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Effects of Inter Row and Intra Spacing on Phenology, Growth and Yield of Chickpea (*Cicer arietinum* L.) In Jimma Horro District, Western Ethiopia

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Abstract: The basic agronomic practice to improve yield potential of chickpea is identification of optimum plant spacing. A field experiment was conducted to assess the effects of inter row and intra spacing on phenology, growth and yield of chickpea (*Cicer arietinum* L.) in Jimma Horro district of Kellem Wollega Zone, Western Oromia, Ethiopia. The treatment consisted of three inter-rows 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. Main effects of intra-row spacing and inter-row spacing were showed significant effect on seed emergency of chickpea. Significantly higher mean days to 50% flowering (73) and days to physiological maturity (132) the lowest (67 days) and (116 days) were recorded at 20 cm inter-row and 5 cm intra row spacing. The interaction effects of inter-row and intera row spacing were significant affected mean plant height of chickpea. The tallest plant height (73cm) was recorded from 20 cm inter-row spacing with 5cm intera row spacing. Significantly the highest (4) number of primary branches plant^{-1} of chickpea was recorded from 40 cm inter- with 15 cm intra- row spacing, whereas, the lowest (2) number of primary branches plant^{-1} was recorded under 20 cm inter with 5 cm intra-row spacing. The highest (23) and lowest (9) number of secondary branches plant^{-1} was obtained from 40 cm inter-row with 20 cm intra-row and 20 cm inter-row with 5 cm intra-row spacing. Significantly the highest (1625 kg ha^{-1}) seed yield of chickpea was obtained from 30cm x 15 cm and the lowest seed yield (1096 kg ha^{-1}) was recorded from 20cm x 5cm row spacing. Thus 30 cm inter-row with 15 cm intra-row spacing can tentatively be recommended for production of chickpea in the study area as compared to the current recommendation of 30 x 10 cm. To give conclusive recommendation the study is repeated at more locations and seasons.

Key words: Inter-Row Spacing · Intra-Row Spacing · Chickpea

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]. It is originated in the present day of South eastern Turkey and joined to Syria [2]. The leading chickpea growing countries in the world are India, Pakistan, Mexico, Turkey, Ethiopia and Myanmar [3]. 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 [4]. Ethiopia is ranked seventh in the world for production and accounts for over 90 % of chickpea production in sub-Saharan Africa [5]. Both (Desi and Kabuli) seed types of chickpea are grown in Ethiopia [6]. Despite the fact that Ethiopia's agroclimatic conditions are suitable to both types, traditionally only Desi chickpea was cultivated [7]. Bekele and Hailemariam [8] Kabuli type chick pea varieties are the most important crop in terms of local and export markets due to their large-seeded type.

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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 [9].

In Ethiopia, pulse crops are important components of crop production in Ethiopia's smallholders' agriculture, providing economic advantage and as alternative source of protein, cash income and food security. The crops have been used for many years in crop rotation practices. Some of them have been also played an important role in the export sector for generating foreign currency for the country. Pulses are grown in 2017/18 cropping season 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 [10]. 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} [10]. Chickpea is widely grown across the country and serves as a multi-purpose crop [8] and it plays a significant role in improving soil fertility by fixing the atmospheric nitrogen in smallholder farming system in Ethiopia.

The optimum planting density for chickpea varies with location, the growing conditions and growth habit of the variety. Low seeding rate has no significant effects on seed yield due to the capacity of the crop to produce 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} [11]. A reduced spacing between the plants can be used for varieties that are more erect and hence plant density can be increased. However, 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 [12]. It is obvious that reduced plant population will be increase the performance of individual plant. However, this does not indicate that maximum productivity as per a given area of land because of inefficient utilization of plant growth factors such as moisture, air, space (land). In the same manner, increased plant population by reducing plant spacing beyond certain limit, will not also resulted in a maximum productivity due to the effect of increased competition for plant growth factors [13]. 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. The objective of spacing in crop plants is to be obtaining the maximum yield on a unit area without sacrificing quality. If the plant population is too high, plants will be tall, spindly and more susceptible to lodging [14]. There was highly significant ($P<0.01$) effect of both inter row and intra row spacing on days to 50% flowering and days to 90% maturity of chickpea [15]. Also, Melaku [15] found that interaction effect of inter row and intra row spacing was showed significant effects on plant height, number of primary branches and grain yield of chickpea. He further stated that for all of the inter row spacing, the number of primary branches was increased as the intra row spacing increased. The 30 cm x10 cm inter and intra row spacing gave significantly higher 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 [15]. Panwar *et al*. [16] reported that the use of 45 cm row spacing increased chickpea yield as compared to 30 and 50cm spacing while others indicated that row spacing had no significant effect on seed yield.

