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Effect of Plant Density on Yield Components and Yield of Kabuli Chickpea (*Cicer arietinum* L.) Varieties at Debre Zeit, Central Ethiopia

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Authors' contributions

This work was carried out in collaboration between all authors. Author MS designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author TT managed the literature searches, analyses of the study and performed the spectroscopy analysis. Author FA managed the experimental process and identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

Variety- and location-specific plant density recommendation is one of the agronomic practices used to increase the production and productivity of chickpea. However, there is a blanket recommendation across locations and varieties of chickpea in Ethiopia. Hence, field experiment was carried out from September 4, 2012 to January 25, 2013 to determine the response of kabuli chickpea (*Cicer arietinum* L.) varieties to plant spacing at Debre-Zeit, Central Ethiopia. Factorial combinations of three kabuli chickpea varieties (Acos Dubie, Chefe and Ejeri), three inter-row spacing (20, 30 and 40 cm) and two intra-row spacing (10 and 15 cm) were laid out in randomized complete block design with three replications. As inter and intra-row spacing increased, the number of pods plant^{-1} was significantly increased whereas biological and seed yield were significantly decreased. Similarly, the main effect of variety showed a significant difference on number of pods plant^{-1} and hundred seed weight. Moreover, the interaction of variety and inter-row spacing were significant on harvest index. The highest seed yield (2340.33 kg ha^{-1}) was obtained at 20 cm inter-

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row spacing whereas 40 cm inter-row spacing gave the lowest (1619.16 kg ha^{-1}). Similarly, 10 cm intra-row spacing had the higher (2081.65 kg ha^{-1}) seed yield as compared to 15 cm intra-row spacing (1758.32 kg ha^{-1}). This result showed that kabuli chickpea varieties can be planted at inter-row spacing of 20 cm and intra-row spacing of 10 cm in Debre-Zeit area to attain maximum yield instead of previously used plant density (33 plants m^{-2}).

Keywords: Ethiopian chickpea varieties; inter-row spacing; intra-row spacing.

1. INTRODUCTION

Chickpea [*Cicer arietinum* (L.)] is the most widely grown pulse crops in Ethiopia, where the whole seeds are eaten fresh, roasted or boiled. Despite its uses, the productivity of the chickpea in Ethiopia under farmers condition is low (1.73 t ha^{-1}) [1] as compared to the potential yield of the crop under improved management conditions (3.5 t ha^{-1}). In Ethiopia, a number of limiting factors contribute to the low productivity of chickpea. The major constraints are low yield potential of landraces and their susceptibility to biotic and abiotic stresses, and poor cultural practices [2]. Lack of variety- and location-specific plant density recommendation is the major limitations of cultural practices for chickpea production in Ethiopia.

Production and productivity of the crop is governed by environmental conditions, genotypic trait and management of the crop. Determining appropriate crop density is therefore the management activities which improves the performance and productivity of plants. However, plant density of chickpea depends on variety and plant habit. Compact, upright-growing plants responded better to increased plant density than the spreading type [3]. [4] compared the results of plant density experiments involving two varieties, one desi (BDN 9) and another kabuli (L 550) and concluded that a spacing of 30 cm x 10 cm for desi type and 45 cm x 15 cm for kabuli type was optimum. The optimum plant population depends also on the environmental conditions under which the crop is grown. In India, a population of 33 plants m^{-2} appears to be the best [5]. In Canada, yield increment was recorded with an increase in population up to 55 plants m^{-2} [6].

However, 30 cm inter-row spacing and 10 cm intra-row spacing is used for both kabuli and desi type chickpea in Ethiopia [7]. Thus, there is no site and variety specific recommendation on the plant spacing of chickpea varieties in Ethiopia. In view of the above facts, the present investigation was undertaken. Therefore, the objective of this study was to determine the response of plant spacing on yield components and yield of kabuli chickpea varieties.

2. MATERIALS AND METHODS

The experiment was conducted using randomized complete block design with three replications in a factorial combination of three kabuli chickpea varieties, three inter-row spacing (40, 30 and 20 cm) and two intra-row spacing (15 and 10 cm) at Debre-Zeit Agricultural Research Center (DZARC), located 8° 44' N latitude and 38° 58' E longitude with annual rainfall of 871 mm on 2012/2013. The soil of DZARC was very fine clay [8]. The kabuli chickpea varieties used in the study were Acos Dubie, Ejeri and Chefe released in the year of 2009, 2005 and 2004, respectively. Plots having 40, 30 and 20 cm inter-row spacing accommodated 6, 8 and 12 rows, respectively, from which the middle 4, 6 and 10 rows were harvested for data source. Gross plot size was 2.4 m x 3 m (7.2 m^2). Spacing of 0.6 m and 1 m were allocated between plots and blocks, respectively.

