RESEARCH ARTICLE

Effect of Plant Spacing on Yield and Some Quality Characteristics of Three Chickpea (*Cicer arietinum* L.) Varieties

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ABSTRACT

A field study was conducted at Grdarasha Research Station of the College of Agriculture/Salahaddin University, Erbil, during growing winter season of 2017, to study the effect of plant spacing on some yield and quality of chickpea varieties. The factorial experiment was applied in "Randomized Complete Block Design" (RCBD), in three replicates, by using four plant spacing (6, 9, 12 and 15 cm), and three varieties of chickpea (Rafedain, Gab and TH85) were implemented. The 15 cm plant spacing produced the highest number of primary branches per plant (4.34), number of pods per plant (15.44), seed yield (1124.33 kg/ha), protein percentage (23.12), protein yield (247.19 kg/ha), and oil percentage (11.81). On the contrary, the 6 cm plant spacing recorded the highest value of carbohydrate percentage (60.91); also, Gab variety exceeds Rafedain and TH85 varieties in number of primary branch per plant (4.07), number of pods per plant (11.71), seed yield (1120.91 kg/ha), protein percentage (22.25), and protein yield (250.26 kg/ha), but the TH85 gave the optimum oil percentage (11.14) and carbohydrate percentage (59.84). From the interaction of plant spacing with varieties, the highest rate was recorded at 15 cm plant spacing with Gab variety seed yield (1192.85 kg/ha) and protein yield (297.16 kg/ha). There was a positive and negative correlation between yield and number of pods per plant and number of seeds per pod ($r = 0.673$ and 0.689) and between carbohydrate percentage with protein and oil percentages ($r = -0.777$ and -0.658), respectively.

Keywords: Chickpea; Plant spacing; Yield and yield component

INTRODUCTION

Chickpea (*Cicer arietinum* L.) belongs to the family Fabaceae, an annual and one of the important pull crops. Chickpea is one of the important pulse crops, which contains high protein and starch percentage, and it is very important for human nutrition. Chickpea suitable for region with warm weather and semi-dry conditions, in addition to having high-protein content (20–22%) and rich in fiber and minerals, and it is the fourth-largest grain legume crops in the world, with a total production of 10.9 million tons from an area of 12.0 million ha, a productivity of 0.91 t/ha. Major producing countries are India, Pakistan, and Iran (FAO, 2016). Chickpea being a leguminous crop improves soil fertility by fixing atmospheric nitrogen up to 99 kg/ha in available from NH_3 and NH_4 in the root through the phenomena of symbiosis (Schwenke et al., 1998). Among the various agronomic practices, plant density is one of the most important agronomic factors that have a great impact on growth and yield, high density initially provokes fast growth of canopy in area unit which, in turn, ejects available stored water in soil through

perspiration and causes the plant to encounter drought stress during flowering and grain filling stages; therefore, under rainfed conditions, suitable seed density must be considered for more absorption of solar energy and improved utilization of water and soil (ICARDA, 1990). The increased seed yield with higher plant density is largely due to improved water use and water use efficiency. The use of high plant density in chickpea production decreases soil water evaporation early in the growing season when plant canopy closure is low; in contrast, low plant density may allow weeds to develop more aggressively and limit crop yield potential. Plants grown at lower plant density are usually shorter and branchy, which increases losses during combine harvest (Turner et al., 2001). Seddique and Sedgely (1985) revealed that the branch number of chickpea is affected by plant density and, thus, chickpea has a lower branch in high densities. Therefore, it is possible to obtain the maximum grain yield by managing the planting density to increase the main stem number and reducing the branch number per unit area. Ali et al. (1999) reported that increase of plant spacing significantly increased the plant height, number of pods per plant and seed yield, and the

wider plant spacing of 15 cm produced greater number of pods per plant (81.7) followed by 10 and 5 cm plant spacing with 74.2 and 68.2 pods per plant, respectively, results further indicated that wider plant spacing 15 and 10 cm caused significantly higher yield of 16.2 and 14.2 g/plant, respectively. Cultivar and planting densities are important factors affecting the growth and grain yield of chickpea (Stieller et al., 1994). It has been reported that the density of 28 plant m^{-2} is the optimum density for chickpea cultivated under irrigated conditions in cold climates (Shams et al., 2005). Kanooni (2013) evaluated the grain yield of two chickpea genotypes in 25, 35, and 45 plant m^{-2} in a dryland farming system in the dry moderate region; in this research, the chickpea genotypes produced the highest grain yield in the density of 45 plant m^{-2} . According to Singh et al. (2011), more number of branches, number of pods per plant, 100 grains weight, and yield were produced by dense and semi-extensive varieties with low density together with high pod erect growing varieties with high density. The objective of this study is to reevaluate the response of three chickpea varieties to different plant spacing on yield, yield components, and some quality characteristics in Kurdistan region.

