



Response of Chickpea (*Cicer arietinum* L.) Genotype to Intra and Inter Row Spacing at Huleteegna Choroko, Southern Ethiopia

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Abstract: Chickpea has a major role in the daily diet of the rural community and urban population as a good source of energy, protein, minerals, vitamins, fiber and its straw is used for animal feed, and it also improves soil fertility by fixing the atmospheric nitrogen. Optimum plant density and appropriate genotypes for a given agro ecology influences plant size, yield components and ultimately the seed yield. Hence, a field experiment was carried out to determine the effect of intra and inter-row spacing on growth, yield and yield component of chickpea (*Cicer arietinum* L.) Genotypes under rain fed condition in Huleteegna Choroko, Southern Ethiopia in 2016 cropping season. A split-split plot design with three replications was used with two chickpea genotypes: Genotypes Habru and Mastewal were arranged in main plot and intra-row spacing of 5, 10 and 15 cm in sub-plot and inter-row spacing's of 30, 40 and 50 cm in sub-sub plot. Days to flowering and hundred seed weight were significantly different between the two genotypes. Intra-row spacing had significantly affected physiological maturity, nodule dry weight plant⁻¹, plant height, primary branch plant⁻¹, pods plant⁻¹, seeds pod⁻¹, above ground biomass and seed yield. Inter row spacing also significantly affected days to flowering, days to physiological maturity, nodule number plant⁻¹, nodule dry weight, plant height, primary branch, pod plant⁻¹, seed number pod⁻¹, above ground dry matter and seed yield. Mastewal genotype obtained the maximum (2.91 t ha⁻¹) grain yield at the combination of 15 cm intra row and 30 cm inter row spacing while Habru genotype obtained (2.57 t ha⁻¹) at the same intra and inter-row spacing. Finally it could be concluded that intra row spacing of 15 cm and inter row spacing of 30 cm were found to be the optimum for maximum grain yield of chickpea using genotype Mastewal and Habru at Halaba, Huleteegna choroko.

Keywords: Chickpea, Intra Row, Inter Row, Spacing, Split Split Plot, Genotypes

1. Introduction

In Ethiopia, chickpea is mainly grown in the central, northern and eastern highland areas of the country at an altitude of 1400-2300 m.a.s.l., where annual rainfall ranges between 700 and 2000 mm [5]. Chickpea, locally known as *shimbra*, is one of the major pulse crops (including faba bean, field pea, haricot bean, lentil and grass pea) and in

terms of production, it is the second most important legume crop after faba beans [27].

The crop has a major role in the daily diet of the rural community and poor sectors of urban population and its straw is used for animal feed. Chickpea also fetch good price when sold in local market and hence generate cash to farmers. Moreover, the crop is being exported to Asia and Europe contributing positively to the country's foreign exchange earnings. The high nutritive value of chickpea can be judged by the fact that it

contains 20% protein, 5% fats and 55% carbohydrates. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen and it meets up to 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg N ha⁻¹ from air. Because of its deep tap root system, chickpea can withstand drought conditions by extracting water from deeper layers in the soil profile [19].

Even though chickpea has a number of uses, the productivity of the crop in Ethiopia under farmers condition is low (1.73 t ha⁻¹) [14] as compared to its potential yield of the crop under improved management conditions (3.5 t ha⁻¹). Access to inputs, low soil fertility and biotic constraints are the major factors currently limiting crop productivity in Ethiopia [33]. Also, constraints include low yield potential of landraces and their susceptibility to biotic and abiotic stresses, and poor cultural practices [26].

Plant density is one of the important characters, which can be manipulated to obtain the maximum production from per unit land area. The optimum plant density with proper geometry of planting depends on genotype, its growth habit and agro climatic conditions. The seed yield of chickpea is highly dependent on plant population [8]. Seed yield increases with increased plant density up to an optimum, which changes according to genotype. Plant density is very important to facilitate aeration and light penetration in to plant canopy for optimizing rate of photosynthesis [22]. Too high or too low plant densities can reduce grain yields as high densities use too much of the available soils nutrients early in the season and low densities do not fully exploit the available nutrients. Among the many yield limiting factors under farmers practice in Huleteegna Choroko; plant population and selecting genotype are important. Due to lack of recommendations on inter and intra row spacing of chickpea genotypes at specific area, plant populations on farmers' fields appear lower or higher than the optimum. As a result very low yield is obtained. Hence, this study was initiated with the purpose of determining optimum planting density and spacing for chickpea production at Huleteegna Choroko Southern Ethiopia.

The specific objectives of the study were to:

- 1) Assess the effect of inter and intra-row spacing on growth, yield and yield components of chickpea under rain fed condition at Huleteegna choroko.
- 2) Evaluate the possible interaction of genotype in response to different inter and intra row spacing.

2. Materials and Methods

2.1. Description of Study Area

The experiment was conducted during the 2016 cropping season from August to December at farmer's field of Halaba special woreda, Huleteegna Choroko in southern nation nationality people region (SNNPR). The kebele is located 315 km south west of Addis Ababa in the coordinates of 7°17' N latitude and 38°06' E longitude with an altitude 1797 m.a.s.l. The average annual rainfall of the area over a decade

was 952.5 mm with a range of 710.2 to 1177.9 mm while the annual temperature ranges from 13.2°C to 29.4°C.