Indeed, a need to evaluate the performance of chickpea variety in varying inter row and intera spacing to determine optimum density of the crop plants for maximum yield in the study area. Number of plants per unit area influences plant size, yield components and ultimately the seed yield [17]. Also, the study area of farmers challenge on chick pea crop spacing. In addition, no research work has been done on the interaction effects of various agronomic practices such as inter and intera spacing of Chickpea in Jimma Horro District, Kellem Wollega Zone, Western Ethiopia. Determining appropriate crop geometry is therefore one of the most important crop management activities which improves the performance and productivity of chickpea [15]. Thus, knowing the inter row and intera spacing recommendation for chick pea in the studying area could be improve the phenology, growth and yield chickpea for small holder farmers. The objectives were to determine the effect of main and interaction effects of inter and intra row spacing on phenology, growth and yield of chick pea Jimma Horro District of Kellem Wollega Zone, western Oromia, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area: The field experiment was conducted in Nunu Inaro Keble (FTC) 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 sea level and receiving mean annual rain fall 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. The soil of the area is characteristically clay loam, with a PH of 7. Agro climatic classification of the area has Dega (19.5%), Woina Dega (48.7%) and Kola (31.8 %) [18].

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.a.s.l. with annual rainfall of 700 -1, 200 mm and takes 93 - 150 days to reach physiological maturity [11].

Treatment and Experimental Design: The treatments consisted of three inter row spacing (20, 30 and 40 cm) and four intera- spacing (5, 10, 15 and 20 cm). The experiment was laid out with randomized complete block design in 3 × 4 factorial arrangement with three replications where a total of twelve treatment combinations. The plot size was 2.4 x1.8 = 4.32m^2 .

Experimental Procedure and Crop Management: A clean seed of Kabuli Chick pea was used for planting. The selected land was l 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 labor. The inter row and intera spacing were 20, 30, 40 and 5, 10, 15, 20 cm respectively. The time of sowing was done in the month of August on dated 28 and similar all agronomic activities and packages of practices of the crop were applied to all the experimental plots for the better crop stand.

Data Collection: Days to 50% emergence: was recorded as number of days from planting to the time when 50% of the seedlings in plots emerged from the soil through visual observation.

Days to 50% Flowering: Was recorded as the number of days from the sowing to the time when 50% of the plants in a plot will produce flowering.

Days to 90% Physiological Maturity: Was recorded in each plot, as the number of days from planting to when 90 % of the plants in a plot showed drying of the leaves and the pods turned to yellow color.

Plant Height: Was recorded from 5 randomly sampled plants per net plot at physiological maturity where plants were measured from the base to the tip of main stem and was expressed on the per plant basis.

Number of Primary Branches per Plant: Was counted at the time of physiological maturity of the crop for 5 randomly taken plants found in net plot and the average was recorded.

Number of Secondary Branches per Plant: Was counted at the time of maturity for 5 randomly taken plants found in net plot and the average was recorded.

Grain Yield: Seeds 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.

Data Analysis: All the data collected were analyzed using properly managed using the Excel computer software and analyzed using SAS computer software package version 9.0 [19]. Mean separation were computed using Least Significance Difference at 5 % probability level [20].

