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Effect of Spacing on Yield Components and Yield of Chickpea (*Cicer arietinumL.*) at Assosa, Western Ethiopia

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Abstract: A field experiment was conducted in Assosa District of western Ethiopia during 2013 cropping season to determine the effect of different inter row (20, 30, 40, 50cm) and intra row spacing (5, 10, 15cm) on growth parameters, yield components and yield of Desi chickpea. The experimental design was randomized complete block design in factorial arrangement with three replications. There was highly significant ($P<0.01$) effect of both inter row and intra row spacing on days to 50% flowering, days to 90% maturity, number of seeds per pod, hundred seed weight. The 50cm inter row spacing gave the highest number of seeds per pod (1.23) and hundred seed weight (25.38 g). Number of seeds per pod and hundred seed weight were significantly increased as the intra row spacing increased. The interaction effect of inter row and intra row spacing was significant on plant height, number of primary branches, number of pods per plant, above ground dry biomass, grain yield and harvest index. For all of the inter row spacing, the number of primary branches was increased as the intra row spacing increased. There was a progressive increase of number of pods per plant as the inter- and intra-row spacing increased while the highest above ground dry biomass (10650.27 kg ha^{-1}) was recorded at 20×5cm spacing. For all of the inter row spacing, the harvest index was increased as the intra row spacing increased. The 30cm inter- by 10cm intra- row spacing gave the highest grain yield (1219 kg ha^{-1}) while the lowest grain yield (733 kg ha^{-1}) was recorded from 50cm × 15cm spacing which was statistically similar to the yield obtained from 40cm × 15cm spacing. From this study it can be concluded that even if 20cm×15cm, 30cm×15cm, 30cm×10cm and 40cm×5cm spacing combinations showed statistical parity, 30cm×10cm or 30cm×15cm spacing can tentatively be recommended.

Keywords: 'Desi' Type Chickpea, Inter-row Spacing, Intra-row Spacing

1. Introduction

Chickpea (*Cicer arietinum* L.)is a high-value crop that is adapted to deep black soils in the cool semi-arid areas of the tropics, sub-tropics as well as the temperate areas (e.g. Canada and Australia). The crop is originated in the present day southeastern Turkey and adjoining Syria where three wild annual species of *Cicer viz., Cicer bijigum* K. H. Rech, *Cicer aerhinosperum* P. H. Davis and *Cicer reticulatum* Ladare found ([83]). Ethiopia is a secondary center of diversity for chickpea [78].

Chickpea is the most important leguminous food grain in the diets of people in South and West Asia and northern Africa. It was grown on about 11.98 million hectares (ha) worldwide and its annual production was 10.89 million tones (t) during 2010 [31]. India alone accounts for 68.5%of the total chickpea growing area with 68.7% of the total world production. The other major chickpea producing countries are Pakistan, Iran, Australia, Turkey, Myanmar and Ethiopia. In Africa, Ethiopia stands first in area (213187 ha) and production (284640 t), but third in productivity (1335.2 kg ha^{-1}) after Egypt and Sudan [31]. This clearly indicates the importance of chickpea in Ethiopian agriculture.

In Benishangul Gumuz Regional State, total area coverage and total production of chickpea crop is more than 377.38 ha of land and 234.46 t, respectively. Of the total area coverage Metekel Zone takes the lion share (208.47 ha) followed by Assosa Zone with 154.92 ha of chickpea land coverage [22].

Two types of chickpea are cultivated in the world: *Desi* and the *Kabuli* types. The *Desi* types have smaller seeds with angular appearance, sharp edges and varying colors. The *Kabuli* type produces large round seeds with white or pale cream or yellow color. Of the two groups, the *Desi* types are more widely cultivated in Ethiopia. Chick pea is generally grown in drought prone areas, and derives most of its water requirements from residual stored soil moisture rather than from rainfall, chickpea yields tend to trail those of cereals and other legumes cultivated in more favourable areas [48, 16].

Chickpea is one of the important cool season food legume crops of Ethiopia which is mainly grown in the central, northern and eastern highland areas of the country where the mean annual rainfall and altitude, respectively, range from 700-2000 mm and 1400-2300 meter above sea level [36]. 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 fetches good price when sold in local market and hence generates cash to farmers. Moreover, the crop is being exported to Asia and Europe contributing positively to the country's foreign exchange earnings. For instance, in 2008 only Ethiopia had exported 39,993 metric t of chickpea crop to different parts of the world [62]. Chickpea also improves the soil fertility through biological nitrogen fixation. Despite these facts, the yield of chickpea in Ethiopia is extremely low which can be attributed to factors such as water deficit, diseases, insects, weeds infestations and poor agronomic practices [83].

One of the main reasons of low yield of *Carietinum* is improper population. Too low and high plant population beyond a certain limit often adversely affects the crop yield. Number of plants per unit area influences plant size, yield components and ultimately the seed yield [14]. Moreover, plant spacing in the field is also very important to facilitate aeration and light penetration in to plant canopy for optimizing rate of photosynthesis. There is very little information available on the relative contribution of various plant spacing towards yield and yield components and also their interaction. It is reported that row spacing of 45cm increased chickpea yield compared to 30 and 50cm spacing while others indicated that row spacing had no significant effect on seed yield [74, 75].