2.2. Experimental Design and Treatments

The experiment was laid out in split-split plot design with chickpea genotypes Habru and Mastewal in main plots, intra-row spacing of 5, 10 and 15 cm in sub-plots and inter-row spacing's of 30, 40 and 50 cm in sub-sub plots, which have three replications. The sub sub-plot sizes were 3.6 m x 3 m (10.8 m²). The total experimental area was 24 m x 36.4 m (873.6 m²). The plot size was uniform for all treatments and the number of rows and number of plants per row were assigned based on the experimental treatments. All agronomic practices (fertilizer application, weeding, and etc.) were done equally for each plot.

2.3. Agronomic Data Collection

2.3.1. Crop Phenology

Days to flowering were determined as the number of days after seedling emergence to the period when 50% of the plants in a plot developed first flower. Days to maturity was taken as the number of days after seedling emergence to the period when 90% of the plants in a plot were ready for harvest as revealed by change in the foliage and pod colour and seed hardening in the pods.

2.3.2. Growth and Nodulation

Plant height was recorded at physiological maturity by measuring the main stem height from the ground up to the canopy height using a ruler from randomly selected five plants. Number of primary branches was counted from randomly selected five plants and the average for each treatment was recorded. Nodulation assessment was conducted at mid flowering stages. Five plants were selected from the second rows of left and right side and gently uprooted after it was excavated. The root was washed with tap water to remove the adhering soil and the number of nodules plant⁻¹ was counted and the values averaged to give the number of nodules plant⁻¹. In addition, the severed nodule from the roots, were oven dried at 70°C for 48 hours and their dry weight recorded to give nodule dry weight plant⁻¹.

2.3.3. Yield and Yield Components

Data on number of pods plant⁻¹ and seeds pod⁻¹ were recorded from 5 randomly selected plants in each plot and average number plant⁻¹ were recorded. The average number of seed per pod was recorded from 20 randomly selected pods taken from five randomly selected plants. The grain yield and above ground biomass was measured from three central rows. The harvested biomass were sun dried and thereafter its dry matter yield ha⁻¹, 100 seed weight and grain yield ha⁻¹, were measured using weighing balance and calculated on hectare basis.

2.4. Statistical Analysis

Results were evaluated by analysis of variance using the

Statistical Analysis System (SAS 9.1) software [32] and mean separation was performed by Fisher's least significant difference (LSD) test when F test was significant at $P < 0.05$ [15].

3. Results and Discussion

3.1. Days to Flowering

There was significant difference between the two genotypes on days to flowering ($p < 0.001$). The mean value indicated that for days to flowering of chickpea genotype in this study ranged from 63 to 65 days (Table 1). Longer duration was observed in Habru (65 days) genotype and a shorter one was observed in Mastewal (63 days) genotype. This means that the duration of the time required for flowering of the genotype Mastewal was earlier in 1.72 days than genotype Habru. This might be attributed to the fact that days to flowering in chickpea are considered to be varietal characteristics, which is genetically controlled. Earlier studies showed that, the differential response to flowering among genotype was different. [45] reported differences among genotypes of chickpea in days to flowering. Intra-row spacing did not significantly influence days to flowering.

Inter-row spacing had significant ($p \leq 0.001$) effect on days to flowering. The lowest (64.00 days) and the highest (65.67 days) number of days to flowering was achieved at 30 and 50 cm inter-row spacing, respectively. This can be described by the fact that as inter-row spacing increases, number of days to flowering of chickpea was delayed since the vegetative growth of the wider spacing was vigorous and prolonged due to the absence of high competition for resource and no stress effect. The interaction effect of both two ways as well as three ways on days to flowering was non-significant.

Table 1. Effect of intra and inter-row spacing on phenology of chickpea genotype.

Treatments	Days to Flowering	Days to Maturity
Genotype		
Habru	65.44a	115.3
Mastewal	63.82b	113.6
CV (%)	2.01	1.48
LSD ($p < 0.05$)	1.52	NS
Intra-row spacing (cm)		
5	64.39	113.72b
10	64.89	114.61a
15	64.61	115.10a
CV (%)	1.36	0.94
LSD ($p < 0.05$)	NS	0.82
Inter-row spacing (cm)		
30	64.00b	113.61b
40	64.22b	113.78b
50	65.67a	116.00a
CV	1.4	0.9
LSD	0.64	0.73

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance, whereas the opposite is true for different letters.

3.2. Days to Physiological Maturity

Data collected for days to physiological maturity indicated that there were no significant differences between the genotypes. [45] reported that there was a difference among genotypes of chickpea in time to physiological maturity.

Intra-row spacing had a significant effect on days to physiological maturity. The lowest (113.72 days) and the highest (115.10 days) number of days to physiological maturity were recorded at 5 and 15 cm intra-row spacing, respectively. The hastened days to maturity in the case of narrower intra row spacing could be because of high competition for available resources in the soil, poor light interception in the canopy as compared to the wider intra row spacing as a result plants were enforced to complete its life cycle in the short period of time. This result was in accordance with [46] who reported a steady increase in the number of days to maturity of chickpea with increased intra-row spacing of 7.5, 10 and 15 cm.

