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Influence of Inter and Intra Row Spacing on Yield and Yield Components of Chickpea (*Cicer arietinum* L.) in Jimma Horro District, Western Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author BC designed the study, performed the field experiment, generated data and wrote the whole manuscript. Author TA performed the statistical analysis, edited, read and approved the final manuscript. Author BN read and approved the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Improved agronomic practices increases yield potential of chickpea in different agroecology of the country. In this view a field experiment was conducted to assess the influence of inter-and intra row spacing on yield and yield components of chickpea (*Cicer arietinum* L.) in Jimma Horro district of Kellem Wollega Zone, Western Oromia, Ethiopia. The treatment consisted of three inter-row spacing (20, 30 and 40 cm) and four intra-row spacing (5, 10, 15 and 20 cm). The experiment was laid out in a randomized complete block design in factorial arrangement with three replications. The highest (52) number of pods plant^{-1} was obtained with the interaction effect of 40 cm inter and 20 cm intra row spacing. The highest dry biomass (8457 kg ha^{-1}) was recorded at 20 cm × 5 cm spacing while the lowest dry biomass (5413 kg ha^{-1}) was recorded at 40 cm × 20 cm spacing

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combination. Significantly higher (248 g) 1000 grain weight was recorded under 40 cm with 20 cm spacing and lowest (165 g) 1000 grain weight under 30 cm x 5 cm row spacing. The highest (1625 kg ha^{-1}) seed yield of chickpea was obtained from 30 cm x 15 cm and the lowest seed yield (1096 kg ha^{-1}) was recorded from 20 cm x 5 cm row spacing. The highest harvest index (34.03%) was achieved for the interaction of 40 cm inter- and 20cm intra-row spacing and the lowest harvest index (12.14%) under 20 cm x 5 cm row spacing. Thus 30 cm inter-row with 15 cm intra-row spacing can tentatively be recommended for the production of chickpea in the study area as compared to the current recommendation of 30 x 10 cm. Further research would be needed at more locations and seasons to give conclusive recommendations.

Keywords: Inter row spacing; intra row spacing; chickpea; seed yield; dry biomass.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most important grain, self-pollinating legume crop, and it is a basic component of the human diet in many countries [1]. The leading chickpea producing countries in the world are India, Pakistan, Mexico, Turkey, Ethiopia and Myanmar [2]. Chickpea 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 [3]. Ethiopia is ranked seventh in the world for production and accounts for over 90% of chickpea production in sub-Saharan Africa [4]. Both (Desi and Kabuli) seed types of chickpea are grown in Ethiopia [5]. Despite the fact that Ethiopia's agroclimatic conditions are suitable for both types, but traditional Desi chickpea was cultivated [6]. International markets favor the Kabuli types and offer higher prices for them, this has attracted attention in Ethiopia, and steps have been taken to increase Kabuli production and export [7].

In Ethiopia, pulse crops are important components of crop production in smallholders' agriculture, providing economic advantage and as an alternative source of protein, cash income, and food security. In 2017/18 cropping season pulses covered 12.61% (1,598,806.51 hectares) of the grain crop area and 9.73% (about 29,785,880.89 quintals) of the grain production [8]. Chickpea is the third most widely cultivated pulse crop in terms of area coverage 1.91% (about 242,703.73 hectares), and production 1.63% (4,994,255.50 quintals) and yield 2.06 t ha^{-1} [8]. Chickpea is widely grown across the country and serves as a multi-purpose crop [9] and it plays a significant role in improving soil fertility by fixing the atmospheric nitrogen in the smallholder farming systems in Ethiopia.

The optimum planting density for chickpea varies with location, the growing conditions, and growth habit of the variety. The use of a low seeding rate has no significant effects on seed yield due to the capacity of the crop to produce a large number of branches to compensate for low plant population. However, it is essential to use high seed rate in ensuring good plant stand under adverse environmental conditions. The recommendation for row planting of chickpea indicates a spacing of 30 cm between rows and 10 cm between plants which gives a density of about 333,334 plants ha^{-1} [10]. A reduced spacing between the plants can be used for varieties that are more erect and hence plant density can be increased. However, the seed rate by broadcast application method appears to be varying depending upon the seed size of the cultivars and growth habit. High seed rates (120-140 kg ha^{-1}) for large-seeded and low seed rates (65-75 kg ha^{-1}) for varieties with small seed size are recommended [11]. The reduced plant population will be increasing the performance of individual plant. However, this does not indicate that maximum productivity as per a given area of land because of the inefficient utilization of plant growth factors such as moisture, air, space (land). Increased plant population by reducing plant spacing beyond a certain limit, will not also result in a maximum productivity due to the effect of increased competition for plant growth factors [12]. In short, too dense plant population resulted from reduced inter and intra-row spacing and fewer plant population resulted from increased inter and intra-row spacing will adversely affect productivity per a given area of land. Higher plant population is producing taller, spindly, and more susceptible to lodging [13].