Production and productivity of the crop is governed by environmental, genotypic trait of the crop and crop management. Determining appropriate crop geometry is therefore one of the most important crop management activities which improves the performance and productivity of plants. Generally based on size of the seed, research results indicated that the recommended seed rate for chickpea in Ethiopia ranges from 60-140 kg ha^{-1} [29]. The planting density of chickpea in Ethiopia is 30cm×10cm spacing regardless of variety and agro climatic conditions. Various studies indicated that chickpea varieties and population densities have significant effects on the growth as well as yield parameters.

Even though the crop has a number of potential uses, the productivity of the crop in Ethiopia is very low under farmer's field. This is possibly due to: lack of improved variety to different environmental conditions, poor agronomic practices such as inappropriate use of seeding rate/plant density and variety selection. In addition to this, limited work has been done on the interaction effects of various agronomic practices such as variety with spacing in the country. There is also no site and variety specific recommendation on the plant population density of chickpea cultivars in Ethiopia rather; there is blanket recommendation of 30×10cm spacing. Therefore, the objective of this study was to determine the effect of inter- and intra- row spacing on yield components and yield of chickpea.

2. Materials and Methods

2.1. Description of the Study Area

A field experiment was conducted in Benishangul Gumuz Regional State at Asossa Agricultural Research Centre (10^0 $02^{'}05^{''}$N latitude; 34^0 $34^{'}09.9^{''}$E longitude; 1580 m above sea level altitude) in the 2013 cropping season. The study area is situated west of Addis Ababa about 663 km distance. The area experiences a monomodal rainfall pattern and has annual total rainfall of about 1275 mm. The rainy season occurs from May to October and the maximum rain is received in the months of July and August. The minimum and maximum temperatures are 16.75°C and 27.92°C, respectively. The soil type of the area is Nitisols and is dark reddish brown to dark red in colour [9].

2.2. Description of Variety Used for the Study

The chickpea variety used in the experiment was an improved *Desi* type variety 'Naatolii'. It was released by DebreZeit Agricultural Research Center (DZARC) in 2007 [67]. Days to maturity of this variety is 136, 100 seed weight of 31g and yield 2.2-2.6 t ha^{-1}.

2.3. Treatments and Experimental Design

A factorial combination of 4 inter row spacing (20, 30, 40 and 50cm) and 3 intra row spacing (5, 10 and 15cm) was laid out in a randomized complete block design (RCBD)with three replications. These treatment combinations are;

1. 20cm × 5cm
2. 20cm × 10cm
3. 20cm × 15cm
4. 30cm × 5cm
5. 30cm × 10cm
6. 30cm × 15cm
7. 40cm × 5cm
8. 40cm × 10cm
9. 40cm × 15cm
10. 50cm × 5cm
11. 50cm × 10cm
12. 40cm × 15cm

2.4. Management of the Experiment

Land was prepared in August 2013 using tractor. The plot size was 3.6 m x 2.4 m and was leveled manually. The width between plots and between blocks was 0.7m and 1.5 m, respectively. As per the treatments there were 18, 12, 9 and 7 rows for 20, 30, 40 and 50cm inter-row spacing, respectively. The number of plants in each row was 48, 24 and 16 for intra row spacing of 5, 10 and 15cm, respectively. The seeds were planted on September9, 2013 by placing a single seed per hole at a specific inter- and intra- row spacing. Gap filling was done to maintain an appropriate population 10days after planting. Weeding was done thrice during the growth of the crop. The first weeding and inter tillage activities were done 25 days after emergence, the second and the third weeding was practiced 30 days and 50 days after the first weeding, respectively. The outer most 3 rows on both sides of the 20cm row spacing and the outer most 2 rows on both sides of the 30cm row spacing served as border rows. In the 40cm row spacing two rows from one side and one row from the other side served as border rows. In the 50cm row spacing plots one row on both sides of the plot served as border rows. In intra row spacing of 5, 10 and 15cm, 6, 3 and 2 plants on both ends of each row were the border plants, respectively. Thus, the net plot size was 2.4 m x 1.8 m.

2.5. Soil Sampling and Analysis

A soil sample was taken of 0-30cm soil depth from 5 random spots of the experimental site with a zigzag method and a composite was made before planting. The composite sample was taken to Assosa Agricultural research center soil laboratory and analyzed for selected physic-chemical properties mainly textural analysis (percent sand, silt and clay), soil pH, total nitrogen, organic matter content, available phosphorous (P), exchangeable potassium (K^+) and cation exchangeable capacity (CEC).

Analysis of organic matter content of the soil in a laboratory was determined by Walkley and wet oxidation method as described by Jackson (1958) and total nitrogen by Kjeldhal method as described by [14]. The pH of the soil was measured in water at soil to water ratio of 1:2.5, and cation exchange capacity was determined using Kjeldhal procedure as described by [73, 80]. Available phosphorous was determined according to the methods of Olsen and Dean and exchangeable potassium by flame photometer [70]. Soil texture analysis was performed by Bouyoucous hydrometer method [26].