Days to physiological maturity was significantly ($p \leq 0.001$) influenced by inter-row spacing. The time required for maturity of chickpea in the present study ranged from 113.61 – 116.00 days (Table 1). The shortest (113.61 days) days to physiological maturity was achieved in 30cm of inter-row spacing which is statistically similar with 40 cm inter-row spacing. The longer duration (116 days) of maturity for inter-row spacing was obtained in 50 cm spacing. A steady increase in number of days to maturity took place with decreasing inter-row spacing (Table 1). These results are in agreement with [46] in chickpea. [18] also reported that decrease in days to physiological maturity by two days with increasing population density of chickpea from 20 to 50 plants m^{-2} on the Canadian prairies.

Table 2. Interaction effect of genotype and inter-row spacing on physiological maturity.

Genotype	Inter row spacing (cm)			Mean
	30	40	50	
Habru	115.11ab	114.22b	116.55a	115.29
Mastewal	112.11c	113.33bc	115.44ab	113.63
CV (%) = 0.93				
LSD ($P < 0.05$) = 1.67				

Means followed by the same letters are not significantly different from each other at 5% level of significance.

3.3. Plant Height

The response of genotype to plant height was found to be non-significant ($P < 0.05$). However, [35, 13, 30] reported that significant differences among the genotypes of chickpea in plant height.

Plant height was significantly affected by intra-row spacing. Maximum plant height (58.9 cm) was recorded in 5 cm intra-row spacing, which was followed by 10 cm spacing (53.8 cm). The shortest plant height (53.6 cm) was recorded in 15 cm spacing, which is not significantly different to 10 cm intra-spacing. In this study, plant height was taller in higher plant population treatments and could be justified on

the basis of increase in the number of plants per unit area causing high plant-to-plant competition for light, water and nutrient within row. In addition to this under close intra row spacing, the space for plant spreading was less and hence plant height increased significantly. Similar observations have been made by [24, 36] who observed plant height increase with high densities.

Effect of inter-row spacing on plant height was statistically found to be significant ($P < 0.05$). Maximum plant height (58.9 cm) was recorded in 30 cm spacing between rows, and followed by 40 cm spacing with 54.3 cm plant height while the lowest plant height (53.2 cm) was recorded in 50 cm spacing. The plant height was increased as the row spacing reduced (Table 3). With reducing row spacing the plant population per unit area was increased. Through increasing of plant density, the competition between plants for radiation interception is

usually elevated which can lead to elongation of internodes. In line with this result [21] also stated that, high population in narrow row spacing for early maturing genotypes potentially increase plant growth, as they are able to utilize environmental factors more effectively. However, [31] had reported that non-significant effects of row spacing on plant height of chickpea. The effect of genotype and inter-row spacing interaction on plant height was found to be significant. The shortest plant height (51.2 cm) was obtained in Mastewal genotype planted at 50 cm spacing and the tallest plant (59.31 cm) was noticed at narrowest spacing of 30 cm (Figure 1). This result might be due to the fact that as the spacing among plants decreased the interplant competition for light increased while sparsely populated plants intercepted sufficient sunlight that enhanced the lateral growth.

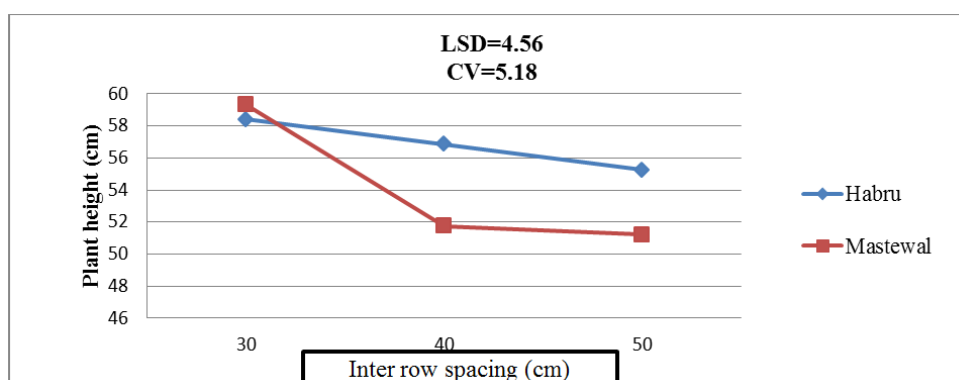


Figure 1. Interaction effect of genotype and inter-row spacing on plant height of chickpea.

3.4. Number of Primary Branch Plant⁻¹

Result on number of primary branch plant⁻¹ shows that there were no significant differences between genotypes. In line to this result [34] stated that the number of branches was not affected by genotype. Similarly, [4] also stated that there were no significant differences between genotypes for primary branch. In contrast with this, significant variations in number of primary and secondary branches plant⁻¹ among the different genotypes of chickpea were reported by [3, 40].

The data in Table 3 revealed that intra-row spacing had significant ($p > 0.001$) effect on number of primary branches plant⁻¹. The number of branches plant⁻¹ decreased with decreasing intra-row spacing. The treatments sown at 15 cm intra-row spacing produced the maximum branches (6.4) and it differed significantly from 5 cm and 10 cm intra-row spacing plant⁻¹. The minimum number of branches plant⁻¹ (4.4) was recorded from the treatments sown at the intra-row spacing of 5 cm (Table 3). The decrease in intra-row spacing resulted in more plants per unit area and hence less number of branches plant⁻¹ due to more competition for nutrients, light, water and air. [36] Stated that the numbers of branches plant⁻¹ were significantly affected by different seed rates. [13] Obtained that primary branches increased when population density decreased in which the highest value, 2.75 branches plant⁻¹ was observed at the lowest population density which was 300,000 plants ha⁻¹. The increment of branch number in

this study was 12.73% as spacing changed from 5 to 15 cm.