MATERIALS AND METHODS

A field study was conducted at the Grdarasha Research Station of the College of Agriculture/Salahaddin University, Erbil (latitude 36°4' N and longitude 44°2' E) 415 m above sea level having annual rainfall (250–600 mm) during growing winter season of 2017 to study the effect of plant spacing on yield and some quality characteristics of chickpea varieties.

The factorial experiment was applied in "Randomized Complete Block Design" (RCBD), in three replicates, by using four plant spacing (6, 9, 12 and 15 cm), and three varieties of chickpea (Rafedain, Gab and TH85) were implemented. The representative soil samples were taken from various locations of the field at depth of 0–30 cm after tillage. These samples were air-dried then sieved using 2 mm sieve, then packed for analysis.

An experimental unit size (2 m×2 m) was used consisting of six rows (with 30 cm row spacing). Sowing was done manually on the first of March and two seeds were placed in

each hole percentage germination of sowing depth of 3 cm and distributed according to plant density combination [Table 1]. Five plants were randomly selected from each experimental unit to study the quantitative characteristics: Plant height (cm), number of primary branches plant⁻¹, number of pods plant⁻¹, number of seeds pod⁻¹, and the 100 seed weight (g) and were calculated. All middle line plants of each experimental unit were harvested to calculate yield (kg/ha) and qualitative characteristics: Protein percentage, protein yield, oil percentage, and carbohydrate percentage.

The data were statistically analyzed for all of the studied traits according to the analysis of variance using the Statistical Analysis System (SAS Institute, 2005). Duncan's multiple range test at 5% level was used to determine among means (Steel and Torrie, 1997). Simple correlation coefficient was calculated between the seed yield and other traits, and among the traits themselves and simple regression among some studied traits (Al-Rawi, 1984).

RESULTS AND DISCUSSION

Number of Primary Branches Plants⁻¹

Table 2 shows the effect of plant spacing, varieties, and their interaction for components analysis of chickpea. The maximum no. of primary branch registers in 15 cm plant spacing (4.34) whereas the minimum was for 6 cm plant spacing which was (2.94). Among the various agronomic practices, plant density is one of the most important agronomic factors that have great impact on number of primary branches; Seddique and Sedgely (1985) revealed that the branch number of chickpea is affected by plant density and also Singh et al. (1988) have examined the effects of density on the number of branches and stated that the number of branches decreases with the increase in density. However, the different varieties, Gab variety obtained significantly higher number of primary branches followed by Rafedain variety. The highest value was at 15 cm plant spacing with Gab variety (4.66), but the lower value was recorded for Rafedain variety when planted at 6 cm (2.47).

Number of Pods/Plant

The results of number of pods plant⁻¹ are displayed in Table 2. A wide variation was observed in these results, the highest number of pods plant⁻¹ was at 15 cm plant spacing

Table 1: Plant density combinations (intrarow spacing)

Row spacing (cm)	Plant spacing (cm)	One plant area (cm ²)	Number of plants m ⁻²	Number of plants ha ⁻¹
30	6	180	55.55	555,555
30	9	270	37.03	370,370
30	12	360	27.77	277,777
30	15	450	22.22	222,222

(15.44), while the lowest number was recorded at 6 cm plant spacing which was 8.10. The maximum was for Gab variety 11.71, whereas the minimum was for Rafedain variety (10.85). Referring back to Table 2, there was no coincidence in the results of Gab variety when planted at 15 cm plant spacing which also gives the highest number of pods/plant (16.33), but the lowest was 7.33 for TH85 variety when planted at 6 cm plant spacing. From Table 3, there was a

positive and highly significant correlation between this trait and number of primary branches per plant ($r = 0.820^{**}$). From Figure 1a, the linear component showed a direct proportional relationship between number of primary branches per plant and the number of pods per plant according to the following equation ($\hat{Y} = 5.51X + 8.72$) which means an increase of one branch per plant result increase of number of pods per plant by 5.51 pod.