2.6. Data Collection

2.6.1. Phenological Data

Days to emergence was recorded as the number of days from sowing to when 50% of the plants emerged in each plot. Similarly, number of days to flowering was recorded when 50% of the plants reached flowering stage. Days to maturity was recorded as the number of days from planting to the stage when 90% of the plant reached physiological maturity, i.e. when the plants and the pods turned pale yellow in colour based on visual observation.

2.6.2. Growth, Yield Components and Yield

Five plants in the net plot area were tagged just before flower initiation for taking observations on number of primary branches, plant height, and number of pods/plant, number of seeds/pod, aboveground dry biomass and harvest index at physiological maturity.

Number of primary branches was taken by counting the number of primary branches from the main stem at harvest. The aboveground biomass was sun dried until constant weight and its total and grain weight was recorded for calculating the harvest index. Number of pods per plant was recorded by counting the total number of pods from the tagged five plants and their average was taken as number of pods per plant at harvest. The twenty pods were randomly picked from the total pods as above and the seeds were counted to determine their number per pod.

The initial crop stand count was recorded by counting the total number of plants per net plot area 25 days after planting and final plant stand count was taken from net plot areas when the plants attained physiological maturity, the percent survival was calculated to determine the change in stand count due to competition and pest effect. One hundred grains from the bulk of harvested produce was counted from each plot and their weight was recorded as 100-seed weight adjusted at 10% grain moisture content.

Grain yield from the net plot area of each plot was recorded by measuring the grain yield and adjusted at 10% grain moisture content using the formula.

Adjusted grain yield = Recorded grain yield × 100-M/100-D; where M is the measured moisture content and D is the designated moisture content (10.0%).

2.7. Statistical Data Analysis

The various agronomic data collected were subjected to analysis of variance (ANOVA) appropriate to factorial arrangement in RCBD according to the Generalized Linear Model (GLM) of SAS and interpretations were made following the procedure described by [40]. Whenever the effects of the factors and interactions were found to be significant, the means were compared using the least significant differences (LSD) test at 5% level of significance.

3. Results and Discussion

3.1. Physico-Chemical Properties of Experimental Soil

According to the laboratory analysis, the soil texture of the experimental area was clay (Table 1). The soil texture (proportion of sand, silt and clay in the soil) controls water contents, water intake rates, aeration, root penetration, and soil fertility. Though the best suited soils for chickpea are deep loam or silty clay loam soil, the texture of the experimental area was good [44], [70]. The pH of the soil was 6.0, which is moderately acidic. It is indicated that plants grow well between pH 5.5 andpH 8.5 [64]. Chickpea specifically grows well under the pH range of 6.0 to 8.0 [44].

The CEC of the soil of the experimental site was analyzed to be 22.6cmol/kg. According to the rating made by Landon (1984), this value lies in the lower range (15-25cmol/kg), which means the soil, is not satisfactory for agricultural production. Further, the analysis indicated that the experimental soil had values of 0.168%, 2.460%, 2.480 ppm and 0.1443 meq 100 g^{-1}fortotal nitrogen, organic matter, available phosphorous and exchangeable potassium, respectively (Table 1). When the results of the analysis are compared with the broad ratings made by Metson A. J. all the values lie in the lower range for plant growth [63]. Though chickpea grows well on the marginal fertility areas, the deficiency of the soil for those major nutrient elements may cause yield reduction.

Table 1. *Major physico-chemical properties of the experimental soil.*

No.	Soil characters	Values
1	pH (by 1: 2.5 soil water ratio)	6.0
2	Organic matter (%)	2.46
3	Total nitrogen (%)	0.168
4	Available phosphorous (ppm)	2.48
5	Cation exchange capacity (cmol(+)/kg)	22.6
6	Exchangeable potassium (meq/100g soil)	0.1443
7	Soil texture:	
8	Sand (%)	30.5
9	Silt (%)	9.1
10	Clay (%)	60.4
11	Textural class	Clay

3.2. Phenological Parameters

3.2.1. Days to 50% Emergence

There was no significant difference among inter- and intra-row spacing on days to 50% emergence as the plants emerged in about seven days after planting (Appendix Table 1). The adequate amount of soil moisture during planting might have triggered the seeds to germinate and emerge from the soil uniformly. This result was in agreement with a report where seed germination and establishment rate of faba bean were not affected by the sowing rate [7]. Similarly, It is also reported no significant effect of the inter- and the intra-row spacing as well as their interactions on days to 50% emergence on sesame [35].

3.2.2. Days to 50% Flowering

The main effect of inter- and intra- row spacing was highly significant ($P<0.01$) while their interaction had no significant effect on days to 50% flowering (Appendix Table 1). Days to flowering was significantly decreased from 50.67 to 49.56 days as the inter-row spacing increased from 20cm to 50cm (Table 2). This might be due to the fact that wider inter row spacing had a better light interception as compared to the narrower row spacing resulting in less number of days to flower as chickpea needs direct sunlight coverage for its various physiological processes. Further, more nutritional area available in wider row spacing might have caused the crop to flower earlier than the closer spacing. On the other hand, in narrower inter row spacing due to competition for nutrients, moisture and space, the crop revealed delayed flowering. Besides moisture and nutrient utilization was more luxurious in the wider spaced inter rows as compared to the narrower row spacing. In agreement to this, the wide plant spacing of 50cm reduced number of days to flower in broad bean than 40cm plant spacing [32]. In contrast, it has been found that the denser plant population hastened days to flowering in lentil While, other found no significant effect of plant population on days to flowering in common bean [94], [1]. Similarly, in the wider intra row spacing, the plants attained50% flowering earlier than the narrower spacing (Table 2). But works on safflower reported that inter- and intra- row spacing did not affect significantly the number of days to 50% flowering [69]. Therefore, it seemed that the influence of plant population on days to flower initiation varies from crop to crop as well as the prevailing environmental conditions under which the crops are grown.