The result in (Table 3) indicated that inter-row spacing had a significant effect on number of primary branches plant⁻¹. The number of branches plant⁻¹ increase with increase in inter row spacing. The plot sown at inter row-spacing of 50 cm produced the maximum branches (5.94) and did not differ statistically from 40 cm (5.33). The minimum number of branches plant⁻¹ (4.83) was recorded from the plots sown at the inter-row spacing of 30 cm, which was not significantly different from 40 cm inter-row spacing. The results showed that, wider spaced plants produced the greatest number of primary branches. As indicated earlier, wider spacing means less competition among plants for growth resources such as water, nutrients and solar radiation. This would mean more assimilates would be available to growth, and hence, greater allocation for more branching. This observation is in agreement with the report of [11] who indicated that plants in wider row spacing are capable of partitioning more resources to increase branch number in response to plant density. When inter-row spacing was shifted from 30 cm to 50 cm inter-rows, the average primary branch was increased by 6.89%. [2] and [29] reported that reduction in the number of branches with increasing plant density is probably due to the intensified competition between adjacent plants and reduce light penetration into the plant canopy preventing growth of buds that making branches.

Table 3. Effect of intra and inter-row spacing on growth and nodulation of chickpea genotype at Huletegn choroko.

Treatments	Plant height(cm)	Number of 1 ⁰ branch plant ⁻¹	Nodule number plant ⁻¹	Nodule dry weight plant ⁻¹ (g)
Genotype				
Habru	56.83	5.26	11.09	0.034835
Mastewal	54.09	5.48	12.92	0.043364
CV (%)	5.15	15.82	22.44	24.53
LSD	NS	NS	NS	NS
Intra-row spacing (cm)				
5	58.92a	4.39b	10.83	0.024234b
10	53.80b	5.28b	12.14	0.048756a
15	53.66b	6.44a	13.03	0.044308a
CV (%)	7.89	24.89	23.19	18.08
LSD	3.3663	1.0276	NS	0.0055
Inter-row spacing (cm)				
30	58.86a	4.83b	13.63a	0.0374b
40	54.30b	5.33ab	11.99ab	0.0359b
50	53.22b	5.94a	10.39b	0.0448a
CV (%)	5.17	21.28	21.19	13.14
LSD	1.9746	0.7861	1.7496	0.0035

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance, whereas the opposite is true for different letters.

3.5. Nodule Number Plant⁻¹

Nodule number plant⁻¹ between chickpea genotype and among intra-row spacing was not significantly different. The average number of nodule number plant⁻¹ for intra-row spacing was increased as intra-row spacing increased from the narrower to the wider spacing, but there was no significant difference among them. Inter-row spacing had significant ($p < 0.001$) effect on mean nodule number plant⁻¹. The lowest number of nodule plant⁻¹ (10.39) was obtained in 50 cm inter-row spacing and the highest (13.63) was obtained in 30 cm inter-row spacing (Table 3). Similarly, [48] found that the lowest number of nodule plant⁻¹ (6.85) was observed from the highest population density (30 cm inter row spacing) of chickpea crop. The interaction effects between genotype, intra-row and inter-row spacing on mean number of nodule per plant was non-significant

3.6. Nodule Dry Weight Plant⁻¹

Dry weight of nodule plant⁻¹ in chickpea was not significantly influenced by genotype. The Nodule dry weight was significantly influenced by intra-row spacing ($p < 0.001$). The maximum value of nodule dry weight plant⁻¹ for intra-row spacing was obtained at 10 cm (0.0488 g) spacing which is at par with 15 cm (0.0443 g) spacing. There were significant interaction effects among, genotype and intra-row spacing of chickpea crop). Mastewal genotype with 10 cm intra row spacing recorded maximum value (0.056 g) while Habru genotype with 5 cm spacing recorded the lowest (0.0242 g) nodule dry weight

Table 4. Interaction effect of genotype and intra-row spacing on nodule dry weight of chickpea.

Genotype	Intra-row spacing (cm)		
	5	10	15
Habru	0.0242c	0.0411b	0.0392b
Mastewal	0.0243c	0.0564a	0.0494ab

Genotype	Intra-row spacing (cm)		
	5	10	15
CV (%) = 18.09			
LSD = 0.0123			

Means followed by the same letters are not significantly different from each other at 5% level of significance.

The response of nodule dry weight was significant to effects of inter-row spacing ($p < 0.01$). There were increments in nodule dry matter of chickpea with increase in inter-row spacing (Table 3). Higher nodule dry matter was recorded in plots with 50 cm (0.0469 g) followed by 40 cm (0.0360 g) while the minimum value was achieved at 30 cm (0.0366 g) but it was not significantly different from 40 cm spacing (Table 3). Even though the number of nodules plant⁻¹ were higher at narrower inter row spacing (30 cm) the dry weight was highest at wider spacing (50 cm) due to larger size of the nodule. There were highly significant interaction effects among intra and inter-row spacing on nodule dry weight of chickpea crop in this study). The maximum value of nodule dry weight was obtained in 10 cm intra row spacing with 30 cm inter row (0.056 g) while the minimum value was recorded in 5 cm intra row with 40 cm inter row spacing (0.162 g).

