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EFFECT OF PLANT DENSITY ON YIELD AND QUALITY OF PEANUT (*Arachis hypogaea* L.) CULTIVARS

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ABSTRACT

Plant density can have a major impact on peanut (*Arachis hypogaea* L.) yield. Information is limited in the Eastern Mediterranean Transition Region of Turkiye on growth, development, and yield of peanut cultivars based on plant density. To address this limitation, the cultivars Aysehanim, Rigel, Halisbey, Masal, and NC 7 were established in a single row planting pattern consisting of rows spaced 70 cm apart with an inter-row plant distance of 15 cm (95.000 plants ha^{-1}) versus a twin row planting pattern consisting of rows spaced 20 cm apart on 90 cm centers with an intra-row distance of 15 cm (148.000 plants ha^{-1}). The interaction of cultivar × plant density was significant for most variables. Irrespective of cultivar, establishing a plant population of 148.000 plants ha^{-1} in the twin row planting pattern resulted in greater pod yield than the single row planting pattern with a plant density of 95.000 plants ha^{-1}. Pod yield was similar for Rigel, Masal, and NC 7 in the twin row planting pattern and exceeded that of Aysehanim and Halisbey. Conversely, yield of Rigel and Halisbey was similar in the single row pattern and exceeded yield of Aysehanim and NC 7.

Keywords: Cultivars, single row pattern, seeding rate, twin row pattern

INTRODUCTION

Peanut (*Arachis hypogea* L.) is a *Fabaceae* oil crop that is used in both human and animal nutrition due to its high protein, mineral, and carbohydrate content (Yasli et al., 2020). Peanut seed is composed of 43-55% oil and 25-28% protein, counting on market type and growing conditions and contains the essential minerals like Ca, Cu, Fe, K, Mg, Na, and Zn. Vitamin B, E, and K are also important constituents of peanut (Onat et al., 2017; Yilmaz et al., 2022). Peanut contributes to the nutritional needs of humans and livestock (Bakal and Arioglu, 2019). Peanut can diversify cropping systems and contribute to N balance through biological nitrogen fixation (Caliskan et al., 2008; Nigam et al., 2018).

In 2020, the worldwide production of peanut was 53.7 million tonnes of shelled peanut grown on 31.6 million ha (FAO, 2022). Production in Asia and Africa contributed approximately 90% of total production, with the balance produced in the Americas. China (18 million tonnes) and India (10 million tonnes) were the two largest producers, sums of more than half of total production output. Turkiye contributed 215.927 tonnes to total production in the same year, covering approximately 54.775 ha. Peanut production per ha has increased in Turkiye compared with other countries (FAO, 2022; TUIK, 2022).

Numerous factors influence peanut yield and can include agronomic and cultural practices and pest management (Nigam et al., 2018). Of particular importance is plant population (Gulluoglu et al., 2016; Nigam et al., 2018; Oakes et al., 2020). Konlan et al. (2013) suggested that maximum yield is only possible if the plant community produces enough leaf area optimize photosynthesis. Equidistant spacing between plants is also important to minimize intra-row competition between plants for resources.

Higher plant populations can decrease the negative impact of tomato spotted wilt virus (Family *Tospoviridae*, genus *Orthotospovirus*) and groundnut rosette disease (Family *Tombusviridae*, genus *Umbravirus*) in peanut. However, incidence of southern stem rot (caused by *Sclerotium rolfsii* Sacc.) can increase when plant populations are higher due to plant-to-plant infection (Sconyers et al., 2005). The negative impact of weeds on peanut can be reduced when peanut is established at higher plant populations compared with peanut at lower populations (Tubbs et al., 2011).