Indeed, there will be a need to evaluate the performance of chickpea variety in varying inter and intra row spacing to determine the optimum density of the crop plants for maximum yield in the study area. In the study area, no research work has been done on the interaction effects of various agronomic practices such as inter and intra spacing of Chickpea. Thus, knowing the inter row and intra row spacing recommendation for chick pea in the studying area could be improve the yield and yield components for small holder farmers. The objective was to determine the effect of inter and intra row spacing and their interaction on yield and yield components of chickpea in Jimma Horro District, Kellem Wollega, Western Ethiopia.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The field experiment was conducted in Nunu Inaro Keble Farmers Training Center in Jimma Horro district, Oromia Regional National State, Western Ethiopia in 2019/20 cropping season. It is situated in the Western Parts of Ethiopia Oromia region, Kellem Wollega, at the distance of 652 km away from Finfinnee and 133 km distance away from Kellem Wollega. It lies between 9°6' N latitude, 34° 30' E Longitude and at an altitude of 1600 meter above mean sea level and receiving mean annual rainfall of 1300 mm with unimodal distribution. The rainy seasons ranges from March to October and maximum rain is received in the months of June to August. In the study area, semi humid climate reported with mean minimum and mean maximum temperatures of 23 and $34°_C$, respectively. The soil of the area is characteristically clay loam, with a pH of 7. Agroclimatic classification of the area has Dega (19.5%), Woina Dega (48.7%) and Kola (31.8%) [14].

2.2 Planting Materials

Improved seed of Kabuli chickpea (Habru) variety from the Debre Zeit Agricultural Research Center was used for the experiment. The variety was released from Debre Zeit Agricultural Research Center in 2004 E.C. The Habru variety can be adapted to an altitude of 1,600 - 2,600 m with annual rainfall of 700-1200 mm and takes 93-150 days to reach physiological maturity [10].

2.3 Treatment and Experimental Design

The treatments consisted of three inter row spacing (20, 30 and 40 cm) and four intra row spacing (5, 10, 15 and 20 cm). The experiment was laid out in randomized complete block design in 3 × 4 factorial arrangement with three replications, and a total of twelve treatment combinations. The plot size was 2.4 × 1.8 m^2.

2.4 Experimental Procedure and Crop Management

A clean seed of Kabuli Chick pea was used for planting. The selected land was cleaned, properly and ploughed using oxen and prepared to a depth of 25-30 cm during initial ploughing and two additional ploughing was done and one ploughing done during sowing. Leveled properly with the traditional hoe with human labour. The inter and intra row spacing were 20, 30, 40 cm and 5, 10, 15 cm, 20 cm, respectively. The recommended seed rate 130 kg ha^{-1} was used for chickpea. The sowing was done in 28 August 2019 and similar all agronomic activities and packages of practices of the crop were applied to all the experimental plots for the better crop stand.

2.5 Data Collection

I. Number of pods per plant was counted for 5 randomly taken plants found in net plot at the maturity time and the average was recorded.
II. Number of seeds per pod was averaged from five randomly taken plants in each net plot by counting all the number of seeds for each plant.
III. Dry biomass was obtained from 48 hrs and sun dried five randomly selected sample plants per plot.
IV. 1000 grain weight was counted by taking sample seeds randomly per net plot area at harvest and the weight of 1000 seeds was taken and adjusted to 10% moisture level.
V. Grain yield: Crop harvested from the net plot area were dried in sun and were cleaned, weighed and converted in to seed yield in kg ha^{-1}. The weight was adjusted to 10% moisture level.
VI. Harvest index was computed as a ratio of seed yield (kg ha^{-1}) to dry biomass yield (kg ha^{-1}) *100.