Table 2. *Main effects of inter- and intra- row spacing on days to 50% emergence, days to 50% flowering and on days to physiological maturity of chickpea.*

Treatment	Days to 50% emergence	Days to 50% flowering	Days to physiological maturity
Inter row spacing (cm)			
20	7.11	50.67[a]	104.78[a]
30	7.11	50.33[b]	104.22[b]
40	7.11	50.00[c]	104.00[bc]
50	7.11	49.56[d]	103.78[c]
LSD (0.05)	NS	0.291	0.358
Intra row spacing			
5cm	7.08	50.67[a]	104.50[a]
10cm	7.17	50.17[b]	104.25[a]
15cm	7.08	49.58[c]	103.83[b]
LSD (0.05)	NS	0.252	0.310
CV (%)	4.8	0.59	0.35

Mean values within column followed the same letters are not significantly different; NS= not significant, LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation

3.2.3. Days to Physiological Maturity

The main effects of both inter- and intra- row spacing were highly significant ($P<0.01$) on number of days taken by the crop to reach physiological maturity. However, their interaction did not show significant effect (Appendix Table 1). The narrowest inter row spacing (20cm) took 104.78 days to attain physiological maturity which was significantly enhanced by wider spacing of 30, 40 and 50cm spacing (Table 2). The reason for this may be that in the wider inter row spacing, there existed a lower competition for resources like moisture and essential nutrients than the narrower inter row spacing. In addition, light would be intercepted better in the wider inter row spacing as compared to the narrower inter row spacing and also the better free air circulation in the canopy of the wider spaced rows could have its own contribution for shorter days to maturity.

With regard to the effects of intra row spacing, days to maturity was increased with lower intra row spacing (5cm) as compared to wider intra row spacing. However, it did not differ significantly with 10cm spacing but both these spacing resulted in significant delay in physiological maturity compared to 15cm intra row spacing. The prolonged 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 and air circulation in the canopy as compared to the wider intra row spacing. In line with the present result, wider inter- and intra-row spacing hastened maturity of safflower [69]. But in disagreement with the report no significant effect of row spacing on maturity of soybean was reported [43]. In general, the difference in days to flowering and physiological maturity was very small which may not be practically important though statistically significant.

3.3. Growth Parameters

3.3.1. Plant HeightatMaturity

Main effect of inter- and intra- row spacing and their interaction had highly significant (P<0.01) effect on plant height of the chickpea crop (Appendix Table 2). The interaction of 20cm inter- and 5cm intra- row spacing resulted in significantly taller plants (34.7cm) while the plants in 50cm inter- and 15cm intra- row spacing were the shortest in height (31.7cm) (Table 3). 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. In agreement with this, It was reported that plant height of chickpea and green bean was taller in higher plant population treatments due to more competition for light [34, 87, 102]. Similarly, others indicated that plant height significantly increased with the increase in plant density primarily because of lower amount of light intercepted by a single plant resulting into increased inter node length [76, 88]. More competition for light in narrow spacing resulted in taller plants while at wider spacing light distribution was normal [93]. Moreover, spacing experiment on soybean observed that increasing the density of plants led to significant increases in plant height [85]. In contrast with this, plant height was not affected by increasing plant density of faba bean reported by [84].

Table 3. *Interaction effect of inter- and intra-row spacing on plant height (cm) of chickpea.*

Intra row spacing (cm)	Inter row spacing (cm)			
	20	30	40	50
5	34.7^{a}	34.4^{bc}	34.3^{cd}	34.0^{e}
10	34.5^{b}	34.1^{de}	34.1^{e}	32.1^{h}
15	34.3^{cd}	33.6^{f}	33.2^{g}	31.7^{i}
LSD (0.05) = 0.17 CV (%) = 0.29				

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.
LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation

3.3.2. Number of Primary Branches

Analysis of variance revealed highly significant (P<0.01) effect of the main effects of inter- and intra- row spacing and significant effect (P<0.05) of their interaction on the number of primary branches per plant (Appendix Table 2). As a result, in response to the interaction of 50cm inter- and 15cm intra-row spacing resulted in the highest number of primary branches plant^{-1} which was statistically at par with the interaction of 50cm inter- and 10cm intra-row spacing (Table 4).