Table 2: Effect of plant spacing on yield and its component of chickpea varieties

Plant spacing (cm)	Number of primary branches plant ⁻¹	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	250 seed weight (g)	Seed yield (kg/ha)
6	2.94 ^d	8.10 ^d	1.07 ^c	49.89 ^d	913.58 ^d
9	3.46 ^c	9.14 ^c	1.18 ^c	56.56 ^c	968.51 ^c
12	3.77 ^b	12.40 ^b	1.34 ^b	60.21 ^b	1063.45 ^b
15	4.34 ^a	15.44 ^a	1.60 ^a	69.28 ^a	1124.33 ^a
Varieties	Number of primary branches plant ⁻¹	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	250 seed weight (g)	Seed yield (kg/ha)
Rafedain	3.29 ^c	10.85 ^c	1.35 ^a	49.18 ^c	985.79 ^b
Gab	4.07 ^a	11.71 ^a	1.31 ^{a,b}	68.18 ^a	1120.91 ^a
TH85	3.53 ^b	11.24 ^{a,b}	1.23 ^b	59.58 ^b	945.71 ^b
Plant spacing×Varieties	Number of primary branches plant ⁻¹	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	250 seed weight (g)	Seed yield (kg/ha)
6 Rafedain	2.47 ^h	8.44 ^d	1.18 ^{c,d,e}	42.92 ^g	938.89 ^c
6 Gab	3.55 ^{e,f}	8.55 ^d	1.02 ^{d,e}	57.20 ^d	946.33 ^{a,b}
6 TH85	2.81 ^{g,h}	7.33 ^e	1.00 ^e	49.55 ^e	1048.15 ^{a,b,c}
9 Rafedain	3.21 ^{f,g}	9.11 ^d	1.28 ^{b,c,d}	46.55 ^f	1136.51 ^{a,b}
9 Gab	3.82 ^{c,d,e}	8.99 ^d	1.18 ^{c,d,e}	64.77 ^c	1083.33 ^{a,b,c}
9 TH85	3.33 ^f	9.33 ^c	1.08 ^{d,e}	58.36 ^d	1076.18 ^{a,b,c}
12 Rafedain	3.44 ^{e,f}	11.55 ^c	1.36 ^{b,c}	48.49 ^e	718.52 ^d
12 Gab	4.22 ^{a,b,c}	13.66 ^b	1.34 ^{b,c}	68.81 ^b	1160.31 ^a
12 TH85	3.66 ^{d,e,f}	11.99 ^c	1.34 ^{b,c}	63.33 ^c	911.11 ^c
15 Rafedain	4.03 ^{b,c,d}	14.33 ^b	1.61 ^a	58.77 ^d	1077.03 ^{a,b,c}
15 Gab	4.66 ^a	16.33 ^a	1.70 ^a	81.96 ^a	1192.85 ^a
15 TH85	4.33 ^{a,b}	15.66 ^a	1.51 ^{a,b}	67.01 ^b	924.48 ^c

Means with the same letters are not significantly difference

Figure 1: (a-f) Regression among some studied characteristics

Number of Seeds/Pod

The number of seeds pod⁻¹ is displayed in Table 2 showing that the highest was recorded for the sample collected at 15 cm plant spacing (1.60), whereas the sample collected at 6 cm plant spacing (1.07) was statistically similar to 9 cm plant spacing (1.18). (Singh et al., 1988) reported that increase in density affects the number of grains per plant, causing it to decrease, but the number of grains per unit area is higher in high density than low ones. Many researchers believe that increase in yield is due to increase in the number of grains (Bagheri et al., 1997). The heights number of seed per pod was obtained by Rafidain variety (1.35). Considering the interaction between plant spacing and varieties, the highest was 1.70 for Gab variety at 15 cm plant spacing, but the lowest value was recorded from TH85 variety at 6 cm plant spacing (1.00).

250 Seed Weight (g)

Table 2 shows the highest 250 seed weight for 15 cm plant spacing which was 69.28 g, while the lowest weight was recorded at 6 cm plant spacing which was 49.89 g. However, the maximum rate of varieties was at Gab variety (68.18 g) and the minimum was at Rafedain (49.18 g). The highest interaction was recorded for the sample collected from Gab variety with 15 cm plant spacing (81.96 g), but the lowest was 42.92 g for Rafedain variety at 6 cm plant spacing.