Twin row planting patterns are one approach to increase plant populations without increasing intra-row competition between peanut plants (Lassiter et al., 2016a, 2016b; Mkandawire et al., 2021). Greater yields in twin row planting patterns compared with single row planting patterns have been observed (Lanier et al., 2004). Peanut yield response to planting pattern, plant density, and cultivar can vary. Currently, NC 7 is the most prominent cultivar in Turkiye, and this cultivar is often planted in single rows spaced 70 cm apart with a final plant population of 95.000 plants ha^{-1} (Onat et al., 2017). Several new cultivars are available and are also grown on 70 cm spacing in a single row planting pattern. Given research has demonstrated that peanut yield can be greater in twin row planting patterns compared with single row planting patterns, research was conducted in the Eastern Mediterranean of Turkiye to determine if plant density, established through differentiation in planting pattern, affected peanut yield and other growth characteristics of cultivars currently available in Turkiye.

MATERIALS AND METHODS

Materials

Agronomic and market quality characteristics of five Virginia type peanut cultivars (Aysehanim, Rigel, Halisbey, Masal, NC-7) (Table 1) with different growth characteristics were established at plant populations of 95.000 plants ha^{-1} or 148.000 plants ha^{-1}. These respective plant populations were established using a single row planting pattern with a 70-cm spacing or a twin row planting pattern consisting of two rows spaced 20 cm apart on 90 cm centers. In both planting patterns, the inter-row distance was 15 cm (Figure 1). The experiment was conducted at Osmaniye (37°07′24”N, 36°11′53”E; 63 m) at the Oil Seeds Research Institute in 2020 and 2021 with a climate associated with the Eastern Mediterranean climate. A clay soil common for the region (1% sand, 20% silt, 79% clay) was present in the experiment area with a soil pH of 8.0 and 2.0% organic matter.

Table 1. Growth habit and origin of five cultivars included in the experiment.

Cultivars	Growing habit	Market type	Origin
Aysehanim	Semi-spreading	Virginia	Turkiye
Rigel	Semi-erect	Virginia	Turkiye
Halisbey	Semi-erect	Virginia	Turkiye
Masal	Semi-erect	Virginia	Turkiye
NC 7	Semi-spreading	Virginia	USA

Precipitation and average temperature for both the year and growing period in 2020 and 2021 are presented in Table 2. In 2020, there was 237 mm of precipitation overall, and 88 mm in 2021. The long year (267 mm) was comparable to 2020 but different from 2021. This discrepancy was brought on by rainfall in April and May of 2021. There were no appreciable variations in the mean temperature or humidity between the years and the long-term average with an average of 24.3 to 25.0 °C in 2020 and 2021.

Table 2. Climate parameters of the research field (2020, 2021 and long-year average)

Months	Precipitation (mm)			Temperature (°C)			Relative Humidity (%)		
	LY	2020	2021	LY	2020	2021	LY	2020	2021
April	86.5	123.9	32.3	17.0	17.1	17.7	64.2	69.4	64.8
May	72.6	83.5	4.6	21.3	22.1	22.9	63.2	62.4	59.8
June	42.4	5.5	1.8	25.2	24.0	25.0	62.7	68.7	65.9
July	19.8	2.0	15.7	27.9	28.4	28.9	66.4	71.7	64.6
August	10.7	21.5	19.7	28.6	28.6	29.3	64.9	64.0	62.8
September	34.5	0.9	14.0	25.7	28.6	25.9	60.7	61.8	60.8
Total/Av.	266.5	237.3	88.0	24.3	24.8	25.0	63.7	66.3	63.1

Av.: Average; LY: Long Year.

Methods

Experiments were arranged in as a split-plot arrangement (RCBD) with factorial arrangement of treatments with three replications. Cultivars served as main plots with plant densities serving as sub-plot units. Plot size was four main rows (single rows or centers for the two twin rows) with a length of 5 m for both planting patterns as described previously. Di-ammonium phosphate (18% N and 46% P_2O_5) was applied at 25 kg ha^{-1} within 2 weeks prior to sowing on April 29 (2020) and April 25 (2021). Plots were maintained weed-free throughout the season by hand weeding. At peak flowering (approximately 45 days after sowing), overhead sprinker irrigation was initiated and administered as needed throughout the cropping cycle for a total of 362 mm in 2020 and 512 mm in 2021. Peanut pods were harvested by hand on September 21 (2020) or September 19 (2021) based on shell out method. Optimum maturity after sowing for the five cultivars requires approximately the same number of days under irrigated conditions (Sahin et al., 2022).