RESULTS AND DISCUSSION

Days to 50% Emergency: Both intra row spacing ($P<0.01$) and inter row spacing ($P<0.05$) on seed emergency of chick pea but interactions of inter and intra row spacing showed non-significant effect on seed emergency (Table 1). Inter-row spacing increased from 20 to 40 cm days to emergency was decreased from 6.42 to 6 days. Five cm intra-row spacing and 20 inter row –spacing was hastened germination (5.56 and 6 days)

Table 1: Main effects of inter-row and intera row spacing on days to 50% emergency of chick pea in Jimma Horro District

Treatments	Days to 50 % emergency
Inter-row spacing(cm)	
20	6.[b]
30	6.42[a]
40	6.42[a]
LSD (5%)	0.309
Intera-row spacing (cm)	
5	5.56[b]
10	6.33[a]
15	6.56[a]
20	6.67[a]
LSD (5%)	0.357
CV (%)	5.83

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

Table 2: Interaction effects of inter row and intera row spacing on the days to 50% flowering of chick pea in Jimma Horro District

	Intera row spacing (cm)				
Interrow spacing (cm)	5	10	15	20	Mean
20	67.000[e]	67.000[e]	67.000[e]	67.000[e]	67.000[c]
30	67.000[e]	68.667[d]	70.333[c]	71.333[b]	69.333[b]
40	71.333[b]	72.333[a]	72.667[a]	72.667[a]	72.250[a]
Mean	68.444[c]	69.333[b]	70.000[a]	70.333[a]	
	Inter row spacing	Intera row spacing	Inter row spacing X Intera row spacing		
LSD (5%)	0.4980	0.5750	0.9960		
CV (%)	0.85				

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

lowest germination was obtained (6.42) was recorded at 40 cm inter-row spacing. This might be due to the fact that narrower inter and intra-row spacing had a better competition nutrient than as compared to wider inter and intra-row spacing resulting in more hastened days to reach 50% emergency. Due to competition of nutrient hastened germination. In contrary, Amato *et al*. [21] reported that seed germination and establishment rate of faba bean were not affected by the seeding rate.

Days to 50% Flowering: The main effect of inter and intra row spacing and their interaction was showed highly significant ($P<0.01$) effect on mean days to 50% flowering of chick pea (Table 2). Mean days to 50% flowering of chick pea was delayed (73 days) and hastened (67 days) with 40 x 20 cm inter-and intra-row spacing and 20cm inter row spacing with 5cm intera row spacing respectively (Table 2). Mean days to 50% flowering of chick pea was delayed (70 days) and hastened (68 days) with 20 cm and 5 cm intra-row spacing respectively (Table 2). This might be due to the fact that wider inter and intra-row spacing had a better light interception as compared to narrower inter and intra-row spacing resulting in a greater number of days to reach 50% flowering stage as chickpea needs direct sunlight coverage for its various physiological process. This indicates surface area available in wider row spacing might have caused the crop to flower late as compared to those crops planted in relatively closer spacing.

The hastened time of flowering in narrower inters and intra-row spacing might be due to competition for nutrients, moisture and space. In contrary, Farag [22] reported that the wide plant spacing of 50cm reduced number of days to flower in broad bean than 40cm plant spacing. Melak [15] also reported that a day to 50% flowering was significantly decreased from 50.67 to 49.56 days as the inter-row spacing increased from 20 cm to 50 cm. 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 [23, 24]. 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.

Days to 90% Physiological Maturity: Significant ($P<0.01$) effect due to inter and intra row spacing and their interaction on mean days to 90% physiological maturity of chick pea (Table 3). Mean days to 90% physiological

Table 3: Interaction effects of inter row and intera row spacing on the days to 90% physiological maturity of chick pea in Jimma Horro District

	Intera row spacing (cm)				
Inter row spacing(cm)	5	10	15	20	Mean
20	116^{h}	119^{ef}	120^{e}	120^{e}	118.92^{c}
30	117^{gh}	119^{ef}	123^{d}	124^{d}	120.75^{b}
40	117^{h}	125^{c}	129^{b}	132^{a}	125.75^{a}
Mean	116.67^{d}	121.00^{c}	124.22	125.33^{a}	
	Inter row spacing	Intra row spacing	Inter row spacing X Intra row spacing		
LSD (5%)	0.8326	0.9615	1.6653		
CV (%)	0.81				

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

maturity of chick pea was delayed (132 days) under 40 cm inter- and 20 cm intra-row spacing respectively while it was hastened (116 days) under 20 cm inter-row and 5 cm intra-row spacing respectively (Table 3). There was significant difference between 30 and 20 cm inter-row spacing and among 10, 15 and 20 cm intra-row spacing on days to 90 % physiological maturity of chick pea. Similarly, Valimohammadi *et al.* [25] reported that there is a steady increase in the number of days to maturity with increased intra-row spacing. Also, Alemayehu [26] indicated that a respective increase in inter-row and intra-row spacing from 20 to 40 cm and 10 to 15 cm increased days to 90% physiological maturity.

