HARAMAYA UNIVERSITY
POST GRADUATE PROGRAMS DIRECTORATE

EFFECTS OF INTER-ROW AND INTRA - ROW SPACING ON GROWTH, YIELD AND YIELD COMPONENTS OF CHICKPEA (*Cicer arietinum L.)* AT FUNYAN DIIMO AREA, CHIRO DISTRICT, WEST HARARGHE, ETHIOPIA

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Effects of Inter-Row and Intra-Row Spacing on Growth, Yield Components and Yield of Chickpea (*Cicer arietinum* L.) **at Funyan Dimo Area**, **Chiro District**, **West Hararghe Ethiopia**

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As Thesis Research advisors, we hereby certify that we have read and evaluated this thesis prepared under our guidance by **Mulu Zenebe Worku** entitled **"Effects of Inter and Intra-Row Spacing on Growth, Yield Components and Yield of Chickpea** (*Cicer arietinum* L.) **at Funyan Diimo Area Chiro District, West Hararghe, Ethiopia"** and we recommend that it be submitted as fulfilling of the MSc Thesis requirement.

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Final approval and acceptance of the Thesis is contingent upon the submission of its final copy to the Council of Graduate Studies (CGS) through the candidate's School Graduate Committee(SGC).

DEDICATION

This Thesis manuscript is dedicated to my beloved wife Ejigayo Beyene who has a great space and role in the success of my life

STATEMENT OF THE AUTHOR

I earnestly declare that this thesis is my bona fide work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of the Thesis. And that all sources of materials used for this thesis have been duly acknowledged and any scholarly matter that is included in the thesis has been given recognition through citation.
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BIOGRAPHICAL SKETCH

The author was born from his father Zenebe Worku and his mother Nigat Jenber on September 10, 1978 G.C. in Dobba District of West Hararghe Zone, Oromia National Regional State, Ethiopia.

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LIST OF ACRONOMS AND ABRIVIATIONS

CAR	Center of Agricultural Research
CSA	Central Statistical Authority
CV	Coefficient of variation
DZARC	Debre Zeit Agricultural Research Center
EARO	Ethiopian Agricultural Research Organization
EEPA	Ethiopian Export Promotion Agency
FTC	Farmer training center
FAO	Food and Agriculture organization
FAOSTAT	Food and Agricultural Organization Statistical
GLM	Generalized Linear Model
IAR	Institute of Agricultural Research
ICARDA	International Center of Agricultural Research
ICRSAT	International Crop Research Institute for Semi-Arid Tropics
ILRI	International Livestock Research Institute
LSD	Least Significant Difference
MOA	Ministry of Agriculture
NPS	Nitrogen, phosphates and sulfur containing fertilizer
SNNPR	Southern Nations, Nationalities and Peoples Region

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Effects of Inter- Row and Intra-Row Spacing on Growth, Yield Components and Yield of Chickpea (*Cicer arietinum* L.) **at Funyan Diimo area, Chiro District, West Hararghe, Ethiopia**

ABSTRACT

One of the basic agronomic practices to improve the yield potential of chickpea is identification of optimum plant spacing. Thus, field experiment was conducted to assess the effect of inter-row and intra-row spacing on the growth, yield components and yield of chickpea at Chiro District. The treatment consisted of four inter- row (20, 30, 40 and 50 cm) and four intra- row (5, 10,15 and 20 cm) spacing. The experiment was laid out in a randomized complete block design (RCBD) in factorial arrangement with three replications. The main effect of inter-row and intra- row spacing showed highly significant effect on days to 50% flowering and physiological maturity. The highest days to 50% flowering (66.00 days) and days to physiological maturity (106.5 days) were recorded at 50 cm inter-row spacing. On the other hand, at 20 cm intra-row spacing, the highest days to 50% flowering (65.17 days) and days to physiological maturity (108 days) were recorded. The main effects of intra-row and inter-row spacing were significant on plant height. The tallest plant height (50.54 cm) under inter-row spacing was recorded at 20 cm, whereas the tallest (50.88 cm) under intra-row spacing was obtained at 5 cm. The 40 x15 cm, 40 x 20 cm and 50 x20cm produced the highest number of primary branches (5.500) and 50cm x20cm produced highest number (11.60) of secondary branches per plant respectively, while the lowest number of primary branch (2.667) and secondary branch (4.93) were scored under the same 20 x 5 cm and 20 x 5 cm respectively. Stand count at harvest was increased from 86.63% to 95.30% as intra-row spacing increased from 5 to 20 cm respectively. The 50 x 20 cm spacing produced the highest number of pods (89.00) per plant and number of seeds (1.867) per pod. The highest hundred seed weight of 29.64 g and 28.71 g were recorded at 50 cm inter-row and 20 cm intra-row spacing respectively. The highest seed yield (3888 kg ha^{-1}) was recorded under 40 cm inter-row with 15 cm intra- row spacing.

Keywords: *kabuli type Habru variety chickpea*, *Desi type chickpea.*

1. INTRODUCTION

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 139.81 million hectares (ha) worldwide and its highest 3759kg/ha annual production was observed in China during 2016 (FAO, 2016). India alone accounts for 71% of the total chickpea growing area with 72% of the total world production. Chickpea were planted to 3.40% (about 427,696.80 hectares) and the production obtained from this crop was 3.02% (about 878,010 .9 tons) of the total grain production in the country (CSA, 2017). The country is considered as seventh largest producer worldwide and contributes about 3% to the total chickpea production. Ethiopia produced 458,682 tons of chickpea on 239,747 ha of land and the average productivity of 1.9 ton per hectare which is 57% of the 3 tons/ha of the potential yield of chickpea (CSA, 2015).

Chickpea seed has 25.3-28.9% protein, 38-59% carbohydrate, 3% fiber, 4.8-5.5% oil, 3% ash, 0.2% calcium and 0.3% phosphorus. Digestibility of protein varies from 76-78% and its carbohydrate from 57-60% (Hulse, 1991). Raw whole seeds contain per 100 g: 357 calories, 4.5-15.69g moisture, 0.8-6.4g fat, 0-225 mg bcarotene, 0.21-1.1mg thiamin, 0.12-0.33mg riboflavin and 1.3-2.9 mg niacin (Duke, 1981).

Chickpea is a less labor-intensive crop as compared to most pulses and its production demands low external inputs compared to cereals. It plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. It can fix 140 kg Nha^{-1} and meet most of its nitrogen requirement. After harvest it leaves substantial amount of residual nitrogen for subsequent crops and adds same amount of organic matter to maintain and improve soil health and fertility.

It has the ability to grow on residual moisture which gives farmers the opportunity to engage in double cropping, where it is sown at the end of the rainy season following the harvest of the main crop. This allows more intensive and productive use of land, particularly in areas where land is scarce. The growing demand in both the domestic and export markets provides a source of cash for small holder producers.

It also increases livestock productivity as there is due is rich in digestible crude protein content compared to cereals (CSA, 2016). There are two types of chickpea produced globally, namely *desi* and *kabuli* chickpeas. K*abuli* chickpeas have a larger cream-colored seed with a thin seed coat whereas the *desi* type has a smaller, reddish brown-colored seed with a thick seed coat. On average, world production consists of about75% of *desi* and 25% of *kabuli* types (EARO, 2004).

There is a wide potential to increase the production by utilizing improved varieties in the future. The chickpea development plan prepared by MOA estimated to achieve 1.4 million tons of chickpeas from 509,749 ha as a long-term plan (EEPA, 2004). This is possible not only by the use of improved varieties but also by the use of proper agronomic practice (such as appropriate plant spacing, land preparation and other cultural practices) bridging the gaps and solving the problem through research work is important to the area.