2.6 Data Analysis

All the data collected were computerized and analyzed using SAS computer software package version 9.0 [15]. Mean separation were computed using Least Significance Difference at 5% probability level [16].

3. RESULTS AND DISCUSSION

3.1 Number of Pods per Plant

The analysis of variance showed that both the main effects of inter and intra row spacing and their interactions had highly significant (P<0.01) effect on the mean number of pods per plant of chick pea (Table 1). The highest (52) number of pods plant-^{1} of chick pea was obtained with the interaction effect of 40 x 20 cm inter and intra-row spacing, which had as par with the interaction of 20 x15 cm, 20 x20 cm, 40 x 15 cm and 40 x 20 cm inter- and intra- row spacing respectively. The lowest (9) number of pods plant^{-1} of chick pea was obtained at 20 x 5 cm inter and intra row spacing (Table 1).

The difference among the inter row spacing in response to intra row spacing on mean number of pods per plant of chick pea might be due to the fact that, as the plant population increased (narrower spacing), there was high competition for the growth factors as compared to wider spacing; and this has an impact on the branching habit of plants which had direct impact on the number of pods per plant. The reduced competition for light and reduced overlapping from adjacent 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} [17]. Similarly, [18] reported that number of pods plant-^{1} was higher at wider spacing of 40 cm inter-row with 10 cm intra- row spacing and 50 cm inter-row with 10 or 15 cm intra row spacing as compared to the closest spacing of 20 cm inter with 5 cm intra-row spacing. 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 [19]. Similarly, [20] 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 in faba bean.

3.2 Number of Seeds per Pods

The main effects of inter- and intra- row spacing revealed highly significant (P<0.01) effect on the mean number of seeds per pod of chick pea but their interaction effects showed non-significant (P<0.05) (Table 2).The main effects of 40 cm inter- and 20 cm intra- row spacing gave higher (1.63) and (1.57) number of seeds per pod of chick pea, respectively. The lowest (1.26) number of seeds per pod was recorded at 20 cm inter- row with 5 intra row spacing (Table 2). Similarly, [21] reported that the number of seeds per pod increased with decreased plant density (wider spacing) of faba bean. In contrary, [22] showed that the highest number of seeds per pod was obtained at the narrowest spacing of 20 cm with 10 cm for *Arertie* cultivar of chickpea. [23] also showed non-significant effects of seeding densities on the number of seeds per pod of chickpea. But in our study highest number of seeds per pods found in wider inter and intera 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 [21,24]. Moreover, in safflower higher number of seeds per pod was reported in association with wider inter and intra-row spacing [25]. 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 [19]. Similarly, numbers of seeds per pod were also significantly affected by main effect of intra row spacing. Mung bean crops planted at 20 cm intra row spacing gave the highest number of seeds per pod, while minimum numbers of seeds per pod were recorded in intra row spacing of five cm.

3.3 Dry Biomass Yield

The main effects of inter row spacing and intra row spacing showed a highly significant (P<0.01) effect on dry biomass of chick pea but the interaction had non-significant effect (Table 3). The highest dry biomass (7607 kg ha^{-1}) was recorded from 20 cm inter row spacing. Significantly higher (8457 kg ha-^{1}) dry biomass of chick pea was recorded from 5 cm intera row spacing. The lowest dry biomass (6004 and 5413 kg ha^{-1}) of chick pea was recorded from 40cm inter row spacing and 20 cm intera row spacing (Table 3). The highest number of mean dry biomass was recorded as the intra row spacing decreased.

The highest mean dry biomass at the highest density of plants might be due to a greater number of plants per unit area. However, if the number of plants per unit area keeps on increasing, the dry biomass will reduce as there is lodging problem and lower photosynthetic

Table 1. Interaction effects of inter and intra row spacing on the number of pods per plants of chick pea in Jimma Horro District

Inter row spacing (cm)	Intra row spacing (cm)				
	5	**10**	**15**	**20**	**Mean**
20	9^{g}	22^{f}	22^{f}	25^{f}	19.183^{c}
30	30^{e}	36^{d}	43^{c}	45^{c}	38.433^{b}
40	33^{de}	48^{b}	52^{a}	52^{a}	46.267^{a}
Mean	24^{c}	35.311^{b}	38.778^{a}	40.422^{a}	
	Inter row spacing	**Intra row spacing**		**Intra x inter row spacing**	
LSD (5%)	1.6852	1.9459		3.3704	
CV (%)	5.75				