On the other hand, the crop matured was delayed where the crop was planted at wider inter row spacing and intra row spacing. The effect of inter and intra row spacing on mung bean phenology has been reported by different authors. Ahmed *et al.* [27] reported that mung bean crop planted maintaining inter and intra row spacing of 30cm and 20cm, respectively, matured earlier than in inter and intra row spacing of 40 cm and 10 cm, respectively.

The narrowest inter row spacing (20cm) hastened days to attain physiological maturity which was significantly enhanced by wider spacing of 30, 40 and 50 cm spacing. 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 [28]. 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 [29].

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 [29]. The difference in days to flowering and physiological maturity was very small which may not be practically important though statistically significant.

Plant Height: Highly significant ($P<0.01$) effect of inter and intra row spacing and their interaction on mean plant height of chick pea (Table 4). As inter-row spacing increased from 20 to 40 cm mean plant height of chick pea was decreased from 73 to 42 cm. Significantly higher (73cm) plant height of chick pea was obtained from 20x5cm and the lowest (33.33cm) was recorded at 40x 20 cm spacing (Table 4). The longest plant height was obtained at closer spacing than wider once. This might be due to the highest plant population under closer spacing that might have afford several competitions among the crop for growth resources, especially the nutrient, moisture and light. In addition, plants at wider inter-row spacing intercept sufficient sunlight those enhance lateral growth rather than terminal growth that was resulted relatively in shorter plant height. Similarly, Felton *et al*. [30] reported that plant height of chickpea and green bean was taller in higher plant population (closer spacing) treatments due to more competition for light. Qayyum *et al*. [31] reported that increase in row spacing from 20 to 30 cm significantly decreases plant height. More competition for light in narrow spacing resulted in taller plants while at wider spacing light distribution was normal [32].

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, Tuarira and Moses [33]

Table 4: Interaction effects of inter row and intera row spacing on the plant height of chick pea in Jimma Horro District

	Intera row spacing (cm)				
Interrow spacing (cm)	5	10	15	20	Mean
20	73.00^{a}	67.40^{b}	65.17^{b}	57.20^{c}	65.692^{a}
30	52.87^{d}	49.93^{de}	47.67^{e}	42.75^{f}	48.304^{b}
40	42.13^{f}	37.73^{g}	35.73^{gh}	33.33^{h}	37.233^{c}
Mean	56.000^{a}	51.689^{b}	49.522^{c}	44.428^{d}	
	Inter- row spacing	Interarow spacing	Inter-row spacing X Intera-row spacing		
LSD(5%)	1.4870	1.7171	2.9740		
CV (%)	3.48				

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

reported that plant height of chickpea and green bean was taller in higher plant population treatments due to more competition for light. 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 [34]. More competition for light in narrow spacing resulted in taller plants while at wider spacing light distribution was normal [34]. Moreover, spacing experiment on soybean observed that increasing the density of plants led to significant increases in plant height. In contrary, plant height was not affected by increasing plant density of faba bean reported by Shahein *et al.* [35].

Plant height was highest with the highest seed rate of in all the chick pea production which could be due to competition amongst the plants for sunlight. As the seed rate increased, pods plant^{-1} decreased, as also reported by other researchers [36-38], which could be due to competition amongst the plants for nutrients and moisture. Singh *et al*. [39] observed significant increase in plant height with decrease in spacing between inter and intra rows spacing. In contrary, Mansoor *et al.* [40] reported that increase in row spacing 30 cm resulted in taller plants (83.78 cm), followed by 20 cm row spacing with plant height of 66.67 cm, whereas closer row spacing (10 cm) had minimum plant height of 59.89 cm per plant. The finding agrees with Pramanik *et al.* [41], Qayyum *et al.* [42]. It was further observed from the data that plant to plant spacing of 15 cm recorded maximum plant height (76.56 cm) followed by 10 cm (71.67 cm), whereas minimum plant height (62.11 cm) was observed under closer plant spacing of 5 cm. Mohammed [43] also observed reduction in plant height under close spacing.