Seed Yield (kg/ha)

Table 2 displayed seed yield performed that the highest was at 15 cm plant spacing (1124.33 kg/ha), while the lowest was at 6 cm plant spacing (913.6 kg/ha); this variation is due to when planting chickpea by wide plant spacing (15 cm) leads to increase 250 seed weight and number of seed/pod and consequently resulted to increase yield components [Tables 2 and 3]. The highest value was also for Gab variety (1120.91 kg/ha), but the lowest value was recorded for TH85 variety (945.71 kg/ha). These variations in results, in the samples, confirm that the interaction between plant spacing and varieties is different. The optimum value was at 15 cm plant spacing for Gab variety (1192.85 kg/ha), whereas the minimum was 12 cm plant spacing for Rafedain variety (718.52 kg/ha). From Table 3, there was a positive and highly significant correlation between this trait and number of pods per plant, number of seeds per pod, and 250 seed weight ($r = 0.673^{**}$, 0.689^{**} , and 0.659^{**}), respectively. From Figure 1b and c, the linear component showed a direct proportional relationship between seed yield with number of pods per plant and number of seeds per pod according to the following equations: $\hat{Y} = 28.0X + 701.9$ and $\hat{Y} = 406.7X + 497.5$, respectively, which indicate that for each increase of one pod per plant and one seed per pod will result in increase in seed yield by 28.0 and 4007 kg/ha for number of pods and number of seeds per pod, respectively.

Table 3: Correlation coefficient analysis among the traits of chickpea cultivars

	Number of primary branches/plant	Number of pods/plant	Number of seeds/pod	250 seed weight	Seed yield	Protein percentage	Protein yield	Oil percentage	Carbohydrate percentage
Number of primary branches/plant	1.000								
Number of pods/plant	0.820 ^{**}	1.000							
Number of seeds/pod	0.628 ^{**}	0.829 ^{**}	1.000						
250 seed weight	0.862 ^{**}	0.720 ^{**}	0.513 ^{**}	1.000					
Seed yield	0.683 ^{**}	0.673 ^{**}	0.689 ^{**}	0.659 ^{**}	1.000				
Protein percentage	0.668 ^{**}	0.530 ^{**}	0.560 ^{**}	0.610 ^{**}	0.397 [*]	1.000			
Protein yield	0.648 ^{**}	0.427 ^{**}	0.457 ^{**}	0.621 ^{**}	0.913 ^{**}	0.713 ^{**}	1.000		
Oil percentage	0.524 ^{**}	0.673 ^{**}	0.495 ^{**}	0.425 ^{**}	-0.60	0.426 [*]	0.119 ^{**}	1.000	
Carbohydrate percentage	-0.657 ^{**}	-0.727 ^{**}	-0.729 ^{**}	0.415 [*]	-0.254	-0.777 ^{**}	-0.507 ^{**}	-0.658 ^{**}	1.000

*and ** significance level at $P \geq 0.05$ and 0.01 respectively

Table 4: Effect of plant spacing on some quality characteristics of chickpea varieties

Plant spacing (cm)		Protein (%)	Protein yield (kg/ha)	Oil (%)	Carbohydrate (%)
6		19.11 ^d	175.43 ^c	7.81 ^d	60.91 ^a
9		22.18 ^b	249.35 ^a	8.80 ^c	59.59 ^b
12		21.74 ^c	210.32 ^b	10.42 ^b	59.23 ^c
15		23.12 ^a	247.19 ^a	11.81 ^a	58.13 ^d
Varieties		Protein (%)	Protein yield (kg/ha)	Oil (%)	Carbohydrate (%)
Rafedain		21.36 ^b	210.82 ^b	9.15 ^b	59.06 ^c
Gab		22.25 ^a	250.26 ^a	8.84 ^c	59.53 ^b
TH85		21.07 ^c	200.64 ^b	11.14 ^a	59.84 ^a
Plant spacing×Varieties		Protein (%)	Protein yield (kg/ha)	Oil (%)	Carbohydrate (%)
6	Rafedain	17.30 ^f	162.46 ^e	6.53 ^h	61.12 ^a
	Gab	20.84 ^d	225.76 ^{b,c,d}	8.33 ^g	60.43 ^b
	TH85	19.20 ^e	138.07 ^e	8.56 ^{f,g}	61.29 ^a
9	Rafedain	22.05 ^c	250.59 ^{b,c}	8.46 ^{f,g}	59.37 ^e
	Gab	22.20 ^c	257.57 ^b	8.70 ^f	59.26 ^e
	TH85	21.75 ^d	239.88 ^{b,c,d}	9.23 ^e	60.15 ^c
12	Rafedain	22.21 ^c	210.19 ^{c,d}	9.30 ^e	58.62 ^f
	Gab	21.04 ^d	626.00 ^d	8.70 ^f	59.83 ^d
	TH85	21.98 ^c	200.24 ^d	13.26 ^b	59.26 ^e
15	Rafedain	23.88 ^b	220.04 ^{b,c,d}	12.30 ^c	57.15 ^g
	Gab	24.93 ^a	297.16 ^a	9.63 ^d	58.59 ^f
	TH85	20.83 ^d	220.65 ^{b,c,d}	13.50 ^a	58.66 ^f