Table 4. *Interaction effect of inter- and intra- row spacing on number of primary branches plant^{-1} of chickpea.*

Intra row spacing (cm)	Inter row spacing (cm)			
	20	30	40	50
5	1.47h	2.20fg	2.40def	2.33efg
10	1.60h	2.47cde	2.60cd	2.87ab
15	2.13g	2.47cde	2.67bc	3.00a
LSD (0.05) = 0.251 CV (%) = 6.329				

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.
LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation

The lowest number of branches (1.47) was found due to the interaction of 20cminter- and 5cm intra-row spacing which did not differ significantly with the interaction of the same inter row spacing and 10cm intra row spacing. The differential responses among the interaction of inter- and intra- row spacing might be due to differences in the access to growth factors by the plants grown under their respective environments. The increased number of branches under lower plant densities could be attributed to higher sunlight interception for photosynthesis. In contrast, the decreased number of branches in the narrower plant spacing might be due to the high competition for the resources and with the overlapped plant canopy, the crop might have been subjected to lower interception of sunlight which led to lower photo assimilation. This also indicated the plasticity response of plants to various plant spacing.

This result was in agreement with the finding that increased number of branches at the wider plant spacing for soybean and the reason for this was more interception of sunlight for photosynthesis, which may have resulted in production of more assimilate for partitioning towards the development of more branches [60]. In addition, others reported that the number of primary branches decreased with the increase in density of chickpea [91, 12]. Moreover, similar findings also reported faba bean, soybean and common vetch, respectively, reduced the number of branches with increased plant population [7, 11, 4, 56].

3.4. Yield Components

3.4.1. Stand Count

The main effects of inter- and intra- row spacing and their interactions were not significant on percent of final stand count of chickpea as compared to the initial count. This showed that the competition among the plants grown under varying plant population/densities had no remarkable effect on the survival of the plants at harvest.

Table 5. *Main effect of inter- and intra-row spacing on stand count percentage of chickpea at harvest.*

Treatment	Stand count (%)
Inter row spacing (cm)	
20	96.74
30	97.12
40	96.99
50	96.70
LSD (0.05)	NS
Intra row spacing (cm)	
5	97.15
10	96.72
15	96.79
LSD (0.05)	NS
CV (%)	0.982

NS= not significant, LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation

3.4.2. Number of Pods Per Plant

The main effects of inter- and intra- row spacing and their interaction had a highly significant ($P<0.01$) effect on the number of pods plant^{-1} (Appendix Table 3). The highest number of podsplant^{-1} (34.7) was obtained with the interaction effect of 40cm inter- and 10cm intra- row spacing which had no significant difference with the number of pods found in response to the interaction of 50cm inter row spacing with 10 and 15cm intra row spacing (Table 6). Further, the latter two interactions were statistically at par with the interactions of 40cm inter-and 15cm intra-row spacing as well as 30cm inter- and 10cm intra- row spacing. In general, the number of pods plant^{-1} increased with the increase in inter row spacing at the same level of intra row spacing. The lowest number of pods plant^{-1}(16.7) was found in the closest spacing, i.e. 20cm inter- and 5cm intra-row spacing which was significantly lower than the other interactions. Thus, the interactions of 40cm × 10cm, 50cm ×10cmand50cm ×15cm resulted in an increase of 107.8, 103.6 and 101.8% increase in number of pods over 20cm × 5cm (Table 6).

Table 6. *Interaction effect of inter- and intra- row spacing on number of pods plant^{-1} of chickpea.*

Intra row spacing (cm)	Inter row spacing (cm) 20	30	40	50
5	16.7^{g}	21.0^{f}	23.7^{e}	30.7^{d}
10	22.7^{e}	33.0^{bc}	34.7^{a}	34.0^{ab}
15	20.0^{f}	32.7^{c}	33.3^{bc}	33.7^{abc}
LSD (0.05)= 1.285CV (%) = 2.710				

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance, LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation

The difference among the inter row spacing in response to intra row spacing on number of pods might be due to the fact that, as the plant population increased there was high competition for the growth factors as compared to wider spacing which had impact on the number of pods per plant. 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 (Table 4) and subsequently, the greater number of pods plant^{-1}. In agreement to the present result, higher number of pods plant^{-1}(41.47) was reported in the wider inter row spacing (45cm) of chickpea [50]. Similarly, researches worked on faba bean reported that the development of more and vigorous leaves on low plant density helped to improve the photosynthetic efficiency of the crop and supported higher number of pods [4, 42, 1].

3.4.3. Number of Seeds Per Pod

Table 7. *Main effects of inter- and intra- row spacing on number of seeds pod^{-1} and hundred seed weight (g) of chickpea.*

Treatment	Number of seeds per pod	Hundred seed weight (g)
Inter row spacing (cm)		
20	1.10^{c}	21.58^{c}
30	1.17^{b}	24.24^{b}
40	1.16^{b}	24.46^{ab}
50	1.23^{a}	25.38^{a}
LSD (0.05)	0.040	0.962
Intra row spacing (cm)		
5	1.12^{b}	22.48^{b}
10	1.18^{a}	24.52^{a}
15	1.19^{a}	24.75^{a}
LSD (0.05)	0.035	0.833
CV (%)	3.5	4.1

Means in column followed by the same letter are not significantly different at 5% level of significance; LSD (0.05) = Least Significant Difference; CV= Coefficient of Variation