Twenty randomly selected plants from the center two rows of each plot were used to determine main stem plant height to the nearest cm, number of pods per plant, number of branches, shelling percentage, and protein content in seed. Four randomly selected groups of pods were collected and used to determine weight for 100 pods and 100 seeds. Pods from all plants in the plot were collected to determine pod yield and converted to kg ha^{-1} at a moisture of 7%.

Statistical Analysis

Data for main plant height, number of pods per plant, number of branches per plant, weight of 100-pods and 100-seeds, shelling percentage, pod yield, and protein content were subjected to analysis of variance considering the experimental design and the factorial treatment arrangement. Treatment factors included 2 levels of year, 5 levels of cultivar, and 2 levels of plant density using MSTAT-C and SPSS v22 (Kurt et al., 2017). Means of significant main effects and interactions were separated using Duncan's Multiple Range test at $p \leq 0.01$ (Steel and Torrie, 1980).

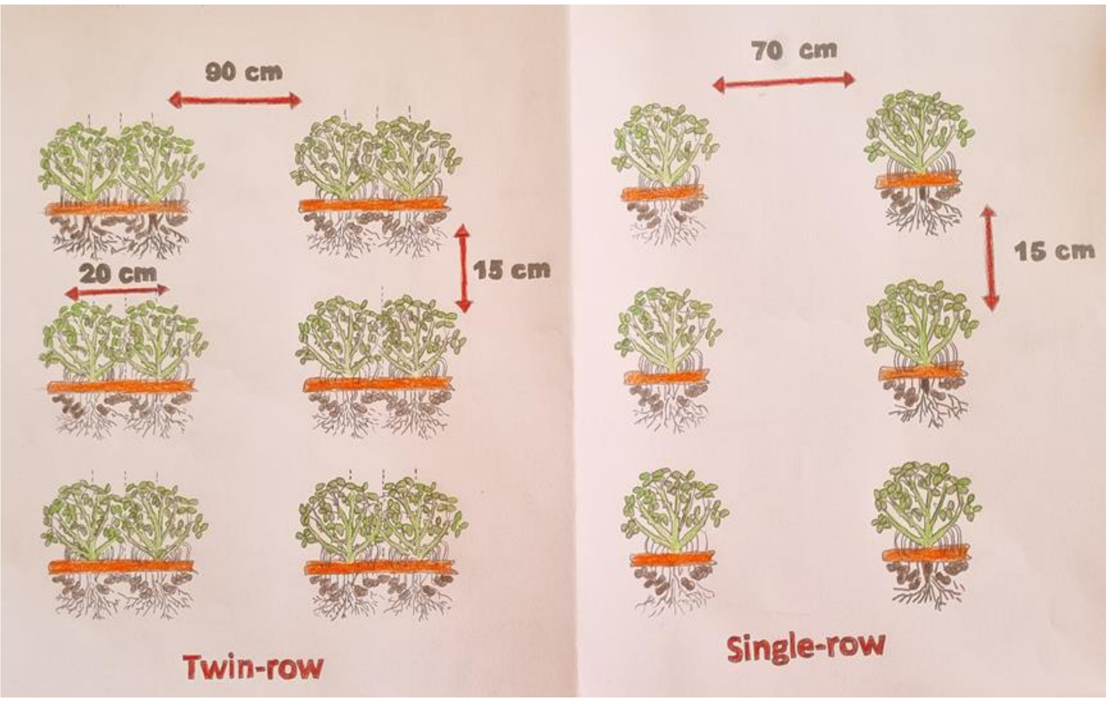

Figure 1. Layout of plants for the twin row and single row planting pattern

RESULTS AND DISCUSSION

Plant Height

Plant height was affected by the interaction of cultivar and plant density (Table 3). When pooled over years, main stem height was shorter in the twin row pattern compared with single rows for the cultivars Rigel and Masal but not for the cultivars Aysehanim, Halisbey, and NC 7 (Table 4). No difference in main stem height was noted among cultivars in the twin-row planting pattern. In contrast, main stem height for Rigel and Masal exceeded that of Aysehanim and NC 7 in the single row planting pattern. Plant height is highly affected by different planting light interception planting patterns, and the more effective capture and use of light contributes to yield (Wang et al., 2017). The findings plant height of present study was similar with Magagula et al. (2019) but higher than Tubbs et al. (2011), Essilfie et al. (2020).