Sowing was done on September 4, 2012 by putting two seeds per specified intra row spacing and thinning to one plant after planting. Harvesting took place when the foliage, stem and pods color of plant changed to golden brown and fully dried on January 25, 2013.

Number of pods plant^{-1} was recorded on 10 randomly taken plants from each plot. Hundred seed weight was determined by weighing 100 randomly taken dry seeds in each plot whereas biological and seed yield was recorded on plot basis leaving the side rows as non-experimental. Harvest index was computed as the ratio of seed yield to biological yield. Data were subjected to analysis of variance (ANOVA) using SAS software Version 9.20 [9] and mean separations were done using Least Significance Difference test at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Number of Pods Plant^{-1}

Analysis of variance showed that varieties highly significantly differed ($P < 0.01$) for number of pods plant^{-1} (Appendix Table 1). The highest number of pods plant^{-1} was recorded for variety Chefe followed by variety Ejeri while the lowest number of pods plant^{-1} was recorded for variety Acos Dubie (Table 1). The differences in the number of pods plant^{-1} might have been caused due to varietal differences. In line with this result, [2] reported significant differences among genotypes of chickpea for the number of pods plant^{-1}.

Number of pods plant^{-1} was also significantly affected by inter and intra-row spacing (Appendix Table 1). The number of pods plant^{-1} increased with increasing inter and intra-row spacing (Table 1). The highest numbers of pods plant^{-1} in wider inter and intra-row might be due to low competition of plants in the field which facilitated more aeration, greater light interception and more photosynthetic activity plant^{-1}. Similarly, [10] reported significant increase in number of pods plant^{-1} with increasing inter and intra-row spacing of chickpea.

3.2 Biological Yield

Biological yield was not significant due to the main effects of variety (Appendix Table 1). The decrease in biological yield of variety Acos Dubie due to low branching habit might have been compensated by the increase in other parameters such as plant height and stem thickness. This might be the reason for the non-significant difference in biological yield among the varieties. In agreement with this, [11] reported non-significant differences of the biological yield among varieties of chickpea.

The analysis of variance revealed that biological yield had a highly significant effect ($P < 0.01$) due to the main effect of inter and intra-row spacing (Appendix Table 1). As inter and intra-row spacing increased, the biological yield decreased (Table 1). The increase in biological yield due to the favor of population did not compensate the increase in biological yield due to the favor of spacing and eventually the biological yield increased with increased plant population. This might be the reason for the increase in biomass yield with decreased inter-row spacing. Similar result was obtained by [12] who reported that narrow inter-row spacing (30 cm) produced the highest biological yield as compared to wider inter-row spacing (45 cm and 60 cm) on mungbean varieties.

3.3 Hundred Seed Weight

The result of the experiment indicated that varieties had highly significant differences ($P < 0.01$) on hundred seed weight (Appendix Table 1). The highest hundred seed weight was recorded for variety Acos Dubie followed by variety Ejeri whereas the lowest hundred seed weight was recorded for variety Chefe (Table 1). This result was in accordance with [11] and [13] who reported significant differences among genotypes of chickpea on hundred seed weight. However, the main effects of inter and intra-row spacing showed non-significant differences on hundred seed weight (Appendix Table 1).

3.4 Seed Yield

Varieties showed a non-significant effect on the seed yield of chickpea (Appendix Table 1). However, relatively lower yield was recorded for variety Acos Dubie as compared to varieties Chefe and Ejeri (Table 1). This might be due to low branching habit and low number of pods per plant for the variety Acos Dubie.

The analysis of variance showed that the main effects of inter and intra-row spacing had a highly significant effect ($P < 0.01$) on seed yield of kabuli chickpea varieties (Appendix Table 1). The highest average seed yield was recorded in 10 cm intra and 20 cm inter-row spacing while the lowest yield was recorded in 15 cm intra and 40 cm inter-row spacing (Table 1). In line with this result, [14] reported that high plant density gave higher seed yield as compared to low plant density in chickpea. The lowest seed yield in wider inter and intra-row spacing might be due to the relatively inefficient utilization of available resources (light, space and nutrients) per unit area as compared to narrow spacing. For instance, [15] justified that when soil moisture and nutrients are not limited, higher density is necessary to utilize other growth factors (solar radiation efficiency) of chickpea.