The analysis of variance showed a highly significant ($P<0.01$) effect of the main effects of inter- and intra- row spacing, but their interaction had no significant effect on the number of seeds pod^{-1} (Appendix Table 3). Significantly higher number of seeds pod^{-1} (1.23) was obtained at 50cm than the other inter row spacing (Table 7). There was no significant difference between 30 and 40cm inter row spacing while 20cm inter row spacing recorded significantly lower number of seeds pod^{-1} than the other inter row spacing. The plants grown in plots with 50cm inter row spacing had 11.8, 5.1, 6.0% higher number of seed pod,$^{-1}$ respectively, than the plants grown in 20, 30 and 40cm inter row spacing. Plants compete for limited resources being essential for their life, i.e. light, water, and nutrients. Yet, whole plant growth and competitive ability depends not only on the photosynthetic rate of individual leaves, but also on the geometry and dynamics of a plant's canopy, and the pattern of energy all Cation among all organs [13].

On the other hand, 15cm intra row spacing resulted in the highest number of seeds pod^{-1} which was statistically in parity with 10cm intra row spacing (Table 7). Both the intra row spacing registered significantly higher number of seeds pod^{-1} than 5cm intra row spacing. This increase in the number of seeds pods^{-1}was 6.3 and 5.4% over 5cm with 10 and 15cm intra row spacing. As the number of plants within a row increased, intra row plant competition got increased while light interception reduced and resulted in decreased number of seeds pod^{-1}. In agreement with the present result, the number of seeds per pod reported increased with decreased plant density of faba bean [2, 10, 1]. Moreover, in safflower higher number of seeds per pod was reported in association with wider inter and intra-row spacing [69]. In accordance with the present result, decreased number of seeds pod^{-1} from 1.87 to 1.81 was reported as seed rate increased from 60 kg ha^{-1} to 75 kg ha^{-1} on chickpea [50].

3.4.4. Hundred Seed Weight

The main effects of inter- and intra- row spacing were highly significant (P<0.01) whereas their interaction had no significant effect on the hundred seed weight of chickpea (Appendix Table 3). The highest hundred seed weight (25.38g) was observed with 50cm inter row spacing which had no significant difference with 40cm inter row spacing. On the other hand, no significant difference in 100 seed weight existed between 30 and 40cm inter row spacing. However, 20cm inter row spacing had significantly the lowest 100 seed weight compared to the other inter row spacing (Table 6). The variation in 100 seed weight due to intra row spacing was similar to the response of number of seeds pod^{-1} wherein the 100 seed weight increased with an increase in intra row spacing but no significant difference was observed between 10 and 15cm. The 100 seed weight was 8.3 and 9.2% lower at 5cm than at 10 and 15cm intra row spacing (Table 7).

Decreasing inter- and intra- row spacing might have increased inter specific competition which eventually caused reduction in weight of seeds. Moreover, decreasing plant density might have caused more sunlight to penetrate the canopy that made plants to benefit more from the natural environment. Thus, this might have caused an increase in number of branches and the increased level of photosynthesis resulting in more assimilates translocated and stored in seeds. In agreement with the result obtained, hundred seed weight that decreased from 19.5 g to 17.56 g was reported as plant density increased from 40cm × 16cm to 40cm× 7cmin haricot bean [89]. Similarly, other authors also reported that hundred seed weight of faba bean was negatively related with plant density [4, 95, 59]. Moreover, higher hundred seed weight (29.87g) was reported in the wider inter row spacing of 45cm than 30cm inter row spacing of chickpea [50]. However, the result of this experiment was not in line with other authors who reported that individual seed weight is rarely affected by growth factors except in case of severe water stress and hot desiccating winds that caused forced maturity [95]. Similarly, no significant effect of plant density was obtained on hundred seed weight of soya bean [54].

3.5. Yield and Harvest Index

3.5.1. Above ground Dry Biomass Yield (kg ha^{-1})

The analysis of variance revealed that the main effects of inter row spacing and intra row spacing showed a highly significant (P<0.01) effect on above ground dry biomass. Moreover, the interaction effect of inter row and intra row spacing had also a highly significant (P<0.01) effect (Appendix Table 4). The highest above ground dry biomass (10650.27 kgha^{-1}) was recorded at 20cm ×5cm spacing combination and the lowest above ground dry biomass (2186.69kgha^{-1}) was recorded at 50cm ×15cm spacing combination (Table 8). For all of the inter row spacing, the highest number of above ground dry biomass were recorded as the intra row spacing decreased. The highest total dry biomass at the highest density of plants might be due to more number of plants per unit area. However, if the number of plants per unit area keeps on increasing, the aboveground dry biomass will reduce as there is lodging problem and lower photosynthetic efficiency in highly crowded plant population. In agreement with this study, an author reported that dry biomass per ha was significantly increased with increased plant density (40cm ×10cm) on haricot bean [89]. Similar report revealed increment of total dry biomass with increasing plant population of soya bean up to a certain point and subsequently no addition in biological yield can be obtained thus decrease in economic yield [88]. In line with this, lower plant densities of 5 and 7 plants m-1 resulted in a greater aboveground DM biomass and number of pods per plant of the common bean; grain yield was not decreased [101].