Mean values within the same columns followed by the same letters are not significantly different 5% probability level

Table 2. Main effects of inter and intra row spacing on number of seeds per pods of chick pea in Jimma Horro District

Treatments	Number of seeds per pods
Inter row spacing (cm)	
20	1.2583^{c}
30	1.5083^{b}
40	1.6250^{a}
LSD (5%)	0.0464
Intra row spacing (cm)	
5	1.3111^{c}
10	1.4556^{b}
15	1.5222^{a}
20	1.5667^{a}
LSD (5%)	0.0536
CV (%)	3.74

Mean values within the same columns followed by the same letters are not significantly different at 5% probability level

Table 3. Main effects of inter and intra row spacing on dry biomass yield of chick pea in Jimma Horro District

Treatments	Dry biomass yield (kg ha^{-1})
Inter row spacing (cm)	
20	7607^{a}
30	6735^{b}
40	6004^{c}
LSD (5%)	270.90
Intra row spacing (cm)	
5	8457^{a}
10	7256^{b}
15	6001^{c}
20	5413^{d}
LSD (5%)	312.80
CV (%)	4.72

Mean values within the same columns followed by the same letters are not significantly different at 5% probability level

efficiency in highly crowded plant population [21]. Likewise, [11] reported that dry biomass per ha was significantly increased with increased plant density (40 cm ×10 cm) on haricot bean. Similarly, [26] reported that 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. Biological yield increased with an increase in seed rate, which may be the result of increased plant population. Biological yield is known to increase with increased plant population [27].

3.4 1000 Grain Weight

The main effects of inter row and intra-row spacing showed highly significant (P<0.01) effect on 1000 grain weight of chick pea whereas their interaction was also significant (P<0.05) on 1000 grain weight of chickpea (Table 4). The highest 1000 grain weight (248 g) of chick pea was recorded from 40 x 20 cm inter row spacing and intera row spacing. The use of 30 cm inter row spacing and 5 cm intera row spacing for planting of chick pea resulted in significantly low 1000 grain weight (165) of chick pea as compared to the other inter row spacing (Table 4). This indicates that closer inter-row spacing (30 cm) resulted in reduced 1000 grain weight.

The highest 1000 grain weight (208) was scored from 20 cm intra- row spacing while 5cm intra-row spacing produced the lowest 1000 grain weight (170). This indicates that 20 and 15 cm intra-row spacing were resulted in higher 1000 grain weight as compared to 5 and 10 cm intra-row spacing. Likewise, [19] reported higher hundred seed weight in the wider inter-row spacing of 45 cm than 30 cm inter- row spacing of chickpea. Similarly, [18] indicated that the highest hundred seed weight at 50 cm as compared to 20 cm inter-row spacing. He also further stated that that hundred seed weight was increased with an increase in intra-row spacing. 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 [17]. 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 in haricot bean [26]. Similarly, [28-31] reported that hundred seed weight of faba bean was negatively related with plant density. Higher hundred seed weight (29.87 g) was reported in the wider inter row spacing of 45 cm than 30 cm inter row spacing of chickpea [19]. [32] reported highest 1000-seeds weight at 45 cm and 60 cm inter row spacing compared to 30 cm inter row spacing.

3.5 Seed Yield

The main effects of inter- and intra-row spacing and their interactions showed significant (P<0.01) effect on mean seed yield of chick pea (Table 5). The interaction of 30 cm x 15 cm inter- and intra- row spacing gave the highest (1625 kg ha^{-1}) seed yield and had statistically at par with 30 x20 cm inter and intera row spacing. The lowest seed yield (1096 kg ha^{-1}) of chick pea was recorded with interaction of 20 x 5 cm. Similarly, [33] reported that extremely higher population (20 cm with 5 cm) and the narrowest inter-row spacing could cause in yield reduction which might be due to intense intra and inter-plant competition. Furthermore, he stated that too narrow or too wide spacing affect yield due to competition for plant growth resources such as moisture, nutrient air circulation, and shading effect.