A number of limiting factors contribute to this low productivity, but the major constraints are low yield potential of landraces and their susceptibility to biotic and abiotic stresses, and poor cultural practices (Legesse et al., 2005). Lack of variety and location specific plant density recommendation is the major limitations of cultural practices for chickpea production in Ethiopia. Production and productivity of the crop is governed by environmental conditions, genotypic trait and the management of the crop. Appropriate crop density is one of the management activities that improves the performance and productivity of plants. However, plant density of chickpea depends on variety and plant growth habit. Compact, upright-growing plants respond better to increased plant density than the spreading type (Calcagno et al., 1988)

The optimum planting density for chickpea varies with location, the growing conditions and growth habit of the variety. In some cases, 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 spacing of 30cm between rows and 10cm between plants which gives density of about 333,334 plants ha^{-1} (DZARC,2004). a reduced spacing between 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 vary depending up on the seed size of the cultivars and growth habit. High seed rates (120-140kg ha^{-1}) for large seeded and low seed rates (65-75 kg ha^{-1}) for varieties with small seed size are recommended (Solomon, 2010). It is obvious that reduced plant population was increase the performance of individual plant. However, this does not indicate maximum productivity per 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, was not also result in maximum productivity due to the effect of increased competition for plant growth factors 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 was adversely affect productivity per a given area of land. in deed there was a need to evaluate the performance of chickpea variety in varying inter and intra-row spacing and determine optimum density of the crop for maximum yield.

West Hararghe, Chiro District is one of the districts where optimum population of Chickpea have not been studied so far, because of limited research work done on the interaction effects of various agronomic practices such as inter and intra-row plant spacing. Thus, it is with this understanding that this study was undertaken in the area.Therefore, the objectives of the study were:

1. To assess the effect of inter and intra - row spacing on growth, yield components and yield of a kabuli type chickpea variety.

2. To identify the optimum combination of inter and intra - row spacing that improve the productivity in the area.

2. LITRATURE REVIEW

2.1. Origin and Distribution

Chickpea was most probably originated in the present day southeastern Turkey and adjoining Syria. This crop was gradually introduced to the west Mediterranean region, to Eastern and Southern Asia and East Africa. It reached the Indian subcontinent before 2000 BC (Martin *et al.,* 2000). Chickpea cultivation is expanding where it has been introduced, e.g.in Australia, New Zealand, the United States and Canada. In tropical Africa it is mainly cultivated in East Africa (Sudan, Eritrea, Ethiopia, Kenya and Tanzania) and in Malawi; it is grown particularly in areas with a marked cool season. Although the crop is essentially adapted to sub-tropics, it can be grown in a wide range of environments.

The crop is now being grown in about 58 countries around Asia, Africa, North, Central and South America, Europe and Australia. Ethiopia is a second center of diversity for chickpea (Pundir and Mengesha, 1983). Globally, chickpea is adapted to *Vertisol* in the cool semi-arid areas of the tropics, sub-tropics as well as the temperate areas. It is the third most important pulse gown in the world after dry bean and pea and constitutes 20% of the worlds' pulse production (Joshi *et al*., 2001).

It was first produced in the Middle East about 7, 000 years ago (*Martin et al., 2000*). It is produced in Over 58 countries represented in all continents. However, the most important chickpea producing countries are India, Turkey, Pakistan, Iran, Mexico, Australia, Ethiopia, Myanmar, and Canada. Chickpea is grown on about 10.7million hectares worldwide with average annual production of 8.2 million tones. About 95% of chickpea cultivation and consumption is in the developing countries (Saxena and Singh, 1987).

The diverse agro-climatic conditions in Ethiopia make it very suitable for growing chickpeas. It widely grown across the high lands and semi-arid regions of Ethiopia and serves as a multi-purpose crop. According to Van der Maesen (1972), as cited in Redden and Berger (2007), recognized the primary center of diversity is in the Fertile Crescent where the crop was originally domesticated, and with the geographic spread of chickpea secondary centers of diversity developed, some older than 2000 years in Mediterranean Europe, the Indian subcontinent and north-east Africa, and some more recently in Mexico and Chile with post Columbus introduction. According to the same authors, the distribution of old landraces and wild relatives of chickpea occurs in three main regions from 8° to 52°N latitude and 8° W to 85° E longitude: (i) western Mediterranean, Ethiopia, Crete and Greece; (ii) Asia-minor, Iran and Caucasus; and (iii) Central Asia, Afghanistan and the Himalayan region. The geographic distribution differs for these two types, with the kabuli tending to be restricted to the western Mediterranean where the desi are mainly absent. The desi range more widely from the eastern Mediterranean to central Asia and the Indian sub-continent (Moreno and Cubero1987).

Chickpea is cultivated in four regions of the country, Amhara, Oromia, Southern Nations, Nationalities and People's Region (SNNPR) and Tigray. Amhara and Oromia regions together produce 93% of total chickpea production in Ethiopia while SNNPR and Tigray produce 3.5% and 3%, respectively. In future, chickpea can also be grown in other regions having suitable agro ecological condition for chickpea crop production. Thus, the area coverage and the importance of the crop in the country are expected to increase in the future (CSA, 2015).

The major chickpea producing areas are concentrated in the two regional states Amhara and Oromia. These two regions cover more than 90% of the entire chickpea area and constitute about 92% of the total chickpea production. The top chickpea producing zones (North Gonder, South Gonder, North Shewa, East Gojam, South Wello, North Wello, West Gojam, Gonder Zuria) belong to the Amhara region and account for about 80% of the country's chickpea production. In the Oromia region, the major producing zones are in West Shewa, East Shewa and North Shewa, which account for about 85% of the total area and production in this regional state (CSA, 2016).

2.2. Botany and development of chickpea

Chickpea seeds have a seed coat, two cotyledons, and an embryo. The seed coat consists of two layers, the outer testa and the inner tegmen, and a hilum. The hilum is the point of attachment of the seed to the pod. There is a minute opening above the hilum called the micro Pyle, and a ridge formed by the funicle called the raphe. The embryo consists of an axis and two fleshy cotyledons. The pointed end of the axis is the radicle and the feathery end is plumule. Chickpea seeds germinate at an optimum temperature varying with in (28-33°C) and proper moisture level in about 5-6 days. Germination begins with the absorption of moisture and swelling of the seed. The radical emerges first followed by the plumule.

The portion of the axis above the cotyledon called the epicotyl, elongates and pushes the plumule upward. The growth of the plumule produces an erect shoot and leaves, and the radicle grows to produce the roots. The first true leaf has 2 or 3 pairs of leaflets plus a terminal one. The plumular shoot and lateral branches grow continuously to develop into a plant (Cubero, 1987).

Chickpea plants have a strong taproot system with 3 or 4 rows of lateral roots. The parenchymatous tissues of the root are rich in starch. All the peripheral tissues disappear at plant maturity, and are substituted by a layer of cork (Cubero, 1987). The roots grow 1.5-2.0 m deep and bear Rhizobium nodules. Several key attributes of chickpea roots, such as their high water absorption efficiency per unit root length density, their ability to change the rooting pattern across soil depths to efficiently access the available soil moisture and their ability to produce a larger root surface area per unit root biomass, seem to make chickpea the best choice for dryland cropping systems compared with other legumes or cereals (Tilahun and Schubert, 2003).