Number of Branches

With the exception of NC 7, the number of branches for each plant was greater in the single row pattern compared with the twin row planting pattern (Table 4). In the twin row planting pattern, NC 7 had fewer branches than the other cultivars. However, no difference in branching was observed among cultivars in the single row pattern. High planting densities can result in reduced branching and a reduction in the number of lateral stems in each plant (Onat et al., 2017). However, Dapaah et al. (2014) reported that greater branching may have a favorable impact on production because each branch supports leaves that may contribute to greater photosynthesis. According to Giayetto et al. (1998), the number of branches per plant decreases proportionally as plant density increase when less occurs plants grew more branches and pegs. Competition for growing resources (e.g. nutrients, water, and light) increased, when number of plants per unit area increase (Konlan et al., 2013; Ahmad et al., 2007). Magagula et al. (2019) reported that greater planting densities result in reduced branching and a reduction in the number of lateral stems in each plant.

Number of Pods Per Plant

The number of pods per plant was affected by the interaction of cultivar and plant density (Table 3). As expected, fewer pods per plant were noted for all cultivars when the pant density was increased compared with the single row planting pattern with fewer plant ha^{-1} (Table 4). Differences in the number of pods per plant differed for cultivars when comparing within planting patterns. For example, a greater number of pods was recorded for Rigel and Masal compared with all other cultivars in the twin-row planting pattern with the higher plant density. In contrast, the number of pods for Aysehanim and Rigel had a similar number of pods in the single row pattern and exceeded the number for Masal. Yousif and Hussain (2019) reported that the genetic heritage of the distinct peanut types was mostly responsible for the difference in the number of pods per plant. Variation in the number of pods per plant was noted among seed rates. The number of pods per plant findings were similar with Kurt et al.

Table 3. Analysis of variance for plant height (PH), number of branches per plant (NB), number of pods per plant (NP), 100-pods weight (HPW) and 100-seeds (HSW), shelling percentage (SP), pod yield (PY), and protein content (PC) in seed as influenced by year, plant density, and cultivar.

Source of variation	df	PH	NB	NP	PW	HPW	HSW	SP	PY	PC
Block	2	ns	ns	ns	ns	ns	Ns	ns	ns	ns
Year	1	**	ns	**	**	ns	Ns	ns	ns	ns
Plant density (PD)	1	**	**	**	**	**	**	ns	**	ns
Cultivars	4	**	**	**	**	**	**	**	**	**
Y x PD	1	ns	**	ns	ns	ns	Ns	**	ns	ns
Y x C	4	ns	ns	ns	ns	ns	**	**	ns	ns
PD x C	4	**	**	**	**	**	Ns	ns	**	**
Y x PD x C	4	**	ns	ns	ns	ns	**	ns	ns	ns
CV (%)		14.0	26.4	18.3	24.0	3.6	4.4	4.9	20.3	2.0

Table 4. Average values of plant height, number of branches, and number of pods per plant as influenced by cultivar, plant density, and the interaction of these treatment factors.