Means with the same letters are not significantly difference

Protein (%)

Table 4 shows the protein percentage which was the maximum level of 15 cm plant spacing which was 23.12% and the minimum was 6 cm plant spacing that was 19.11%; this result is agreed with Valimohamadi et al., 2009, pointed out that at higher plant populations, competition for photoassimilates due to nitrogen deficiency caused reduction in protein content and Gab variety has the highest rate (22.25%), whereas the interaction between plant spacing and varieties, the maximum rate was also at 15 cm plant spacing with Gab variety which was 24.93% and the minimum was at 6 cm plant spacing with Rafedain variety that was 17.30%.

Protein yield (kg/ha)

The protein yield kg/ha is displayed in Table 4 shows that the highest level was observed at 9 cm plant spacing and 15 cm plant spacing which was 249.35 kg/ha and 247.19 kg/ha respectively, while the maximum rate of varieties was at Gab variety (250.26 kg/ha) and the minimum was at Rafedain and TH85 that were 210.82 kg/ha and 200.64 kg/ha, respectively. The plant spacing with varieties recorded the highest rate of protein yield interaction which was at 15 cm plant spacing with Gab variety. From Table 3, there was a positive and highly significant correlation between this trait and seed yield ($r = 0.913^{**}$). From Figure 1d, the linear component showed a direct proportional relationship between seed yield and protein yield according to the following equation ($\hat{Y} = 0.212X + 5.31$) which means that an increase of 1 kg/ha in seed yield will result in increase in protein yield by 0.212 kg/ha.

Oil (%)

Table 4 displayed the oil percentage that obtained the maximum 15 cm plant spacing which was 11.81% and the minimum was at 6 cm plant spacing which was 7.81%; on the other hand, the optimum oil percentage was at TH85 variety (11.14%). The highest Value of oil% was obtained at 15 cm plant spacing with TH 85 variety which was (13.50 %) and the lowest was at 6 cm plant spacing with Rafidain variety that was (6.53 %).

Carbohydrate (%)

The highest level of carbohydrate percentage was at 6 cm plant spacing that was 60.91% and the minimum was at 15 cm plant spacing which was 58.13%, while the highest rate was TH85 variety which was 59.84%. The optimum rate of interaction between plant spacing and varieties was at 6 cm plant spacing with TH85 variety that was 61.29% which was statistically similar to 6 cm plant spacing with Rafedain variety which was 61.12% and the minimum was at 15 cm plant spacing with Rafedain variety that was 57.15%. From Table 3, there was a negative and highly significant correlation between this trait and protein and oil percentages ($r = -0.777^{**}$ and -0.658^{**}). Furthermore, Figure 1e and f showed the linear component revealed an inversely proportional between carbohydrate percentage with protein percentage and oil percentage according to the following equations: $\hat{Y} = -0.63X + 73.1$ and $\hat{Y} = -0.62X + 65.5$ for protein and oil percentages, respectively, which indicate that the reduction of protein percentage and oil percentage one degree, it leads to increase in carbohydrate percentage by 0.63% and 0.62%, respectively.

CONCLUSION

The result showed that the 15 cm plant spacing has highly positive direct effect of number of primary branches, number of pods per plant, seed yield, protein percentage, protein yield, and oil percentage. Furthermore, the Gab variety gave the top value of number of primary branches, number of pods per plants, seed yield, protein percentage, and protein yield. Then, the interaction between 15 cm plant spacing and Gab variety gave optimum seed yield. However, the 6 cm plant spacing appeared highly carbohydrate percentage; the TH85 variety gave the optimum rate of oil percentage and carbohydrate percentage.

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