The chickpea stem is erect, branched, viscous, hairy, terete, herbaceous, green, and solid. The branches are usually quadrangular, ribbed, and green. There are primary, secondary, and tertiary branches (Cubero, 1987). Primary branches arise from the ground level as they develop from the plumular shoot as well as the lateral branches of the seedling. They are thick, strong, and woody, and may range from one to eight in number. Secondary branches develop at buds located on the primary branches. They are less vigorous than the primary branches. Their number ranges from 2 to 12 The number of secondary branches determines the total number of leaves, and hence, the total photosynthetic area. Tertiary branches arise from the secondary branches. The primary branches form an angle with a vertical axis, ranging from almost a right angle (prostrate habit) to an acute angle (erect). Generally, stems are incurved at the top, forming a spreading canopy.

Chickpea leaves are petiolate, compound, and unimpaired pinnate (pseudo impair pinnate). Some lines (genotypes) have simple leaves. The rachis is 3-7 cm long with grooves on its upper surface. Each rachis supports 10-15 leaflets each with a small pedicel. The leaflets do not end at the true terminal position (the central vein continuing the rachis) but at the sub terminal position (the central vein oblique to the rachis). This indicates the presence of two terminal leaflet buds, one of them being aborted or transformed into a mucro or foliar shoot which is sometimes quite large (Cubero ,1987).

The leaflets are 8-17 mm long and 5-14 mm wide, opposite or alternate with a terminal leaflet. They are serrated, the teeth covering about two-thirds of the foliar blade. The shape of the leaflets is obovate to elliptical with the basal and top portions cuneate or rounded. Leaves are pubescent. The solitary flowers are borne in an axillary raceme. Sometimes there are 2 or 3 flowers on the same node. Such flowers possess both a peduncle and a pedicel. The race mose peduncle is 6-30 mm in length. At flowering, the floral and racemal portions of the peduncle form a straight line, giving the appearance that the flowers are placed on the leafy axil by a single peduncle.

2.3. Environmental Requirements of Chickpea

Chickpea is traditionally grown in the northern hemisphere, mostly at relatively high elevations in India and Ethiopia. However, most of the Desi type chickpea is grown between 20 º N and 30 º N while Kabuli type is grown above 30 º N (Saxena and Singh, 1987). These environmental conditions give significance difference in photoperiod, temperature and precipitation, all of which have a profound effect on growth and development (Saxena and Singh, 1987). The crop is a quantitative long-day plant which needs a moderately high temperature for its normal growth. A daily temperature fluctuation with narrow amplitude is also required by the crop.

Chickpea grows best on heavy clay soils and in a rough seed-bed and it is moderately tolerant to drought conditions (Van der Maesen, 1972). Cool nights, moderate relative humidity, evenly distributed rainfall and well drained seed-beds are conducive to the crop and are considered as the ecological optimum of the crop for its normal growth and development (Van der Maesen, 1972).

In major chickpea growing regions of the world, the average maximum temperature ranges from 21 to 29 º C during the day and from 15 to 25º C during the night. The crop needs daily mean temperature of above 15º C to allow fertilization of flowers and pod setting (Trang and Giddens, 1980). Considerable differences in ambient and/or soil temperature requirements have also been noticed among cultivars of chickpea. There is also a considerable variation among cultivars for soil temperature requirement for germination, but generally it should exceed 5ºC, and preferably be above 15 º C. For high yields, bright sunshine is required; cloudy weather, particularly if accompanied by high humidity, reduces flowering and seed setting.

Chickpeas are normally grown in areas with an annual rainfall of about 650-750 mm although they can be grown successfully in areas with a rainfall of about 1000 mm/annum. Chickpeas can be grown on a wide range of soil types provided that the drainage is good, and they cannot withstand water-logging. For optimum results, clay loams are required. In general, chickpea are moderately sensitive to photoperiod and the vegetative period is shortened in long days, but short days (9 hours) do not prevent flowering (Kay, 1979).

2.4. Chickpea Area, Production and Yield Trends in the World

Chickpea is the most important food legume crop in the world grown on about 11 million ha worldwide with a total production of 9 million tons in 2006-08 (Akibode and Maredial, 2011). South Asia is by far the largest producer of chickpea (76%) in the world with a share of more than 80% of area harvested. The share of developing world in total area and production of chickpea is 95% and 93%, respectively.

The region of Middle East and North Africa is the second most important region for chickpea area and production followed by Sub-Saharan Africa. The South East Asia and Latin American and Caribbean region as have more than 100 thousand ha^{s} of chickpea, but are relatively insignificant players from the global perspective.

The regions that have seen a substantial increase in area harvested under chickpea in the last 14 years include the South East Asia region (67%) and the developed countries (rest of the world) (48%).

Over the same period, the area also increased by 18% in Sub Saharan Africa and marginally in South Asia (less than 1%).Both the Latin American and Caribbean region and Middle East and North Africa regions have seen declining area and production of chickpea in the last 14 years (Akibode and Maredia1, 2011).

World chickpea yields have increased by 10% from 1997 to 2010.Yields in South Asia, the leading producer of chickpea, increased by 5% in the same period. In Middle East and North African regions, the next important chickpea producing regions, yields declined by 2%. The region of South East Asia saw chickpea yields double in the last 14 years from 0.6 t ha $^{-1}$ to 1.2 t ha $^{-1}$ (Akibode and Maredia1, 2011). India is by far the largest chickpea growing country in the world. The two South Asian countries (India and Pakistan) together cover more than 75% of total world chickpea area.

The other top chickpea growing countries from the developing world include Iran and Turkey (5% share in world chickpea area each), and Myanmar 4% and Ethiopia 3% share each, Mexico 1%, USA 1%, and other small producers having 6% share in world chickpea area (FAO annual report 2016/17 India).

2.5. Chickpea Sub-sector in Ethiopia

Chickpea is one of the major pulse crops (including faba bean, field pea, haricot bean, and lentil) in Ethiopia and in terms of production, it is the second most important legume crop after faba beans (Menale *et al.,* 2009). It contributed about 16% of the total pulse production during 1999-2008 and the total annual average (1999-2008) chickpea production was estimated at about 173 thousand tons.

2.5.1. Production, productivity and future potential

The largest growing regions of chickpea in Ethiopia are Amhara, Oromia and few districts of Tigray and SNNPR (EEPA, 2004; FDRE, 2010). Although chickpea is widely grown in Ethiopia, the major producing areas are concentrated in the two regional states of Amhara and Oromia. These two regions cover more than 90% of the entire chickpea area and constitute about 92% of the total chickpea production (Menale *et al.,* 2009).The top 7 chickpea producing zones (North Gondar, South Gondar, North Shewa, East Gojam, South Wello, North Wello and West Gojam) are found in Amhara region and account for about 80% of the country's chickpea production. In the Oromia region, the major producing zones are West Shewa, East Shewa and North Shewa, which account for about 85% of the total area and production in the regional state.

Ethiopia produced 458,682 tons of chickpea on 239,747 ha of land and the average productivity of 1.9 ton per hectare which is 57% of the 3 tons/ha of the potential yield of chickpea (CSA, 2015). The two types of chickpea, Kabuli and Desi, are currently produced in Ethiopia. the production of Kabuli types is currently limited to few areas and covers about 25 to 30% (personal communication). Desi type chickpea is traditionally widely grown in the country. Several new Desi and Kabuli type chickpea varieties have been developed by DZARC through collaborative research programs involving ICRISAT and ICARDA (Shiferaw *et al.,* 2007) Yields of chickpeas in the majority of traditional small holding farms range from 0.3-0.6 t ha^{-1}. However, improved varieties developed by Ethiopian Agricultural Research Organization (EIAR) reported to yield up to 2.9 t ha^{-1} (EEPA, 2004).