Cultivars	Plant height (cm)		Plant height avg. (cm)	Number of branches/plant		Number of branches/plant avg.	Number of pods per plant		Number of pods per plant avg.
	Twin-row	Single-row		Twin-row	Single-row		Twin-row	Single-row	
Aysehanim	39.5 D	40.2 D	39.9 b	6.9 C	10.6 AB	8.8 bc	17.8 G	28.3 AB	23.1 bc
Rigel	41.6 CD	52.3 A	47.0 a	6.0 C	10.2 AB	8.1 c	22.0 F	29.4 A	25.7 a
Halisbey	42.7 CD	46.2 BC	44.5 a	6.8 C	11.6 A	9.2 b	19.0 G	27.2 BC	23.1 bc
Masal	42.5 CD	50.7 AB	46.6 a	6.5 C	12.0 A	9.3 ab	22.9 EF	25.7 CD	24.3 ab
NC 7	40.4 D	40.7 D	40.6 b	9.3 B	10.8 AB	10.1 a	19.4 G	24.9 DE	22.2 c
Mean	41.3 y	46.0 x		7.1 y	11.0 x		20.2 y	27.1 x	

A, B: Display the interaction between year x cultivar x planting method.
a, b: Display the differences between the cultivars.
x, y: Display the differences between sowing methods.

(2017), lower than Onat et al. (2017), Essifie et al. (2020) but higher than Konlan et al. (2013).

Pod Weight Per Plant

Pod weight per plant was affected by the interaction of cultivar × plant density (Table 3). Regardless of cultivar, pod weight per plant was greater when peanut was grown in single rows at a lower plant density compared with the higher plant population in the twin-row planting pattern (Table 5). The relative difference in pod weight among cultivars was different depending on planting pattern. When planted in twin rows, the greatest pod weight per plant was observed for Halisbey while the lowest was noted for NC 7. In the twin row planting pattern, Rigel had the greatest weight per plant while Aysehanim and NC 7 had the lowest weight. Sternitzke et al. (2000) carried out a similar peanut experiment and discovered that reducing plant density considerably enhanced pod weight per plant. The pod weight per plant findings were higher than Nwokwuet et al. (2020), lower than Kurt et al. (2017) and Onat et al. (2017).

Table 5. Average values of pod weight per plant, 100-pod weight, and 100-seed weight for cultivar, plant density, and the interaction of these treatment factors.

Cultivars	Pod weight per plant (g)		Pod weight per plant avg. (g)	100-pod weight (g)		100-pod weight avg. (g)	100-seed weight (g)		100-seed weight avg. (g)
	Twin-row	Single-row		Twin-row	Single-row		Twin-row	Single-row	
Aysehanim	49.1 E	54.7 D	51.9 b	260.4 B	247.5 EF	254.0 b	107.2 ABC	106.3 BC	106.8 ab
Rigel	46.5 EF	67.6 A	57.1 a	260.7 B	260.7 B	260.7 a	108.0 AB	111.8 A	109.9 a
Halisbey	53.9 G	64.6 B	59.3 d	253.9 CD	250.3 CDE	252.1 bc	102.6 C	106.2 BC	104.0 b
Masal	46.3 EF	58.9 C	52.6 b	255.5 BC	242.5 F	249.0 c	107.0 ABC	111.5 A	109.3 a
NC 7	45.2 F	54.1 D	49.7 c	269.1 A	247.8 DEF	258.5 a	105.7 BC	105.0 BC	105.4 b
Mean	48.2 y	60.0 x		259.9 x	249.8 y		106.1	108.2	

A, B: Display the interaction between year x cultivar x planting method.
a, b: Display the differences between the cultivars.
x, y: Display the differences between sowing methods.

100-Pod and Seed Weight

The interaction of cultivar × plant density was significant for seed weight of 100-pods while only cultivar was significant for weight of 100 seeds (Table 3). Weight of pods was greater for the cultivars Aysehanim, Masal, and NC 7 compared with weights in the single row planting pattern (Table 5). No difference was noted for the cultivars Rigel and Halisbey. The greatest weight of 100 pods was observed when NC 7 was seeded in twin rows.

Weight of 100 seeds was not affected by the interaction of cultivar × plant density but was affected by the main effect of cultivar (Table 3). When pooled over plant density, weight of 100 seeds for Aysehanim, Rigel, and Masal was similar and exceeded weight for Halisbey and NC 7 (Table 5). Konlan et al. (2013) there is no difference between 100-seed weight and plant density. These findings were higher than Nwokwu et al. (2019).