Number of Primary Branches per Plant: Highly significant (P<0.01) effect of inter- and intra- row spacing and their interaction on the number of primary branches per plant of chick pea (Table 5). The highest (3.93) number of primary branches plant^{-1} of chick pea was recorded from 40 x15 cm inter- and intra-row spacing, while the lowest (2.4) number of primary branches plant^{-1} was recorded from 20 x 5cm inter-and intra-row spacing. The decreased mean number of primary branches per plant of chick pea in the narrower plant spacing might be due to high competition for resources and overlapped plant canopy, the crop might have been subjected to lower interception of sunlight which led to lower photo assimilation resulted in lower growth and development of the plant.

Likewise, Mahmet [44] reported that increased number of branches were obtained at wider plant spacing for soybean due to more interception of sunlight for photosynthesis, which may have resulted in production of more assimilate for partitioning towards the development of more branches. Togay *et al*. [45] reported that the number of primary branches decreased with the increase in density of chickpea. Also, Melaku [15] reported that higher number of primary branches obtained as results of the interaction of 50 cm inter- and 15 cm intra-row spacing as compared to narrower inter and intra- row spacing. Moreover, similar findings also reported faba bean, soybean and common vetch, respectively, reduced the number of branches with increased plant population [46, 47]. Regarding the effect of inter row and intra row spacing on number of branches per plant. Kumar [48] reported maximum number of branches per plant in 40x15cm spacing whereas minimum number of branches per plant was in 20x15cm spacing. Mansoor *et al.* [40] observed maximum number of branches per plant in plants grown with 20 cm inter row spacing.

Number of Secondary Branches per Plant: Highly significant effect (P<0.01) of both main effects of inter- and intra- row spacing and their interactions on the mean number of secondary branches per plant of chick pea (Table 6). The highest (23.40) and the lowest (8.67) number of secondary branches plant^{-1} of chick pea was

Table 5: Interaction effects of inter row and intera row spacing on the number of primary branches per plants of chick pea in Jimma Horro District

	Intera row spacing (cm)				
Interrow spacing (cm)	5	10	15	20	Mean
20	2.40^{g}	2.55^{g}	2.57^{fg}	3.23^{d}	2.6875^{b}
30	2.87^{ef}	3.40^{cd}	3.60^{bc}	3.80^{ab}	3.4167^{a}
40	3.13^{de}	3.20^{d}	3.93^{a}	3.73^{ab}	3.5000^{a}
Mean	2.8000^{d}	3.0500^{c}	3.3667^{b}	3.5889^{a}	
	Interrow spacing	Intera row spacing		Interrow X Intera row spacing	
LSD (5%)	0.1520	0.1755		0.3040	
CV (%)	5.61				

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

Table 6: Interaction effects of inter row and intera row spacing on the number of secondary branches per plants of chick pea in Jimma Horro District

	Intera row spacing (cm)				
Interrow spacing (cm)	5	10	15	20	Mean
20	8.67^{g}	11.93^{f}	12.93^{f}	14.80^{e}	12.083^{c}
30	16.27^{de}	17.87^{d}	20.47^{bc}	19.87^{c}	18.617^{b}
40	22.07^{ab}	20.87^{bc}	22.07^{ab}	23.40^{a}	22.100^{a}
Mean	15.667^{c}	16.889^{b}	18.489^{a}	19.356^{a}	
	Inter row spacing	Intera row spacing		Inter row X Intera row spacing	
LSD (5%)	0.8017	0.9257		1.6034	
CV (%)	5.38				

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

Table 7: Interaction effects of inter row an intera row spacing on the seed yield of chick pea in Jimma Horro District

	Intera row spacing (cm)				
Interrow 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}	1556b^{c}	1525^{c}	1448.1^{a}
Mean	1149.0^{c}	1346.7^{b}	1453.0^{a}	1448.8^{a}	
	Inter row spacing	Intera row spacing		Interrow spacing X Interarow 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

obtained from 40 X 20 cm inter-row and intra-row and 20 X 5 cm inter-row and intra-row spacing, respectively. Number of secondary branches increased as the inter- and intra-row spacing increased. This indicates that the simultaneous increment of both inter and intra row spacing have a positive effect on this parameter. The interactions of lower inter and intra row spacing yields low number of secondary branches per plant as compared to higher inter and intra row spacing. The basic reason behind increased number of secondary branches under lower plant densities (wider spacing) could be attributed to higher sunlight interception and accumulating this energy and different growth factors for increased growth and development so that the plants become more branched. In contrast, the decreased number of branches in the narrower plant spacing might be due to high competition for the growth resources such as moisture, minerals and space and the overlapped plant canopy resulted in reduced branching of the crop. Similarly, Togay *et al.* [45], Bakry *et al.* [49] reported that the number of secondary branches decreased with the increase in density (narrower spacing) of chickpea.