There is a wide potential to increase the production by utilizing improved varieties in the future. The chickpea development plan prepared by MOA estimated to achieve 1.4 million tons of chickpeas from 509,749 ha as a long-term plan (EEPA, 2004). This is possible not only by the use of improved varieties but also by the use of proper agronomic practice (such as appropriate plant spacing, land preparation and other cultural practices) bridging the gaps and solving the problem through research work.

2.5.2. Economic importance of chickpea

The crop provides an important source of food and nutritional security for the rural poor, especially those who cannot produce or cannot afford costly livestock products as source of essential proteins. The consumption of chickpea is also increasing among the urban population mainly because of the growing recognition of its health benefits and affordable source of proteins (Shiferaw *et al.,* 2007). In Ethiopia chickpeas are consumed widely fresh as green vegetables, sprouted, fried, roasted and boiled forms (EEPA, 2004). Chickpea seed has 25.3-28.9% protein, 38-59% carbohydrate, 3% fiber, 4.8-5.5% oil, 3% ash, 0.2% calcium and 0.3% phosphorus. Digestibility of protein varies from 76-78% and its carbohydrate from 57-60% (Hulse, 1991). Raw whole seeds contain per 100 g: 357 calories, 4.5-15.69g moisture, 0.8-6.4g fat, 0-225 mg bcarotene, 0.21-1.1mg thiamin, 0.12-0.33mg riboflavin and 1.3-2.9 mg niacin

(Duke, 1981). It is also used to rehabilitate depleted fallow lands by playing active role in crop rotation practices/programs.

In the export market, chickpea contributes a significant portion of the total value of pulse exports. For example, chickpea constituted about 48% of the pulse export volumes in 2002. During this period of time, the exported volume accounted for about 27% of the total quantity of chickpea production while the balance remained for domestic market (Shiferaw *et al.*, 2007)

Due to the improvement of production in the country and new markets demand, Ethiopian chickpeas have gained an important place in India and Pakistan (2000-2002). In 2002 alone the country exported 48,549.9 tons of chickpeas valued at 14.6 million USD mainly to Pakistan, India, UAE, Panama and Bangladesh, taking 73, 7, 6.5, 5.5 and 2.5 percent share of the export (EEPA, 2004). The average annual chickpea export was 34,308 MT, with an estimated annual foreign currency earnings equivalent to US$ 20.93 million each year between 2005 and 2010. Both the volume and value for chickpea showed more accelerated growths than those for common bean.

Destinations of Ethiopian chickpea export include 32 countries in Asia, the Middle East, Africa and Europe. Pakistan, UAE and Sudan accounted for about 34%, 27% and 14% of the total volume. Bangladesh, India, Singapore, Saudi Arabia, Djibouti, Israel and Jordan were among the top 10 destinations for Ethiopian chickpea export. For many smallholder farmers this meant improved income, food security, nutrition and investment in businesses such as seed production and livestock raising. Overall, the increased productivity and production have helped Ethiopia to increase its revenue and diversify exports, instead of relying totally on few export cropping such as coffee (Tsedeke, 2011)

2.6. Spacing and Optimum Population

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 occur due to inefficient utilization of the growth factors. Normally, as population increases yield also increases proportionally. After, it reached a certain level the yield declines. Population density is also dependent on the moisture availability and nutrient status of the soil. Hence, optimum planting density should be determined through research works (Solomon, 2003). The spacing between stands is largely determined by the extent of the root and shoot systems of the crop plant in question.

The spacing between stands per hectare, in turn, determines the number of stands per hectare (On Wueme and Sinha, 1991). The number of stands per ha, and the number of plants per stand together determine the number of plants per ha, or the plant density. A number of factors also influence spacing like fertility status of the soil, growth pattern of the crop and cultural practices (Martin *et al.*, 1976).

In addition, in row crops, the space between rows as well as within rows depends up on factors such as moisture, type of crop, the climate and the variety of a particular crop. Competition in cultivated crop is commonly between plants of like or similar genotype, all sown at the same time and each with similar environmental conditions. Often, the immediate objective in planning studies on plant densities to determine the optimum sowing rate, the data rarely included a sufficiently wide range of densities to permit the definition of the relationship of density to yield, however, a few studies have varied densities from low to very high values.

A major factor influencing optimum seed rate for any particular crop is the growth habit of genotype (Mekonnen, 1999). Genotype by plant density interaction was found to be evident in fababean (Amare *et al*, 1993), field pea (Rezene, 1994), chickpea and lentil (Million, 1994). The population and growth habit interaction affected seed yield in soybean and the interaction was also large for plant height. However, growth habit differences were consistent across populations for days to maturity and number of main stem nodes (Ouattara and Weaver, 1994).

2.7. Importance of Spacing and Optimum Population

Establishment of optimum population per unit area of the field is essential to get maximum yield. Under conditions of sufficient soil moisture and nutrients, higher population is necessary to utilize all the growth factors efficiently. The level of plant population should be such that maximum solar radiation is utilized. The full yield potential of an individual plant is fully exploited when sown at wider spacing. Yield per plant decreases gradually as plant population per unit area increases. However, the yield per unit area is increased due to efficient utilization of growth factors.

High plant density brings out certain modifications in the growth of plants such as an increase in plant height, reduction in leaf thickness, alteration in leaf orientation, and leaves become erect, narrow and are arranged at longer vertical intervals to intercept more sun light (Singh and Singh, 2002).

The crop plants should cover the soil as early as possible to intercept maximum sunlight to produce higher dry matter as the intercepted solar radiation and dry matter production are directly related. Closely spaced and quick growing crops like soybean which can intercept more light within a short period gives higher yield as compared to wider spaced crops. As such, for the proper light interception at various growth stages, optimum plant population is necessary. As plant density increases, the amount of dry matter in vegetative parts also increases. Both the biological an economic yields increase with increasing plant population up to a certain point and subsequently No addition in biological yield can be obtained and economic yield decreases. Therefore, the optimum plant population of individual crop should be worked out under suitable environmental conditions (Singh and Singh, 2002).

2.8. Effect of Plant Spacing on Growth, Yield Components and Yield of Chickpea

The plant population density that produces maximum yield or optimum plant population density of crops, including chickpea, is affected by genotype, environment and their interaction. A range of optimum plant population density has therefore, been reported for various chickpea varieties and environments A great variation exists in number of plants m^{-2} for obtaining higher yield chickpea. Based on the size of the seed, EARO, 2004 and FDRE, 2010 recommended that the optimum seed rate for chickpea in Ethiopia ranges from 60-140 kg ha^{-1} Million, 1995 reviewed that seeding rate of chickpea in the central highlands of Ethiopia showed no or minimal yield differences. According to this study, seeding rates of 70-80 kg ha^{-1} was recommended for chickpea. Whereas, AUA, 1994 showed that seed yield on Mariye chickpea variety was significantly influenced by seeding rates (i.e., 70, 80, 90 and 100 kg ha^{-1}) effects at Debre-Zeit and the highest seed yield of 1.7 t ha^{-1} was obtained from the lowest seeding rate (70 kg ha^{-1}) and compared with this rate, sowing chickpea at seeding rates of 80 and 90 kg ha^{-1} resulted in 35 and 45% seed yield reductions at Debre-Zeit. However, the results from Akaki showed that seed yield was non-significantly influenced by seeding rates.