Table 5. Interaction effect of intra and inter-row spacing on nodule dry weight (gm) of chickpea genotype at Huletegn choroko.

Intra-row spacing (cm)	Inter-row spacing (cm)		
	30	40	50
5	0.0204d	0.0162d	0.0361c
10	0.0558a	0.0451b	0.0454b
15	0.0359c	0.0442b	0.0528ab
CV (%) = 13.14			
LSD = 0.0074			

Means followed by the same letters are not significantly different from each other at 5% level of significance.

3.7. Number of Pods Plant⁻¹

Statistical analysis did not show significant differences ($P < 0.05$) between the two genotypes on number of pods plant⁻¹. There was a significant interaction effect of genotype with intra row spacing. The maximum value (59.56) of pod plant⁻¹ was obtained from Mastewal genotype in 15 cm intra-row spacing while the lowest pod plant⁻¹ (33.00) was

obtained in Mastewal genotype with 5 cm intra-row spacing of chickpea crop (Figure 2). This shows that different genotypes interact in different manner of intra-row spacing of chickpea crop. The wider intra-row spacing gave higher number of pods plant⁻¹ possibly due to sufficient space where plants utilized more water, light, air and nutrients as a result, more photosynthetic activity.

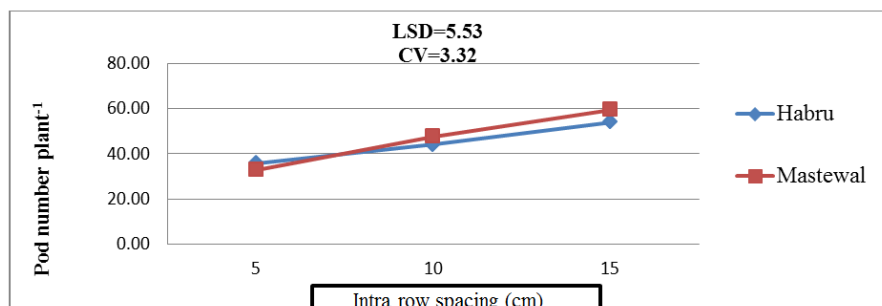


Figure 2. Interaction effect of chickpea genotype and intra-row spacing on pod number Plant⁻¹.

Number of pods plant⁻¹, an important primary yield component, was significantly ($p < 0.001$) affected by different intra-row spacing. The results revealed that maximum number of pods plant⁻¹ (56.78) was obtained from 15 cm intra-row spacing which was followed by (45.89) of pods plant⁻¹ from intra-row spacing of 10 cm. Whereas, minimum number of pods plant⁻¹ (34.39) was obtained from 5 cm spacing. Higher number of pods plant⁻¹ in 15 cm intra row spacing might be due to proper adjustment of plants in the field which facilitated more aeration, greater light interception and more photosynthetic activity on the other hand, in closer row spacing, the plant growth was decreased which resulted in less number of pods plant⁻¹. It was observed that plants stem remained thin in densely populated plants and it might be due to congested plant population within plants which caused lodging to some degree and ultimately, reduce number of branch which can be reflected on number of pods plant⁻¹. This finding is in agreement with that of [38] who reported decreased number of pods plant⁻¹ with decreasing of intra row spacing on faba bean.

Effect of inter-row spacing on number of pods plant⁻¹ was significantly different and average values ranged from 37.72 to 53.56. highest average number of pods plant⁻¹ (53.56) was noted in 50 cm inter-row spacing followed by 40 cm row spacing with 45.8 pods plant⁻¹, while the lowest number of pods plant⁻¹ (37.72) was recorded with 30 cm inter-row

spacing). The increase in the number of pods plant⁻¹ in wider row spacing may be due to vigorous plants as in wider spacing; plant grew vigorously and produced more branches which resulted in high number of pods plant⁻¹. The reduction in number of pods plant⁻¹ (29.57%) in narrower inter-row spacing might be due to higher number of plant per unit area where competition for nutrients, light, space and moisture was very tense as compared with the wider row spacing. Similarly, [28] stated that the number of pods plant⁻¹ decreased with increasing plant density for chickpea. In case of dense population, the production of flower or pod presumably decreased because of competition for assimilates between the vegetative parts and the developing reproductive sink [25]. This part of yield components had the prominent role in legume on seed yield capacity [1]. There were significant interaction effects between intra and inter row spacing of chickpea on number of pod plant⁻¹. The maximum number of pod plant⁻¹ (65.50) was obtained in 15 cm intra-row with 50 cm inter-row spacing while the minimum value (27.5) was obtained in 5 cm intra-row and 30 cm inter-row spacing (Figure 3). The reduced competition for light and reduced overlapping from adjacent chickpea plants could have enabled the plants grown at wider spacing to utilize its energy for more branching and subsequently, the greater number of pods plant⁻¹

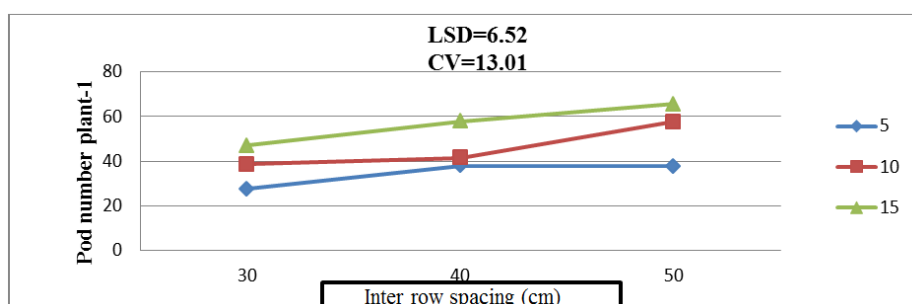


Figure 3. Interaction effect of intra and inter-row spacing on pod number plant⁻¹.