Table 8. *Interaction effect of inter- and intra-row spacing on above ground dry biomass yield (kg ha^{-1}) of chickpea.*

Intra row spacing (cm)	Inter row spacing (cm)			
	20	30	40	50
5	10650.27^{a}	7838.76^{b}	5955.64^{d}	5249.44^{e}
10	7055.58^{c}	4884.22^{f}	3814.96^{g}	3228.76^{h}
15	4840.17^{f}	3421.76^{h}	2590.87^{i}	2186.69^{j}
LSD (0.05) =233.80 CV (%) =2.68				

Means in column and row followed by the same letters are not significantly different at 5% level of significance.
LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation.

3.5.2. Grain Yield (kg ha^{-1})

The main effects of inter- and intra- row spacing and their interaction showed a highly significant (P<0.01) effect on grain yield (Appendix table 4). The interaction of 30cm inter- and 10cm intra- row spacing resulted in the highest grain yield (1219 kg ha^{-1}) which was statistically at par with the grain yield obtained with the interactions of40cm×5cm, 30cm× 15cm and 20cm× 15cm spacing (Table 9). The lowest grain yield (733 kg ha^{-1}) was recorded with the interaction of 50cm× 15cm which was statistically similar to the yield obtained with the interaction of 40cm× 15cm spacing. The possible reason could be that, when inter-and intra-row spacing was decreased, number of plants per unit area increased, resulting in higher yield. Decreased inter- and intra-row spacing implied high plant density, which is concomitantly equal to high yield with every successful pod formation per plant. However, this could be possible only up to certain level of population. At extremely higher population (20cm × 5cm), the adverse effect on the yield was noticed which might be due to intense interplant competition and floral abortion. In spite of lower number of branches plant $^{-1}$ (Table 4), number of podsplant^{-1} (Table 6), number of seeds pod^{-1} and hundred seed weight (Table 7) at narrow inter- and intra- row spacing and or their interaction, i.e. 20cm ×5cm, the grain yield ha^{-1} was significantly higher as compared to the interaction of wider inter- and intra- row spacing (50cm ×15cm)which showed that the main determinant of yield was the plant population which along with other yield attributes contributed towards significant increase in grain yield (Table 9). It can thus be seen that, the total yield per unit area depended not only on the performance of individual plant but also on the number of plants per unit area as confirmed in this study. Further, other reason for seed-yield enhancement under narrow planting could be attainment of sufficient leaf area index (LAI) to produce maximal light interception during the grain formation. But in the wide inter- and intra-row spacing even though the yield per individual plant was higher, since the plant population reduced the grain yield showed decrement. In the same manner, at narrow-row planting seed yield enhancement in determinate soybean was due to greater light interception during pod filling, and not greater leaf area development and dry matter production before this time [13], [92].

Similarly, higher grain yield of chickpea was reported at average (45cm×7.5cm) spacing combination than35cm×5cm and 55cm×10cm spacing combinations [18]. Moreover, reports showed increased yield from higher plant populations are primarily the result of increased light interception during grain-filling by the crop canopy of soya bean [8, 19]. This idea was also in agreement with other authors who reported that the yield per unit area was increased with increasing plant density due to efficient utilization of growth factors [88]. Similarly, the seed yield was increased by 30.81% and 15.53% as inter and intra -row spacing decreased from 40 to 20cm and 15 to 10cm, respectively [100]. Further, reports revealed that too narrow or too wide spacing affect yield due to competition for resources and shading effect [79, 72]. In the case of too wide spacing, yield reduction can occur due to inefficient utilization of the growth factors.

Table 9. *Interaction effect of inter- and intra row spacing on grain yield (kgha^{-1}) of chickpea.*

Intra row spacing (cm)	Inter row spacing (cm)			
	20	30	40	50
5	903^{ef}	1049^{bcd}	1134^{abc}	1019^{cde}
10	1088^{bc}	1219^{a}	1049^{bcd}	957^{def}
15	1150^{ab}	1134^{abc}	856^{fg}	733^{g}
LSD (0.05)= 125.5 CV (%) = 7.2				

Means in columns and rows followed by the same letters are not significantly different at 5% level of significance.
LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation.

3.5.3. Harvest Index

There was a significant difference recorded on the main effects of inter row spacing, intra row spacing and their interaction (Appendix Table 4). The highest harvest index (33.6%) was achieved for the interaction of 50cm inter- and 15cm intra- row spacing which was statistically at par with the harvest index obtained with 40cm × 15cm and 30cm × 15cm (Table 10). The lowest harvest index (9.7%) was accrued with the combination of narrowest inter- and intra- row spacing, i.e. 20cm × 5cm. This reduction in harvest index in narrower spacing might be due to the higher plant population per unit area which might have increased the flower abortion due to competition for nutrients, moisture and solar radiation. Similar result reported by other authors indicated maximum harvest index (41.66%) in the highest row spacing (45cm) of chickpea than 15cm row spacing [50].

Table 1. *Interaction effect of inter- and intra row spacing on harvest index (%) of chickpea.*

Intra row spacing (cm)	Inter row spacing (cm)			
	20	30	40	50
5	9.7^{g}	13.4^{f}	19.1^{e}	19.4^{e}
10	15.4^{f}	25.0^{cd}	27.5^{bc}	29.7^{b}
15	23.8^{d}	33.2^{a}	33.0^{a}	33.6^{a}
LSD (0.05) = 3.24 CV (%) = 8.096				

Means in columns and rows followed by the same letters are not significantly different at 5% level of significant;
LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation.