The field experiment conducted in 2005 at Kermanshah (Iran) showed significant differences between the planting dates and planting density effects on plant height, number of branches. Plant^{-}distance between 1st pod to soil, number of pods plant^{-1}, number of grains plan^{-1}, biological yield and grain yield (Shamsi, 2005) and reported that the maximum grain yield belonged to plants sown on 6th November at a row spacing of 30 cm.

However, the maximum number of pods plant^{-1} and grains plant^{-1} belonged to plants spaced at 40 cm row spacing. Ali *et al.*, 1999 indicated that the increase in intra and inter- row spacing of chickpea mutant (CM2) significantly increased the plant height, numbers of pods plant^{-1} and plot^{-1} and suggested that to obtain better yield from (CM2), crop should be sown at 23 plants m^{-2} instead of previously reported optimum population of 33 plants m$^{2.}$ Yousaf *et al.* ,2010 revealed that pod number, number of empty pods, and number of seeds per pod, weight of hundred seed, seed yield, biological yield, and harvest index were significantly influenced by seeding densities and maximum numbers of empty pods plant seeds pod$^{-1,}$ seed weight and biological yield were significant at the density of 25 plants m^{-2} However, maximum harvest index and highest grain yield were achieved at a density of 45 plants m^{-2} Growth and grain yield response of gram (*Cicer arietinum L.*) cultivar Paidar-1991 to different seeding densities (40, 50, 60, 70 and 80 kg ha^{-1}) and row spacing's (30, 45 and 60 cm) indicated that the seed yield and growth characteristics such as plant height, number of branches plant^{-1}, number of seeds pod$^{-1,}$ and 1000-seed weight were influenced significantly by seeding densities (Sharar *et al.*, 2001).

According to this study, maximum seed yield of 2299.56 kg ha^{-1} was obtained at seeding density of 70 kg ha^{-1}, whereas row spacing had no significant effect on plant height, seed yield and yield components. A research conducted to determine the best equidistance arrangement with different densities of chickpea (Cicer arietinum var. Philip) in Iran showed non-significant effect on seed yield, seed number pod^{-1} but it had significant effect on pod number plant^{-1}, seed weight and number of lateral branches (Biabani, 2011).

The results indicated that the highest seed yield (4665) was obtained from treatment row spacing and plant to plant distance of 18 cm x 18 cm Ahmadkhan *et al.*,2010 concluded that 45 cm row spacing with 75 kg seed rate ha^{-1} of chickpea affected positively different agronomic parameters like number of pods $plant^{-1}$, number of seeds pod^{-1} and 100 seed weight which ultimately contributed to increased. Biological yield, grain yield and harvest index further, 45 cm single row spacing with 75 kg seed rate ha^{-1} was the optimum planting geometry for efficient light interception and photosynthetic activity and same was proposed to the farmers for better yield in chickpea under given environmental conditions.

Beech and Leach, 1989 grew chickpea at row spacing's of 18, 36, 53 and 71 cm with plant population densities of 14, 28, 42 and 56 plants m^{-2} and reported that row spacing had a little effect on above ground dry matter production and seed yield, whereas Singh and Singh, 1989 obtained the highest seed yield of 1.99 t ha^{-1} at row spacing of 45 cm. Sarwar, 1998 reported that row spacing significantly influenced the number of branches $plant^{-1}$ and number of seeds $plant^{-1}$, whereas, plant height, number of seeds pod^{-1}, 100-seed weight, biological yield, Seed yield and harvest index were not affected significantly by row spacing.

3. MATERIALS AND METHODS

3.1 Description of the Experimental Site

The experiment was conducted in Chiro district on demonstration field of Funyan Diimo farmers training center [FTC] in West Hararghe during 2019/20 main cropping season. Funyan Diimo FTC is located at 10 09º 24''- 30 18,43''N latitude and 34º 18,03''-4304,33''E longitude in western Hararghe Zone, Oromia National Regional State, Ethiopia. It receives annual rain fall of 750- 900 mm at an Altitude of 1800 meter above sea level and the site has bimodal rainfall distribution pattern.

The short rainy season extends from April to July whereas the long rainy season extends from July to October and the soil of the experimental site was classified as black clay soil, with Annual mean temperature-22º C (mean minimum and maximum temperatures of 17.5° and 28º degrees Celsius respectively. Source (Chiro District Agriculture and Natural Resource office).

3.2. Experimental Materials

Habru improved variety kabuli type of chickpea and NPS fertilizer in the rat of 50kg/ha was used for the experiment. Habru variety was released by Debre Zeit Agricultural Research Center (DZARC) in 2007 (MoARD, 2010). and can be adapted to an altitude of 1,800 -2 ,600 m.a.s.l requires an annual rainfall of 700-1,200mm/annum and takes 93-150 Days to reach physiological maturity (which is early maturing) and yield of 3.2-3.6 tons' ha^{-1}.

3.3. Treatments and Experimental Design

A total of four inter- row spacing (20cm, 30cm, 40cm and 50cm) and four intra - row spacing (5cm, 10cm, 15cm and 20cm) arranged in 4 x 4 factorial combinations were used to form the 16 treatments combinations of the experiment. A randomized complete block design (RCBD) with three replications was used to lay out the field experiment. the treatments are shown below.

Table 1. Treatment combinations, description of plant densities, net and gross plot.

No	Spacing	Number of plants per row	No. of plants Per m^{-2}	Dimension of gross plot (width x length)	Net area (harvestable Width in m x harvestable length in m =(m^2)
1	20cm x5 cm	60	100	2.4mx3m	2m X 2.9 m = 5.8m^2
2	20cm x10 cm	30	50	2.4mx 3m	2m x 2.8m = 5.6m^2
3	20cm x15 cm	20	33.3	2.4m x 3m	2m x 2.7m = 5.4m^2
4	20cm x20 cm	15	25	2.4m x 3m	2m x 2.6m= 5.2m^2
5	30cm x 5 cm	60	66.67	2.4m x3m	1.80m x2.9m =5.22m^2
6	30cm x10 cm	30	33.33	2.4m x3m	1.80m x 2.8m= 5.04m^2
7	30cm x15 cm	20	22.22	2.4m x3m	1.80m x 2.7m =4.86m^2
8	30cm x20 cm	15	16.67	2.4m x3m	1.80m x 2.6m=4.68m^2
9	40cm x 5 cm	60	50	2.4m x3m	1.60m x2.9m= 4.64m^2
10	40cm x10 cm	30	25	2.4mx 3m	1.60m x 2.8m =4.48 m^2
11	40cm x15 cm	20	16.67	2.4m x3m	1.60m x 2.7m =4.32m^2
12	40cm x20 cm	15	12.5	2.4m x 3m	1.60m x2.6m =4.16m^2
13	50cm x5cm	60	40	2.5m x 3m	1.5m x2.9m=4.35m^2
14	50cm x10cm	30	20	2.5m x 3m	1.5m x 2.8m=4.2m^2
15	50cm x15cm	20	13.33	2.5m x 3m	1.5m x2.7m = 4.05m^2
16	50cm x20cm	15	10	2.5m x 3m	1.5m x2.60m = 3.9m^2

3.4. Management of the Experiment

The experiment field was prepared to a plow depth of 25-30 cm during initial plowing and one additional plowing was held two weeks before sowing. After layout has been done as per the specification, each plot was leveled and planting rows was prepared manually after the rows were prepared based on the row spacing, planting hills were prepared for the planting of seeds and two seeds per hill was sown at the depth of 4-5cm in August 8th 2019.