3.8. Number of Seed Pod⁻¹

As shown in table 6 the number of seed pod⁻¹ was not affected by chickpea genotype and intra-row spacing. In contrast with that of [42] who reported significant differences among genotype of chickpea on number of seeds pod⁻¹. [22] also reported significantly decreased number of seeds pod⁻¹ as seed rate increased from 60 kg ha⁻¹ to 75 kg ha⁻¹ on chickpea.

Data reported in (table 6) show that there were significant differences among inter row spacing of chickpea on number

of seed pod⁻¹. The highest number of seed pod⁻¹ was obtained at 50 cm (1.53) and the lowest number was obtained at 40 cm (1.36) (Table 6). These results may suggest the competition between vegetative and reproductive structures of chickpea plants. In the lower densities, the rate of competition between plants is lower and the maximum potential of photosynthesis for distribution is available. Similarly, [41, 20] reported that with increasing density, due to increased competition, the number of seeds in the pod were reduced.

Table 6. Effect of inter and intra-row spacing on chickpea genotype on yield and yield components at Huleteegna choroko in 2013.

Treatments	Number of Pods plant ⁻¹	Number of seed pod ⁻¹	Grain yield (t ha ⁻¹)	Hundred seed weight (g)	Biomass dry weight(t ha ⁻¹)
Genotype					
Habru	44.63	1.39	2.26	24.89a	5.43
Mastewal	46.74	1.49	2.40	22.06b	5.09
CV (%)	7.79	12.91	9.87	3.43	12.79
LSD (0.05%)	NS	NS	NS	0.9425	NS
Intra-row spacing (cm)					
5	34.39c	1.42	2.01c	23.05	6.05a
10	45.89b	1.46	2.58a	23.13	4.71b
15	56.78a	1.43	2.39b	24.26	5.04b
CV (%)	8.64	3.26	5.17	7.96	11.61
LSD (0.05%)	3.03	NS	0.0925	NS	0.47
Inter-row spacing(cm)					
30	37.72c	1.42b	2.74a	23.43	5.94a
40	45.78b	1.36c	2.44b	23.22	5.05b
50	53.56a	1.53a	1.81c	23.79	4.81b
CV (%)	13.01	5.27	7.0033	4.92	13.66
LSD (0.05%)	4.0894	0.0521	0.1123	NS	0.4948

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance, whereas the opposite is true for different letters.

3.9. Hundred Seed Weight

The data presented in table 6 showed that hundred seed weight was influenced significantly ($P < 0.001$) by the chickpea genotype. The mean value of the genotype showed that genotype Habru had the higher (24.89 g) hundred seed weight than Mastewal (22.06 g). In line with this, [35] and [45] reported significant differences among genotypes of chickpea on hundred seed weight. [37] also reported that genotype had significant difference on hundred seed weight and the highest hundred seed weight was recorded for genotype Acos Dubie (63.53 g) whereas the lowest hundred seed weight was recorded for genotype Chefe (34.08 g).

Seed weight did not vary significantly among the intra-row spacing. These results are in line with the report of [47] and [43]. On the other hand, the findings of [23] showed that different plant densities influenced significantly the 1000-seed weight of chickpea.

Hundred seed weight was also not influenced significantly by inter-row spacing. [42] Reported that non-significant effect of inter-row spacing on hundred seed weight of chickpea. The interaction effects between inter, intra-row spacing and genotype were significant on hundred seed weight. The maximum value (26.56 g) was recorded in Habru genotype with 15 cm intra and 50 cm inter-row spacing while the minimum value (20.28 g) was recorded in Mastewal

genotype with 5 cm intra-row and 30 cm inter-row spacing (Table 7). Lower number of plants per unit area at wider spacing had more nutrients availability and greater partition to seed as compared to closer spacing which resulted in more plump and bold seeds. Lowest density produced healthy individual seeds by receiving maximum sunlight for the process of photosynthesis.

Table 7. Interaction effect of genotype, intra and inter-row spacing on 100seed weight (g).

Genotype	Intra-row	Inter-row (cm)		
	(cm)	30	40	50
Habru	5	25.66ab	23.24b	23.77b
	10	24.78ab	23.94b	25.00ab
	15	25.35ab	25.75ab	26.56a
Mastewal	5	20.28c	21.69bc	23.63b
	10	21.88bc	21.68bc	21.48bc
	15	22.62bc	22.97bc	22.28bc
CV (%)=4.92				
LSD=2.3232				

Means followed by the same letters are not significantly different from each other at 5% level of significance.

3.10. Seed and Biological Yield

Seed yield is ultimate outcome of various physiological, biochemical and phenological processes occurring in the plant

system. The statistical analysis revealed that there was no significant difference between the two chickpea genotypes.