3.5 Harvest Index

Analysis of variance on the harvest index indicated that the interaction effect of variety and

Table 1. Number of pods plant^{-1}, biological yield, hundred seed weight and seed yield as affected by the main effects of variety, inter and intra-row spacing

Treatments	No of pods plant^{-1}	Biological yield (kg ha^{-1})	Hundred seed weight (g)	Seed yield (kg ha^{-1})
		Variety		
Acos Dubie	17.12c	3047.90	63.53a	1821.77
Chefe	27.59a	3454.82	34.08c	1911.50
Ejeri	24.88b	3427.93	37.84b	2026.68
LSD (5%)	1.58	ns	1.42	ns
		Inter row spacing (cm)		
20	21.33b	3863.23a	44.45	2340.33a
30	23.89a	3167.55b	45.37	1800.45b
40	24.38a	2899.88b	45.62	1619.16b
LSD (5%)	1.58	398.51	ns	250.89
		Intra row spacing (cm)		
10	22.34b	3599.85a	45.08	2081.65a
15	24.06a	3020.58b	45.22	1758.32b
LSD (5%)	1.29	325.38	ns	204.85

Means in the same column for a factor followed by different letters are significantly different according to LSD test at 5% probability level; ns=non-significant

inter-row spacing were highly significant ($P < 0.01$) (Appendix Table 1). Variety Chefe at 20 cm inter-row spacing gave the highest harvest index value and same variety at 40 cm inter-row spacing gave the lowest harvest index (Table 2). The increased harvest index of variety Chefe with decreased inter-row spacing was consistent with [16] who reported that chickpeas were most responsive to increased population for harvest index. However, the harvest index of varieties Acos Dubie and Ejeri showed a non-significant difference due to inter-row spacing.

Table 2. Harvest index as affected by the interaction of variety and inter-row spacing

Inter-row spacing (cm)	Variety		
	Acos dubie	Chefe	Ejeri
20	58.32ab	63.33a	60.13ab
30	58.76ab	51.74cd	59.91ab
40	62.42a	48.16d	57.09bc
LSD(5%)		5.38	

Means in rows and columns followed by different letters are significantly different according to LSD test at 5% probability level

Table 3. Harvest index as affected by the main effects of intra-row spacing

Intra-row spacing (cm)	Harvest Index (%)
10	57.84
15	57.67
LSD (5%)	ns

ns: non-significant

Significant differences on harvest index among varieties were observed at 30 and 40 cm inter-row spacing but a non-significant difference among varieties was recorded at 20 cm inter-row spacing. For instance, [17] reported a significant effect of the interaction of cultivar and plant densities on harvest index of white bean (*Phaseolus vulgaris* L.). However, the effect of intra-row spacing on the harvest index was not significant (Appendix Table 1 and Table 1).

4. CONCLUSION

The result of this study showed higher seed yields of kabuli chickpea varieties were associated with narrow inter and intra row spacing. The seed yield was increased by 30.81% and 15.53% as inter and intra-row spacing decreased from 40 to 20 cm and 15 to 10 cm, respectively. Hence, it can be concluded that 20 cm inter and 10 cm intra row spacing is appropriate for maximum light interception and photosynthetic activity and seed yield of kabuli chickpea varieties in Debre-Zeit and similar areas in the country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix Table 1. Mean squares of analysis of variance for number of pods plant-1, biological yield, hundred seed weight, seed yield and harvest index (F value)

		Mean squares				
Source of variation	**df**	**N_0 of pods plant^{-1}**	**Biological yield**	**Hundred seed weight**	**Seed yield**	**Harvest index**
Replication	2	8.68^{ns}	50664.03^{ns}	1.31^{ns}	158444.94^{ns}	81.28^{*}
Variety	2	531.76^{**}	932177.61^{ns}	4622.34^{**}	189916.68^{ns}	154.58^{**}
Inter-row	2	48.37^{**}	4450958.72^{**}	6.85^{ns}	2533272.15^{**}	111.88^{**}
Intra-row	1	40.21^{*}	4529992.77^{**}	0.28^{ns}	1411324.13^{**}	0.36^{ns}
Variety*Inter-row	4	2.52^{ns}	11694.73^{ns}	5.88^{ns}	195151.70^{ns}	156.31^{**}
Variety*Intra-row	2	12.70^{ns}	241275.89^{ns}	0.08^{ns}	118890.07^{ns}	18.86^{ns}
Inter-*Intra-row	2	1.26^{ns}	302317.10^{ns}	0.48^{ns}	99285.06^{ns}	29.98^{ns}
Variety*Inter-*Intra-row	4	7.93^{ns}	420582.05^{ns}	2.18^{ns}	91942.97^{ns}	15.31^{ns}
Error	34	5.44	346073.62	4.37	137167.63	18.84
CV (%)		10.06	17.77	4.63	19.29	7.52

** and ** significant at P < 0.05 and P < 0.01, respectively; ns = non-significant; CV= coefficient of variation; df= degree of freedom*

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