differences between the varieties for the pod yield were statistically significant in a two year average. According to a two year average, pod yield was 5116 kg ha^{-1} in NC-7 and 7160 kg ha^{-1} in Halisbey variety. The highest pod yield (7160 kg ha^{-1}) was obtained for the variety Halisbey with semi-spreading growth habit and the lowest pod yield (5116 kg ha^{-1}) was obtained for variety NC-7 with spreading type growth habit in a two year average. The variation in pod yield of varieties was probably attributable to genetic differences between varieties and how they responded to environmental changes (Konlan et al., 2013). Gulluoglu et al. (2017) reported that the reason of these differences between the varieties for the pod yield could be originated from their genotypic background. The highest pod yield produced by variety "Halisbey" could be attributed to its greater number of pods per plant, pod weight per plant and hundred seed weight. Gulluoglu et al. (2017) reported that pod yield varies between 3666 and 8796 kg ha^{-1} in peanut varieties grown as a main crop.

The differences between the plant densities for the pod yield per hectare were statistically significant in a two year average. Pod yield per hectare values varied between 5688 and 6652 kg ha^{-1} in a two-year average. The variability of planting density had significant effect on pod yield. Pod yield per hectare increased with increasing the plant density in a two year average. Kurt et al. (2017) indicated that, pod yield in peanut is calculated by multiplying the plant number per unit area x pod weight per plant. In this equation, pod yield was decreased when the plant density increased, but the plant number per hectare was increased when the plant density increased. It can be seen in Table 3, pod weight per plant was increased from 32.1 g plant^{-1} to 99.2 g plant^{-1} when the planting density decreased from 28.5 plants m^{-2} to 5.7 plants m^{-2}, whereas the total pod yield per hectare was increased from 5688 kg ha^{-1} to 6652 kg ha^{-1} when the plant density increased in a two year average.

According to a two year average, the highest pod yield (6652 kg ha^{-1}) was recorded from the crop grown with 28.5 plants m^{-2} planting density whereas the lowest pod yield (5688 kg ha^{-1}) was obtained from the lowest plant density (5.7 plants m^{-2}). The lower planting density of 5.7 plants m^{-2} produced 14.5% lower pod yield than 28.5 plants m^{-2} planting density. Wells et al. (1993) indicated that, higher pod yields from higher plant densities are mainly attributed to effective utilization of water, nutrients and perhaps more importantly light. In this study, the interaction between the variety and plant density was not significant. These mean that, pod yield of the varieties was not affected differently by the plant density. similar results were observed by Sconyers et al. (2007), Ahmad et al. (2007), El Naim et al. (2011), Awal and Aktar (2015), Gabisa et al. (2017), Onat et al. (2017), Kurt et al. (2017) and Magagula et al. (2019).

Kernel yield

Kernel yield per hectare was calculated as the pod yield per hectare x shelling percentage (Rasekh et al., 2010). Kernel yield per hectare of the peanut varieties varied between 3737 and 4936 kg ha^{-1} at different plant density in a two year average. The differences between the varieties for the kernel yield were significant in a two year average. The shelling percentage was lower in Halisbey than NC-7 variety, but its pod yield was higher than NC-7 (Table 4). For these reason, kernel yield was found higher in Halisbey than NC-7 variety.

As it can be seen in Table 4, the differences between the plant densities for the kernel yield per hectare were statistically significant. Kernel yield per hectare varied between 3989 and 4738 kg ha^{-1} in a two year average. The kernel yield was increased when the plant density increased like pod yield. The highest kernel yield was obtained from 28.5 plants m^{-2} having plots. Interaction of variety and planting density in this case was not found significant. These findings are supported by Rasekh et al. (2010), Onat et al. (2017), Gabisa et al. (2017), Kurt et al. (2017), Zhao et al. (2017) and Magagula et al. (2019).

CONCLUSION

In this study, pod number and weight per plant and 100 seed weight values were decreased when the plant density was increased, but shelling percentage, pod and kernel yield and protein percentage values were increased. The oil content was not affected by the plant density. The highest pod yield (6652 kg ha^{-1}) was obtained when the seeds planted at 5 cm inter-row spacing (28.5 plants m^{-2} plant density). The highest pod yield was obtained from Halisbey variety. The optimum planting density for Virginia type peanut varieties was found at 70 x 5 cm planting pattern (28.5 plants m^{-1} plant density) in main crop growing conditions.

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