Thinning was done manually immediately after the emergence of seeds where 90% of the seeds germinated 10 days after planting. Since chickpea is a poor competitor with weeds at all stages of growth 3 times weeding were done manually depending on the occurrence of weeds. All the recommended cultural practices including pest and disease control was followed uniformly in all the plots. The crop was harvested at 90-95% of harvesting maturity (EARO, 2004).

3.5. Data Collection

All the data required for this experiment was collected at appropriate stage of the crop growth from the central rows 8 rows, 6 rows, 4 rows and 3rows for 2.4m and 2.5m row width respectively and 10 plants was taken from each plat by random sample.

3.5.1. Phenological Data

3.5.1.1. Phenological parameters

Days to 50% flowering: This was recorded by counting as the number of day from sowing to the time when 50 % of the plants in a plot produced flower.

Days to physiological maturity: This was recorded in each plot from the selected rows, it is the number of days from planting to when 90% of the plant leaves and pods in a plot showed turned to yellow color.

3.5.1.2. Growth parameters

Plant height (cm) This was recorded from 10 randomly sampled plants per net plot at physiological maturity of plants. The plants were measured from the base to the tip of main stem and was calculated and expressed on per plant.

Number of primary branches per plant The numbers of branches rising directly from the main stem were counted at the time of maturity from 10 randomly taken plants found in net plot and the average was recorded.

Number of secondary branches per plant The numbers of all branches arising from the primary branches was counted at the time of maturity from 10 randomly taken plants found in net plot and the average was recorded.

3.5.1.3. Yield components and yield

Stand count at harvest - The total number of plants in the central rows of 8, 6, 4 and 3 for 2.4m and 2.5m row width respectively was counted at harvest from the net plot in each plot. Then the stand count at harvest was calculated by dividing the final stand count to the initial count in the net plot and expressed in percentage.

Number of pods per plant The total number of seed bearing pods on each plant was counted for10 randomly taken plants found in net plot at maturity and the average was recorded.

Number of seeds per pod - The total number of seeds per pod was averaged from ten randomly taken plants in each net plot by counting all the number of seeds for each plant.

Hundred s**eed weight (g)-** This was counted by taking sample seeds randomly per net plot area at harvest and the weight of hundred seeds was taken and adjusted to 10% moisture level.

Seed yield (k ha^{-1}) - Seeds harvested from the net plot area was dried for 5-6 days in sun and was cleaned, weighed and converted in to seed yield in kg ha^{-1}. After the weight was adjusted to10% moisture level.

3.6. Statistical data analysis

All the data collected were analyzed using Generalized Linear Model (GLM) by using GenStat version 16th software (GenStat, 2013) and the interpretation was made following the procedure of Gomez and Gomez (1984). For those treatments showed significant differences, their mean was separated by using Least Significant Difference (LSD) test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. Phenological Parameter

4.1.1. Days to 50% flowering

The analysis of variance showed that the influence of the main effect of inter- and intra-row spacing on days to 50% flowering was highly significant ($P \leq 0.01$) effect, whereas their interaction had no significant effect on this same parameter (Appendix Table 1). Further mean comparison results in (table 1) show that days to 50% flowering was delayed (66.00 days) under wider spacing and compared with narrower spacing of inter row spacing which flowered in (61.92 days).

Results from this same table further showed that plants grown under the inter-row spacing of 40cm flowered later (64.25 days) compared with 30 cm (62.08 days). Similarly, days to 50% flowering was delayed (64.25 days) and hastened (62.08 days) under 5 cm and 10 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 row and intra-row spacing resulting in more 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 this is may be due to higher growth factors leads to luxurious growth as opposed to normal maturity. On the other hand, the hastened time of flowering in narrower inter and intra-row spacing might be due to competition for nutrients, moisture and space.In contrast to this study, Melak (2018) reported that days 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.

4.1.2. Days to physiological maturity

The main effect of inter-and intra-row spacing showed highly significant ($P \leq 0.01$) effect of inter- and intra- row spacing on days to physiological maturity while their interaction effect was non-significant (Appendix Table 1) Results from (table1) further show that Days to physiological maturity was delayed (106.5 and 108 days) under 50 cm inter- and 20 cm intra-row spacing respectively while it was hastened (105.5 and 101 days) under 30 cm inter-row and 5 cm intra-row spacing respectively.

These results were in agreement with Valimohammadi *et al.* (2007) who reported as there is a steady increase in the number of days to maturity with increased intra-row spacing. Similar study conducted by Alemayehu, (2016) 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. Similarly, competition for other plant growth factor is also higher under highly populated plant which lead to stress among plants so stressed plants flower earlier and mature faster. There was no significant difference between 20 and 30 cm inter-row spacing and among 15 and 20 cm intra-row spacing on days to physiological maturity.

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

Treatment	Days to 50% flowering	Days to 90% physiological
Intr-row spacing		
20	61.92^{c}	103.8^{d}
30	63.33^{ab}	105.5^{bc}
40	64.17^{b}	105.7^{b}
50	66.00^{a}	106.5^{a}
LSD (5%)	3.193	0.9430
CV (%)	3	2.275
Intra-row spacing		
5	62.08^{c}	101^{d}
10	63.92^{bc}	105.2^{c}
15	64.25^{b}	107.1^{b}
20	65.17^{a}	108^{a}
LSD (0.05)	3.193	1.730
CV (%)	3.0	1.1

Mean values within the same columns and in the same treatment category followed by the same letters are not statistically significant at the 5 % probability level of significance. CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS= not significant

4.2 Growth Parameter

4.2.1 Plant height

Main effect of inter- and intra- row spacing's was showed highly significant ($P<0.01$) effect on plant height of the chickpea crop and their interaction showed significant effect (Appendix Table 2). Further mean comparison results presented in (Table 2) shows that the plant height was decreased as both inter-row spacing and intra-row spacing increase from 20 cm-50 cm and from 5 cm- 20 cm the plant height decreasing respectively. The taller plants (50.54 cm) were scored under 20 cm inter row and 50.88 cm under 5 cm intra row spacing respectively.

On the other hand, the shortest plant height (46.17cm) and (46.67cm) were observed from 50cm inter-row and 20cm intra-row spacing respectively (Table 3) These results might be due to the fact that as the spacing between plants decreased the inter-plant competition for light increased while, sparsely populated plants intercepted sufficient sunlight that enhanced the lateral growth.

In agreement with this, Fleton *et al.* (1996) and Sharar *et al.* (2001) reported that height of chickpea plant was more in higher plant population treatments due to more competition for light. Similarly, Parvez *et al.*, (1989) and Singh and Singh, (2000) indicated that plant height significantly increased with the increase in plant density primarily because of lower amount of light intercepted by plants resulting in increased inter-node length.

Taj et al. (2002) found more competition for light under narrow spacing that resulted in taller plants while, at wider spacing light distribution was normal. Moreover, Shamsi and Kobraee (2009) who studied on spacing experiment on soybean observed that increasing the density of plants led to significant increases in plant height. In contrast, Shahein *et al.* (1995) reported that plant height was not affected by increasing plant density of faba bean.