4. Conclusion

Chickpea is the most important leguminous food grain in the diets of people in South and West Asia and northern Africa. In Africa, Ethiopia stands first in area (213,187 ha) and production (284,640 t), but third in productivity (1335.2 kg ha^{-1}) after Egypt and Sudan. This clearly indicates the importance of chickpea in Ethiopian agriculture. 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 fetches good price when sold in local market and hence generates cash to farmers. Despite these facts, the yield of chickpea in Ethiopia is extremely low which can be attributed to factors such as water deficit, diseases, insects, weeds infestations and poor agronomic practices.

It is clear that both too narrow and too wide spacing do affect grain yields through competition (for nutrients, moisture, air, radiation, etc) and due to the effect of shading. In the latter case (too wide spacing), yield reduction can Ccur due to in efficient utilization of the growth factors. Normally, as population increases yield also increases proportionally. After, it reached a certain level the yield declines.

Accordingly, the experiment was conducted to determine the effect of inter and intra row spacing on yield components and yield of a *Desi* type chickpea variety Naatolii. A factorial experiment was conducted in RCBD in three replication with 4 inter row spacing, *i.e.* 20cm, 30cm, 40cm and 50cm and three intra row spacing of 5cm, 10cm, and 15cm.

Days to 50% flowering was highly significantly affected by both inter row spacing and intra row spacing. Row spacing of 50cm was earlier (49.56 days) while row spacing 20cm took the longest number of days to flower (50.67 days).

And regarding the intra row spacing, 5cm intra row spacing took longer days than the others and 15cm intra row spacing took the least days to 50% flowering (49.58 days). Days to physiological maturity increased with decreased inter row spacing from 103.78 at 50cm to 104.78 days at 20cm. Similarly, days to maturity increased from 103.83 to 104.50 days as intra row spacing decreased from 15cm to 5cm.

The interaction effect of inter row and intra row spacing was highly significant on plant height. The tallest plant (34.7cm) was recorded in 20cm ×5cm spacing while the shortest plant height (31.7cm) was recorded at 50cm ×15cm spacing. The interaction of inter row and intra row spacing had a significant effect on the number of primary branches of chickpea. For all of the inter row spacing the number of primary branches was increased as the intra row spacing increased.

The interaction of inter row spacing and intra row spacing showed a highly significant effect on number of pods per plant. The highest number of pods plant^{-1} (34.7) was obtained with the interaction effect of 40cm inter- and 10cm intra- row spacing which had no significant difference with the number of pods found in response to the interaction of 50cm inter row spacing with 10 and 15cm intra row spacing while the lowest number of pods plant^{-1} (16.7) was recorded at 20cm ×5cm spacing.

Number of seeds per pod was highly significantly affected by inter row spacing and intra row spacing. The highest number of seed per pod (1.23) was obtained at 50cm inter row spacing and the lowest number of seeds per pod (1.10) was recorded from the 20cm inter row spacing. On the other hand, from the narrowest (5cm) intra row spacing the lowest number of seeds per pod (1.12) was recorded and the highest number of seeds per pod (1.19) was recorded at the 15cm intra row spacing. The main effects of inter row spacing and intra row spacing were highly significant on the hundred seed weight. The widest inter row spacing (50cm) gave the highest hundred seed weight (25.38 g)while the narrower inter row spacing (20cm) gave the lowest hundred seed weight (21.58 g).

Interaction effects of inter- and intra- row spacing had a highly significant effect on the harvest index. For all of the inter row spacing the harvest index was increased as the intra row spacing increased. The interaction effect of inter row and intra row spacing had also a highly significant effect on the aboveground dry biomass yield. The highest above ground dry biomass (10650.27 kg ha^{-1}) was recorded at 20cm×5cm spacing while the lowest number of above ground dry biomass (2186.69 kg ha^{-1}) was recorded at 50cm×15cm spacing.

The interaction effect of the two factors was highly significant on grain yield. The interaction of 30cm inter- and 10cm intra-row spacing gave the highest grain yield (1219 kg ha^{-1}) which was statistically at par with the grain yield obtained with the interactions of40cm×5cm, 30cm× 15cm and 20cm× 15cm spacing. On the other hand, the lowest grain yield (733 kg ha^{-1}) was recorded with the interaction of 50cm× 15cm which was statistically at par with the yield obtained with the interaction of 40cm× 15cm spacing.

In conclusion, the results from the study indicated that inter row spacing and intra row spacing had a significant influence on the phenology, growth, yield components and yield of chickpea. The inter row and intra row spacing of 20cm×15cm, 30cm×10cm, 30cm x 15cm and 40cm ×5cm showed no significant differences in grain yield. But among these spacing combinations, 30cm × 10cm or 30cm × 15cmspacing can be tentatively suggested for the area. However, as this is one season experiment at one location, the experiment has to be repeated over locations and seasons with inclusion of more varieties to reach at a more reliable conclusion.

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