Data given in Table 6 showed that intra-row spacing significantly ($p < 0.001$) affected seed yield of chickpea. Maximum yield (2.58 t ha^{-1}) was obtained in 10 cm spacing followed by 15 cm spacing (2.4 t ha^{-1}). The minimum value (2.01 t ha^{-1}) of seed yield ha^{-1} was obtained in 5 cm spacing. In case of low plant populations, some of the yield components might have increased on individual plant basis (number of pods plant^{-1} and biological yield) but would have decreased on per unit area basis. Hence, the lowest seed yield in 15 cm intra-row spacing might be due to relatively the inefficient utilization of available resources (light, space and nutrients) per unit area as compared to 10 cm intra-row spacing. In line with this, [12] justified that when soil moisture and nutrients are not limited, higher density is necessary to utilize other growth factors (solar radiation) efficiency of chickpea. The result also suggests that moderate intra-row spacing produced maximum grain yield, beyond that significant change in grain yield were observed. Therefore, seed yield of 10 cm spacing seems to be optimum

which could be due to the most desirable population or planting density in the existing environmental conditions of Huletegn choroko.

The results table 6 showed that the effect of inter-row spacing on seed yield had highly significant differences ($P < 0.001$). The highest (2.74 ton ha^{-1}) and lowest seed yields (1.81 t ha^{-1}) were obtained with the narrower (30 cm) and wider (50 cm) inter row spacing respectively (Table 6). This was mainly attributed to, at higher plant density; even though the individual plant performance was poor the grain yield was compensated with higher plant population. Therefore, the higher grain yields observed under higher plant population densities could be attributed to increased number of pods per unit area that resulted from higher number of branches per unit area. In a high plant population, competition between vegetative and reproductive organs arises which reduces the allocation of photosynthetic assimilates and resources to reproductive organs resulting in yield loss [17]. [10] reported that increasing plants population reduced yield of individual plants but increased yield per unit of area.

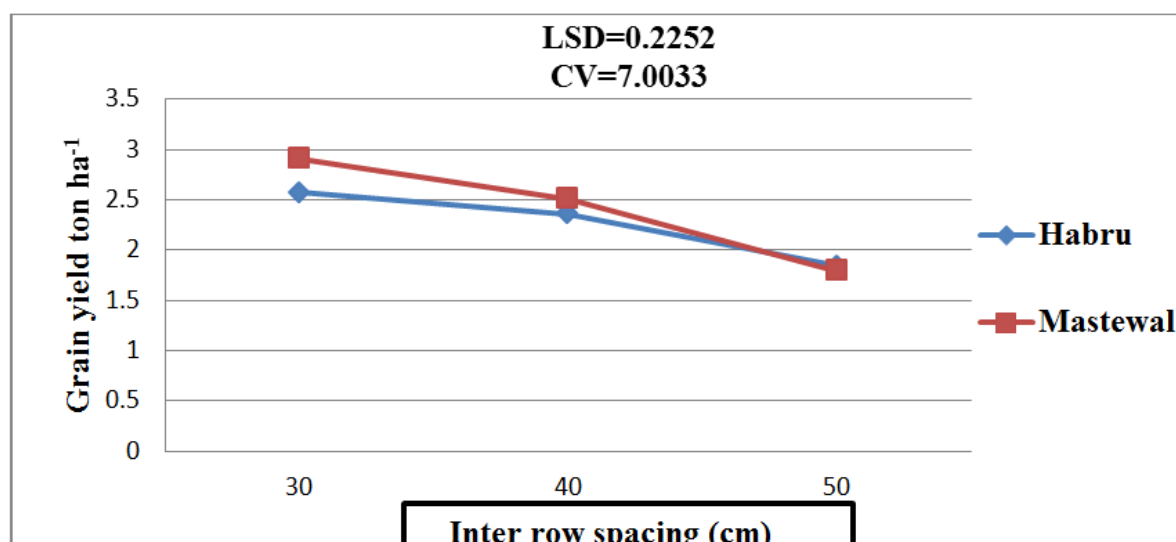


Figure 4. Interaction effect of genotype and inter-row spacing on grain yield in t ha^{-1} .

The interaction of inter row spacing with genotype was significant for grain yield. The maximum average grain yield (2.91 t ha^{-1}) was recorded in 30 cm inter row spacing with Mastewal genotype followed by Habru at the same spacing. Grain yield declined with increasing inter row spacing for both genotypes (Figure 4). There was also significant interaction effects between intra and inter row spacing on grain yield of chickpea. Comparably greater yields were produced under both 10 cm and 15 cm intra row spacing combined with 30 cm inters row spacing (Figure 5). The higher seed yields noted in 15 and 10 cm intra row with 30 cm inter row spacing due to optimum number of plants per unit area which compensated the effect of decrease in other yield components like number of pods per plant, number of

seeds per pod and hundred seed weight. These components though decreased on plant^{-1} basis, yet yield actually increased on per unit area basis. The plants grown with wider spacing had more area of land around them to draw the nutrition and had more solar radiation to absorb for better photosynthetic process and hence performed better at individual basis. The reason for deviation of this linearity in case of seed yield per unit area is that the yield does not entirely depend upon the performance of individual plant but also interact with the total number of plants per unit area and yield contributing parameters. [6] and [11] reported increased yield from higher plant populations are primarily the result of increased light interception during grain-filling by the crop canopy of soya bean.