Table 3. Main effects of inter- and intra- row spacing on plant height

Treatment	Plant height
Intr-row spacing (cm)	
20	50.54^{a}
30	49.08^{b}
40	48.25^{bc}
50	46.17^{c}
LSD (0.05)	3.313
Intra row spacing	
5	50.88^{a}
10	48.62^{b}
15	47.88^{ab}
20	46.67^{c}
LSD (0.05)	2.221
CV (%)	3.8

Mean values within the same columns and within the same category followed by the same letters are not statistically significant at the 5 % probability level of significance. r; CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS= not significant

4.2.2. Number of primary branches per plant

Analysis of variance revealed highly significant ($P \leq 0.01$) effect of inter- and intra- row spacing and their interaction had also significant effect on the number of primary branches per plant (Appendix Table 2). Further mean comparison results in table (4) shows that the highest (5.50) and (5.33) number of primary branches plant^{-1} was recorded under 40 and 50 cm inter - row with 15 and 20 cm intra- row spacing respectively, whereas, the lowest (2.67) and (3.33) number of primary branches plant^{-1} was recorded under 20cm inter- with 5 and 10 cm intra-row spacing.

The decreased number of branches in the narrower plant spacing might be due to high competition for resources and overlapped plant canopy that subjected the plant to lower interception of sunlight which led to lower photo assimilation that resulted in lower growth and development of the plant. In agreement with this result, Mahmet (2008) reported that increased number of branches were obtained at wider plant spacing for soybean due to more interception of sunlight for photo- synthesis, which may have resulted in production of more assimilate for partitioning towards the development of more branches. In addition, Togay *et al* (2005) and Bakry *et, al.* (2011) reported that the number of primary branches decreased with the increase in density of chickpea. The current study also agrees with that of Melak (2018) who reported higher number of primary branches obtained as a result of the interaction of 50 cm inter- and 15 cm intra-row spacing as compared to narrower inter and intra- row spacing.

Table 4. Interaction effects inter-row and intra-row spacing on the number of primary branches per plant

	Intra-row spacing (cm)			
Intr-row spacing	5	10	15	20
20	2.67^{i}	3.33^{fghi}	4.33^{cdefg}	4.67^{bcd}
30	3.43^{fghi}	3.13^{ghi}	4.47^{bcde}	5.00^{ab}
40	3.67^{efghi}	3.97^{cdefg}	5.50^{a}	5.33^{ab}
50	3.83^{defghi}	4.37^{cdef}	5.23^{ab}	4.83^{bc}
LSD				0.8921
CV (%)				12.6

Mean values within same columns and within the same treatment category followed by the same letters are not significantly different from each other; CV= Coefficient of Variation, LSD = Least Significant statistically significant at the at 5% probability level of significance at 5% level; NS=not significant.

4.2.3. Number of secondary branches per plant

Analysis of variance on interaction of inter-and intra-row spacing showed highly significant effect ($P \leq 0.01$) on the number of secondary branches per plant. (Appendix Table 2). And further mean comparison results in table shows that The highest (11.6) and the lowest (4.93) number of secondary branches plant^{-1} were obtained from 40 cm inter-row with 20 cm intra-row and 20 cm inter-row with 5 cm intra-row spacing respectively (Table 5). 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 results from this same table further indicated that interactions at lower inter and intra row spacing yielded 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 accumulate this energy coupled with different growth factors heat increased per plant due to decreased competition that that contributed 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. In agreement to this result, Togay *et al*. (2005) and Bakry *et al*. (2011) reported that the number of secondary branches decreased with the increase in density (narrower spacing) of chickpea.

Table 5. Interaction effects inter-row and intra-row spacing on number of secondary branches per plant

Inter-row spacing	Intra-row spacing(cm)			
	5	10	15	20
20	4.93^{h}	5.90^{h}	8.23^{efg}	8.50^{efg}
30	6.77^{gh}	8.53^{def}	9.67^{cde}	9.67^{cde}
40	7.60^{fgh}	9.20^{cdef}	10.23^{bcd}	10.53^{bc}
50	7.80^{efg}	9.77^{cd}	11.57^{ab}	11.60^{a}
LSD				1.776
CV (%)				12.1

Mean values within the same column and within the same category followed by the same letters are not statistically significant at the 5 % probability level of significance.; CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS= not significant.

4.3. Yield Component and Yield

4.3.1. Stand count at harvest.

The analysis of variance showed that the influence of main effects of inter- and intra- row spacing as well as their interactions on stand count at harvest was significant (Appendix table3). In comparison to the initial stand count as intra-row spacing increase from 5cm to 20cm and inter-row spacing increase from 20 cm to 50cm stand count at harvest increased from 86.63% to 95.30% and 93.10% respectively (table 6) This might be due to competition for light, nutrient and moisture. This showed that the competition among the plants grown under varying plant population/densities had remarkable effect on the survival of the plants at harvest.The current study was agreed with that of Melak (2018) who reported increased percent of stand count as intra-row spacing increased from 5 to 15cm.

Table 6. Interaction effects of intra-row and inter- row spacing on stand count at harvest

Intra-row spacing (cm)	Inter-row spacing in (cm)			
	5	10	15	20
20	86.63^{e}	91.09^{cde}	90.33^{e}	95.30^{bcde}
30	90.36^{de}	94.41^{bcde}	96.79^{abcde}	94.62^{bcde}
40	93.10^{cde}	94.03^{bcde}	97.10^{de}	98.43^{ab}
50	89.78^{e}	96.88^{abcd}	98.03^{abc}	98.82^{a}
CV(%)				4.2
LSD				6.646

Mean values within the columns within the same category followed by the same letters are not statistically significant at the 5% probability level of significance;CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS= not significant.

4.3.2. 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). and The highest number of pods plant^{-1} was obtained from the interaction effect of 50 cm inter-row and 20 cm intra- row spacing, (table 7).

In general, the number of pods plant^{-1}increased with the increase in inter row spacing at the same level of intra row spacing. (Table 7) The lowest number of pods (57.10) plant^{-1} was found in the closest spacing, i.e. 20 cm inter- and 5cm intra-row spacing which was significantly lower than the other interactions and the highest number of pod per plant (89.00) was recorded under 50 cm inter-row and 20 cm intra row spacing respectively.

The difference among the inter- row spacing in response to intra row spacing on number of pods might be due to high competition for growth factors that was resulted from high population 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 energy for more branching and subsequently, the greater number of pods plant^{-1}. (Table 7)

In agreement with the present result, Khan *et al.* (2010) reported higher number of pods plant^{-1}(41.47) in the wider inter row spacing(45cm) of chickpea. Similarly, Al -Abdselam and Abdi (1995), Hodgson and Black man (2005) and Abdel (2008) who 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.

Table 7. Interaction effects of inter-row and intra-row spacing on number of pods per plant

spacing(cm)	5	10	15	20
20	57.10^{f}	65.93^{ef}	72.57^{def}	72.67^{def}
30	72.23^{ef}	73.87^{def}	82.23^{bcd}	82.07^{bcd}
40	76.07^{cde}	82.0^{bcd}	88.70^{ab}	89.00^{a}
50	71.60^{bc}	80.20^{bcd}	88.43^{bc}	88.33^{bcd}
LSD (0.05)				11.002
CV (%)				8.5

Mean values within the same column and within the same category followed by the same letters are not statistically significant at the 5 % probability level of significance. ; CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS= not significant.

4.3.3. Number of seeds per pod.

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.) further mean comparison results shows that higher number of seeds pod^{-1}(1.87) was obtained at the interaction of 50 cm inter- row and 20, 15 intra row spacing. In other hand, the smallest number of seed per pod (1.33) was observed under the interaction of 20cm inter-row and 5 cm intra row spacing (Table 8). The plants grown in plots of 50 cm inter- row spacing had higher number of seed pod $^{-1}$ than plants sown under 20, 30, and 40 cm inter - row spacing. This 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 seeds per pod.

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 canopy and the pattern of energy allocation among all organs (Bange and Caton, 2006).