Shelling Percentage

Shelling percentage result was significant cultivars but not plant density or the interaction of cultivar and plant density (Table 3). The greatest shelling percentage was recorded for Masal and NC 7 with the lowest noted for Halisbey (Table 6). Shelling percentage findings were similar Onat et al. (2017) but higher than Konlan et al. (2013), Kurt et al. (2017), Magagula et al. (2019), Nwokwu et al. (2022).

Table 6. Average values of shelling percentage, pod yield, and protein content as affected by cultivar, plant density, and the interaction of these treatment factors.

Cultivars	Shelling percentage (%)		Shelling percentage avg. (%)	Pod yield (kg ha^{-1})		Pod yield avg. (kg ha^{-1})	Protein content (%)		Protein content avg. (%)
	Twin-row	Single-row		Twin-row	Single-row		Twin-row	Single-row	
Aysehanim	70.1 BC	70.1 BC	70.1 b	6873 BC	4272 F	5573 d	22.90 B	26.60 A	24.75 a
Rigel	71.0 ABC	69.7 C	70.4 b	7670 A	6348 CD	7009 a	20.87 CD	21.09 C	20.98 c
Halisbey	62.3 D	63.3 D	62.8 c	6705 C	6062 DE	6384 bc	23.01 B	21.96 BC	22.49 b
Masal	70.9 ABC	70.6 ABC	70.8 ab	7629 A	5525 E	6577 ab	19.56 DE	21.12 C	20.34 c
NC 7	71.7 A	71.4 AB	71.6 a	7468 AB	4464 F	5966 cd	22.18 B	18.22 E	20.20 c
Mean	69.2	69.0		7269 x	5334 y		21.70	21.80	

A, B: Display the interaction between year x cultivar x planting method.
a, b: Display the differences between the cultivars.
x, y: Display the differences between sowing method

Pod Yield

Pod yield was affected by the interaction of cultivar × plant density (Table 3). Regardless of cultivar, yield was greater when peanut was grown in twin rows at a higher plant density compared with the single row planting pattern with a lower plant density (Table 6). When planted in twin rows, the highest yield was noted for Esfane and Masal. No difference was observed for Aysehanim and NC 7 while yield for Aysehanim and Halisbey was similar. Yield of Rigel and Halisbey was similar and exceeded yield of Aysehanim and NC 7. Previous research (Kirk et al., 2013; Plumblee, 2013) reported a positive relationship of plant density and pod yield. The findings of present study were similar with Kurt et al. (2017), Onat et al. (2017) but higher than Tubbs et al. (2011), Konlan et al. (2013). Mkandawire et al. (2021) reported higher yields when peanut was planted at higher densities using a twin row planting pattern. Lassiter et al. (2016) indicated a significant interaction of peanut market type and planting pattern.

Protein Content

Protein content was greatest when Aysehanim was planted in single rows with the lowest observed when Masal was planted in twin rows and NC 7 was planted in single rows (Table 6). In contrast to our results, Kadiroglu (2012) reported that plant density did not affect protein content.

CONCLUSION

Twin row planting pattern is a new technology in Turkiye peanut production with limited research available to document the effects on yield or grade characteristics. Peanut planting patterns have traditionally consisted of single rows 70 cm apart primarily with the cultivar NC 7. Our results indicate that increasing plant density per unit area by using the twin row planting pattern might serve as an efficient alternative to traditional methods of planting in single rows in order to optimize yield. These experiments were conducted with no significant pest incidence and with irrigation scheduling designed to optimize yield. Additional research with less effective irrigation and/or presence of key pests would inform practitioners on the value of higher plant densities under a range of conditions. The cost of establishing a greater plant density in the twin row planting pattern was much higher with respect to seed cost. The number of seed used to establish the higher plant density was 1.6 times that of the lower plant density. Determining the financial return of the two densities would be informative. Under the conditions of our research, Rigel, Masal, and NC 7 appear to be the highest yielding cultivars. However, if planting in single rows with a lower plant population, Rigel and Halsibey may be the more appropriate cultivars to grow.

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