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 7). The interaction of 30 X 15 cm inter-and intra- row spacing gave the highest (1625kg 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, Ouattara and Weaver [50] reported that extremely higher population (20 cm with 5 cm) and 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 and air and shading effect.

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. Also andrade *et al*. [51], Caliskan *et al.* [52] reported that increased yield from higher plant populations are primarily the result of increased light interception during grain-filling by the crop canopy of soya bean. The yield per unit area was increased with increasing plant density due to efficient utilization of growth factors [53]. Similarly, Shiferaw *et al*. [54] reported that the seed yield was increased by 30.81 and15.53% as inter and intra -row spacing decreased from 40 to 20cm and 15 to 10cm, respectively .Ouattara and Weaver [50], Rajesh *et al*. [55] 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. Some reports showed 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 [15].

Mohapatra *et al*. [56], Ortega *et al*. [57] reported increase in yield by increasing the row and plant spacing's. [58, 59] reported that the optimum plant population appeared to be about 33 plants per m^2. Foysalkabir *et al.* [60] 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 cm, 45 cm and 60 cm, Rasul *et al*. [61] 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 Yadev *et al*. [62] recommended 30 cm inter row and 10 cm intra row spacing for maximum seed yield and harvest index.

Table 8: Pearson correlation of phenology, growth and yield of chick pea due to inter row spacing and intra row spacing

	DE	DF	PH	NPB	NSB	DPM	GY
DE	0.41^{*}	-0.43^{**}	0.41^{*}	0.48^{**}	0.5^{**}	0.6^{**}	
DF		-0.88^{**}	0.7^{**}	0.86^{**}	0.72^{**}	0.78^{**}	
PH			-0.81^{**}	-0.94^{**}	-0.71^{**}	-0.75^{**}	
NPB				0.76^{**}	0.81^{**}	0.81^{**}	
NSB					0.63^{**}	0.74^{**}	
DPM						0.75^{**}	
GY							

DE =Days to 50% emergency, DF = Days to 50% flowering,
PH = Plant height, NPB = Number of primary branches per plant,
NSB = Number of secondary branches per plant,
DPM = Days to physiological maturity, GY = Grain yield

Pearson correlation of phenology, growth and yield of chick pea due to inter row spacing and intra row spacing: Correlation analysis between phenology, growth, 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 8). Negative correlation coefficients were observed between plant height with days to physiological maturity (-0.71), grain yields (-0.75), number of primary branches per plant (-0.81) and number of secondary branches per plants (-0.94). With increased plant population, the green area index, intercepted radiation, radiation use efficiency and total intercepted photo synthetically active radiation increase [63], thereby resulting in higher grain yields. Similarly, Arora and Jeena [64] that seed yield per plant was significantly and positively correlated with days to maturity. Grain yield was significant and positively correlated to days to 50% flowering and not significant to the plant height. Wahid and Ahmed [65]; Yadav and Sharma [66] reported that seed yield had negative and significant correlation with days to flowering.

CONCLUSIONS

Main effects of inter and intera row spacing on mean days to 50% flowering and days to 90% physiological maturity were significantly affected by both inter- row and intra- row spacing. Both mean days to 50% flowering and 90% physiological maturity were delayed due to inter-row spacing of 40 cm with 20 cm intera row spacing. Intra-row and inter-row spacing significantly affected mean plant height of chick pea. Inter-row and intra-row spacing and their interactions showed significantly improved the number of primary branches and secondary branches per plant. The mean number of pods per plants was significantly affected by inter-row and intra-row spacing and their interactions. 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. 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 using one variety at one location requires confirmation with further studies over years, locations and different chickpea varieties to suggest valid recommendation.

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