Table 4. Interaction effects of inter and intra row spacing on thousand grain weight of chick pea in Jimma Horro District

Inter row spacing (cm)	Intra row spacing (cm)				
	5	10	15	20	Mean
20	170^{gh}	177^{fg}	182^{ef}	208^{c}	184.17^{b}
30	165^{h}	188^{de}	192^{d}	193^{d}	184.58^{b}
40	178^{f}	215^{c}	235^{b}	248^{a}	219.17^{a}
Mean	171.11^{d}	193.33^{c}	202.78^{b}	216.67^{a}	

	Inter row spacing	Intra row spacing	Inter x Intra row spacing
LSD (5%)	3.9283	4.5360	7.8566
CV (%		2.37	

Mean values within the same columns followed by the same letters are not significantly different at 5% probability level

Table 5. Interaction effects of inter and intra row spacing on the seed yield of chick pea in Jimma Horro District

Inter row spacing (cm)		Intra row spacing (cm)				
		5	10	15	20	Mean
20		1096^{f}	1159^{ef}	1178^{e}	1211^{e}	1161.3^{b}
30		11500^{ef}	1371^{d}	1625^{a}	1610^{ab}	1438.7^{a}
40		1201^{e}	1510^{c}	1556^{bc}	1525^{c}	1448.1^{a}
Mean		1149.0^{c}	1346.7^{b}	1453.0^{a}	1448.8^{a}	
	Inter row spacing	**Intra row spacing**		**Inter x Intra row spacing**		
LSD (5%)	32.051	37.009		64.102		
CV (%)		2.81				

Mean values within the same columns followed by the same letters are not significantly different at 5% probability level

Even though the yield per individual plant was higher in wide inter- and intra-row spacing, but reduced plant population showed decrease grain yield of chickpea. Also, [34,35] reported that increased yield from higher plant populations are primarily the result of increased light interception during grain-filling by the crop canopy of soybean. The yield per unit area was increased with increasing plant density due to efficient utilization of growth factors [27]. Similarly, [36] reported that 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. [33,37] reported that too narrow or too wide spacing affect yield due to competition for resources and shading effect.

The yield reduction can occur due to inefficient utilization of the growth factors in too wide spacing. The seed yield increase as both inter and intra row spacing increased to their maximum value in this study indicating that the current recommended spacing of 30 cm inter row at 15 cm intra row spacing is best to produce highest seed yield per hectare at the study area. Also, [17] reported that there was increased yield from wider spacing of 30 cm inter row with 10 cm intra row than extremely wider (50 cm with 15 cm) and extremely narrower spacing of 20 cm inter row at 5 cm.

Similarly, [38,39] reported that increase in yield by increasing the row and plant spacing's. [38,40,41] reported that the optimum plant population appeared to be about 33 plants per m^2. [42] reported that maximum seed yield (1.63 t ha^{-1}) in 30 cm × 10 cm spacing treatment while, the lowest (1.10 t ha^{-1}) was found in 20 cm × 10 cm spacing treatment. Comparing three rows spacing viz. 30, 45 and 60 cm. [32] reported that mung bean sown at inter row spacing of 30 cm gave maximum seed yield (675.84 kg ha^{-1}) while minimum seed yield was recorded at inter row spacing of 60 cm. Meanwhile, [43] recommended 30 cm inter row and 10 cm intra row spacing for maximum seed yield and harvest index.

3.6 Harvest Index

Main effects of inter row spacing, intra row spacing and their interaction was showed significant ($P<0.05$) difference on mean harvest index of chick pea (Table 6).The highest mean harvest index (34.03%) of chick pea was obtained from interaction of 40 x20 cm inter and intra row spacing which was statistically at par with 20 × 5 cm, 20 x 10 cm, 20 x 20 cm, 30 × 5 cm, 40 x 5 cm, respectively. The lowest harvest index (12.14%) of chick pea was obtained with the narrowest inter- and intra- row spacing, i.e. 20 × 5 cm. 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. Similarly, [19] reported that maximum harvest index (41.66%) in the highest row spacing (45 cm) of chickpea than 15cm row spacing.