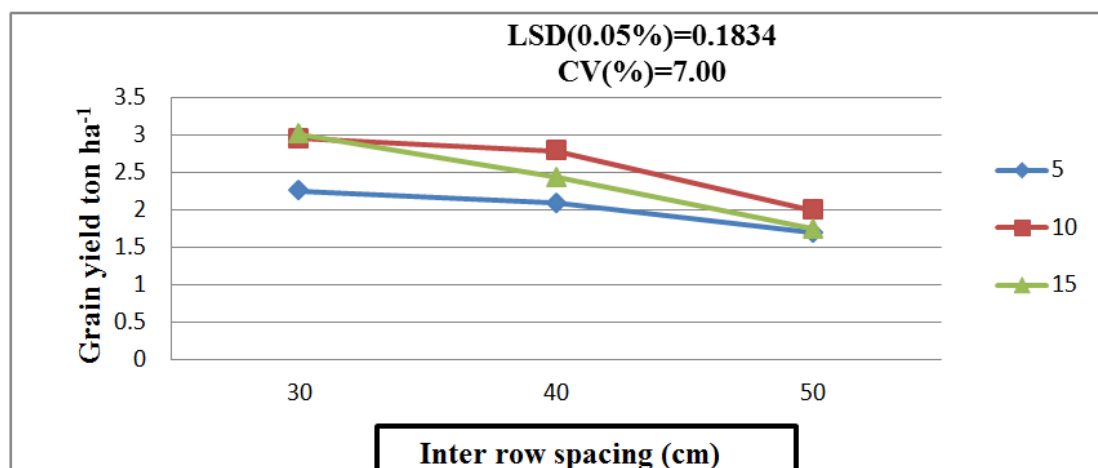


Figure 5. Interaction effect of intra row and inter-row spacing on grain yield in t ha⁻¹.

Biological yield is sum total of all dry matter produced through physiological and biochemical processes occurring in the plant system. There was no significant ($p < 0.05$) difference on above ground dry matter between genotypes. In line with this, [35] reported statistically non-significant differences of the biological yield among genotype of chickpea.

Biological yield was significantly affected by intra-row spacing which ranged from 4.71 to 6.05 t ha⁻¹. Maximum average biological yield of (6.05 t ha⁻¹) was recorded in the treatments with 5 cm intra-row spacing and the lowest biological yield of 4.71 t ha⁻¹ was recorded 10 cm intra-row spacing, which was at par with 15 cm intra-row spacing (Table 6). Although in most circumstance by increasing density biological yield has been raised under various environmental conditions, but in some cases, yield of individual plants is too low to be compensated with the density increment.

Inter-row spacing had significantly different effects ($P < 0.05$) on above ground dry matter yield of chickpea. Maximum biological yield (5.94 t ha⁻¹) was recorded in 30 cm inter-row spacing followed by 40 cm inter-row spacing with a biological yield value of 5.05 t ha⁻¹. The lowest biological yield of 4.81 t ha⁻¹ was obtained at 50 cm inter-row spacing, but it was not significantly different with 40 cm spacing. In case of low plant populations, some of the yield components might have increased on individual plant basis but would have decreased on per unit area basis. On contrary, in dense populations number of plants increased per unit area and yield components decreased on individual basis and eventually the total biological yield increased. These result were in line with [9] who planted chickpea at four different plant population densities (5000, 50,000, 100,000 and 200,000 plants/ha) and reported that dry matters (DM) accumulated over time were affected by plant population densities.

4. Summary and Conclusion

The result of the study showed the presence of significant

differences between the two genotypes and inter-row spacing on days to flowering. Inter-row spacing had significant effect on number of nodule plant⁻¹. Plant height was significantly affected by intra-row and inter-row spacing. The numbers of pods plant⁻¹ and seed pod⁻¹ were highly affected by intra-row and inter row spacing. Above ground dry matter was significantly affected by intra-row spacing which ranged from 4.71 to 6.05 t ha⁻¹. Seed yield was not significantly affected by genotypes. However, intra and inter-row spacing had significantly affected seed yields.

The interaction of intra and inter-row spacing also had significant difference on grain yield. Greater yields were produced under both 10 cm (2.95 t ha⁻¹) and 15 cm (3.01 t ha⁻¹) intra row spacing combined with 30 cm inters row spacing. Even though, the yield of 10 cm and 15 cm intra row spacing had no significant difference 15 cm spacing was selected in order to reduce seed cost. The interaction of inter row spacing with genotype also had significant difference for grain yield. The maximum average grain yield (2.91 t ha⁻¹) was recorded in 30 cm inter row spacing with Mastewal genotype followed by Habru (2.57 t ha⁻¹) at the same inter row spacing. it can be conclude that Mastewal genotype obtained the maximum (2.91 t ha⁻¹) grain yield at the combination of 15 cm intra row and 30 cm inter row spacing while Habru obtained (2.57 t ha⁻¹) yield at the same intra and inter row spacing.

In conclusion, plant density had a significant influence on the phenology, growth, yield and yield components of chickpea genotype. From the above results, seed yield can be considerably enhanced by the use of 30 cm inter and 15 cm intra-row spacing for both (Mastewal and Habru) genotype at Halaba Huleteгна choroko Southern Ethiopia.

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