3.7 Pearson Correlation of Yield and Yield Component of Chick Pea Due to Inter Row Spacing and Intra Row Spacing

Correlation analysis between yield and yield component of chick pea due to inter row spacing and intra row spacing revealed strong and positive associations between more components (Table 7). Significantly, higher and positive correlation coefficients were observed between number of pods per plants with grain yields (0.88) and number of seeds per pods (0.93) (Table 7). This indicated that the higher the number of pods per plants the higher would be effective the

Table 6. Interaction effects of inter and intra row spacing on the harvest index of chick pea in Jimma Horro District

Inter row spacing (cm)		Intra row spacing (cm)				
		5	10	15	20	Mean
20		12.14 [g]	13.13 [g]	17.13 [ef]	19.23 [e]	15.40c
30		14.00 [g]	19.24 [e]	26.47[c]	29.67 [b]	22.35[b]
40		14.84[fg]	23.54 [d]	31.51[ab]	34.03 [a]	25.98[a]
Mean		13.66[d]	18.64[c]	25.04[b]	27.64[a]	
	Inter row spacing	**Intra row spacing**		**Inter x Intra row spacing**		
LSD (5%)	1.3543	1.5638		2.7086		
CV (%)		7.53				

Mean values within the same columns followed by the same letters are not significantly different 5% probability level

Table 7. Pearson correlation of yield and yield component of chick pea due to inter and intra row spacing

	NPP	NSP	DBM	TGW	GY	HI
NPP	0.93**	-0.77**		0.73**	0.88**	0.84**
NSP		0.79**		0.73**	0.82**	0.83**
DBM				-0.85**	-0.79**	-0.95**
TGW					0.64**	0.83**
GY						0.89**
HI						

NPP= Number pods per plant, NSP= Number of seeds per pod, DBM= Dry biomass, TGW= Thousand seed weight, GY= Grain yield, HI=Harvest index

number of pods per plant and grain yield. Negative correlation coefficient was observed between number of pods per plants with dry biomass yields (-0.77). Significantly higher and positive correlation coefficient was observed between number of seeds per pods with grain yields (0.82) and harvest index (0.83) (Table 7). Negative correlation coefficient was observed between number of seeds per pods with dry biomass yields (-0.81), with thousand grain weights (-0.79), grain yield (-0.85) and harvest index, (-0.95). Significantly positive associations between dry biomass weight with number of pods per plants (0.73), number of seeds per pods (0.73) and harvest index (0.83). Grain yields in chickpea are strongly and positively correlated with the number of pods and seeds [44,45]. With increased plant population, the green area index, intercepted radiation, radiation use efficiency and total intercepted photo synthetically active radiation increase [46] thereby resulting in higher grain yields.

Also, [47] reported a direct relationship between 1000-grain weight and number of pods with yield. The grain yield per plant exhibited a significant positive correlation with grain yield and the number of pods. Yield and its components are multigenic traits, which are strongly influenced by the environment and other factors both known and yet to be identified [48]. [49] indicated in his results of the simple correlation between grain yield and yield components of chickpea is showed that the grain yield exhibited a significant positive correlation with the number of pods. Seed size on yield and 1000 seed weight was significant; large seeded chickpea produced more seed yield and larger seed of chickpea [50]. In conclusion, yield and yield component of chickpea had positive relationship with grain yield of chickpea indicated that yield components of chickpea directly influenced the grain yield of chickpea.

4. CONCLUSION

The mean number of pods per plants was significantly affected by inter-row and intra-row spacing and their interactions. Main effects of inter and intra row spacing were produced significantly higher (7606 and 8457 kg ha^{-1}) mean dry biomass of chick pea with 20 cm inter row spacing and 5 cm intera row spacing. Higher dry biomass of chickpea was recorded with decreased intra row spacing. Thousand seed weight of chick pea was significantly improved with inter- and intra-row spacing and their interactions and highest (248 g) was obtained with 40 cm with 20 cm inter and intera row spacing. The interactions of 30 cm with 15 cm inter- and intra- row spacing was produced higher (1625 kg ha^{-1}) seed yield of chick pea. Significantly improved mean harvest index and higher (34.03%) of chick pea was obtained from 40 cm inter- and 20 cm intra row spacing. Thus, 30 cm inter-row with 15 cm intra-row spacing can tentatively be recommended as best for production of chickpea in the study area as compared to the current recommendation of 30 x 10 cm. Conclusive recommendation could be obtained if the study is repeated at more locations and seasons. Further study over years, locations and different chickpea varieties to suggest valid recommendation for the area.

DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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