Table 8. Interaction effects of inter-row and intra-row spacing on number of seed pod-[1]

Inter-row spacing(cm)	Intra-row spacing(cm)			
	5	10	15	20
20	1.33^{g}	1.43^{g}	1.53^{fg}	1.63^{cdef}
30	1.56^{efg}	1.63^{cdef}	1.70^{bcde}	1.76^{bc}
40	1.53^{fg}	1.60^{cdefg}	1.73^{bcd}	1.70^{bcde}
50	1.76^{bc}	1.80^{ab}	1.86^{a}	1.86^{a}
LSD (0.05)				0.1857
CV (%)				6.7

Mean values within the same column and within the same category followed by the same letters are not statistically significant at the 5 % probability level of significance. r; CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS=not significant.

4.3.4. Hundred seed weight

The main effects of inter- row and intra-row spacing where highly significant (P≤0.01) whereas their interaction had no significant effect on hundred seed weight (Appendix Table 3). Further mean comparison results show that The highest (29.64 g) and (28.37g) hundred seed weight was recorded from 50cm and 40cm inter row spacing respectively However, 20 cm inter row spacing resulted in significantly lowest (26.21) hundred seed weight as compared to the other inter row spacing (Table 9). This indicates that closer inter-row spacing (20 cm) resulted in reduced hundred seed weight.

On the other hand, the highest (28.71 g) hundred seed weight was recorded from 20 cm intra-row spacing's Whereas the lowest (27.35 g) hundred seed weight was recorded under narrower (5cm) intra –row spacing. This indicates that 20 and 15 cm intra-row spacing were resulted in higher hundred seed weight as compared to 5 and 10 cm intra-row spacing. This might be due to high resources computation in narrow spacing than wider 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.

In agreement with the result obtained, Khan *et al*. (2010) reported higher hundred seed weight in the wider inter-row spacing of 45 cm than 30 cm inter- row spacing of chickpea. Similarly, the result of Melak (2018) indicated highest hundred seed weight at 50 cm as compared to 20 cm inter row spacing. He also reported that hundred seed weight was increased with an increase in intra-row spacing.

Table 9. Main effects of inter-row and intra-row spacing on hundred seed weight.

Treatment	Hundred seed weight(g)
Inter-row spacing(cm)	
20	26.21^{c}
30	28.07^{b}
40	28.37^{b}
50	29.64^{a}
LSD(0.05)	
Intra-row spacing(cm)	
5	27.35^{c}
10	27.86^{bc}
15	28.37^{ab}
20	28.71^{a}
LSD (0.05)	0.391
CV %)	3.5

Mean values within the same columns and same treatment category followed by the same letters are not statistically significant at the 5% probability level of significance; CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS= not significant.

4.3.5. Seed yield

The main effect of inter-row and intra-row spacing and their interactions showed highly significant (P<0.01) effect on seed yield (Appendix 3). And further mean comparison results in table show that The interaction of 40 cm inter- and 15 cm intra- row spacing resulted in the highest (3888 kg ha^{-1}) seed yield which was statistically at par with the seed yield (3840 kg ha^{-1}) obtained from the interactions of 40 cm with 10 cm spacing. The lowest seed yield (2566 kg ha^{-1}) and 2625kg ha^{-1} was recorded under the interaction of 50cm x 20cm and 20cmx 5cm inter-row and intra-row spacing respectively (Table 10).

At extremely higher population (20 cm with 5 cm) and narrowest inter- row and intra-row spacing yield reduction was noticed and this is may be due to intense intra and inter-plant competition and also too wider 50cm x20cm inter-row and intra-row spacing yield might be reduced due to inefficient land resource utilization. Furthermore, reports revealed 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 (Quattara and Weaver, 1994). In general, seed yield increase as both inter- and intra-row spacing increased to their maximum value.

Table 10. Interaction effects of inter-row and intra-row spacing on seed yield

Inter-row spacing (cm)	Intra-row spacing			
	5	10	15	20
20	2625^{hi}	2792^{ef}	2894^{e}	2708^{gh}
30	3314^{c}	3465^{c}	3528^{bc}	2778^{fg}
40	3695^{ab}	3840^{b}	3888^{a}	3606^{bc}
50	3096^{d}	3103^{d}	3086^{d}	2566^{i}
LSD (0.05)	182.7			
CV (%)	3.4			

Mean values within the same column and same category by the same letters are not statistically significant at the 5 % probability level of significance.; CV= Coefficient of Variation, LSD = Least Significant Difference at 5% level; NS=not significant.

5. SUMMARY AND CONCLUSIONS

Chickpea (*Cicer arietinum L.)* have Mechanism of drought tolerance and less labor-intensive and also its production demands low external inputs compared to cereals. In Ethiopia, chickpea is widely grown across the country and serves as a multi-purpose crop. Ethiopia produced 458,682 tons of chickpea on 239,747 ha of land and the average productivity of 1.9 ton per hectare which is 57% of the 3 tons/ha of the potential yield of chickpea. In Africa, Ethiopia stands first in area and production but third in productivity after Egypt and Sudan.

A number of limiting factors contribute to this low productivity, but the major constraints are low yield potential of landraces and their susceptibility to biotic and abiotic stresses, and poor cultural practices. Lack of variety and location specific plant density recommendation is the major limitations of cultural practices for chickpea production in Ethiopia. Yield reduction can occur due to inefficient utilization of the growth factors by using too wider spacing and too narrow spacing for this reason bridging the gaps and solving the problems of appropriate plant spacing with different variety through research work was very important to the area.

Therefore, the objectives of the study were: 1. To assess the effect of inter and intra - row spacing on growth, yield components and yield of a kabuli type chickpea variety. 2. To identify the optimum combination of inter and intra - row spacing that improve the productivity in the area. Field experiment was conducted in 19/20 main crop season at west Hararghe Zone Chiro district Funyan Diimo FTC to assess the effect of inter and intra row spacing on the growth, yield components and yield of chickpea variety.

The treatments were four inter-row spacing (20cm, 30cm 40cm and 50 cm), four intra- row spacing (5cm,10cm,15cm and 20cm), along with experimental materials of kabuli type Habru Varity chickpea, and NPS as starter fertilizer in Randomized complete block design three replications was used.

The main effect of inter-row and intra- row spacing showed highly significant effect on days to 50% flowering and physiological maturity. The highest days to 50% flowering and days t physiological maturity were recorded at wider inter-row and intra-row spacing. The main effects of intra-row and inter-row spacing were significant on plant height.

The tallest plant under narrow inter-row and intra-row spacing was recorded whereas the shortest plant height under wide inter- and intra-row spacing was recorded. The wider inter row and intra-row spacing produced the highest number of primary branches and secondary branches per plant respectively, while the lowest number of primary branch and secondary branches were scored under narrow inter and intra-row spacing's. Stand count at harvest was increased from 86.63% to 95.30% as both inter-row and intra-row spacing increased. The widest spacing produced the highest number of pods per plant and number of seeds pod $^{-1.}$

The highest hundred seed weight were recorded at wider inter-row and wider intra-row spacing respectively. The highest seed yield (3888 kg ha^{-1}) was recorded under 40 cm inter-row with 15 cm intra- row spacing and followed by 3840 kg $^{ha-1}$ seed yield was recorded in the combination of 40cm inter-row and 10 cm intra-row spacing's. These indicated that the combination of 40cm inter-row x 15cm intra-row spacing was better than the currently used spacing of 30 cm inter-row with 10 cm intra- row spacing and can tentatively recommended for the study 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 to a more reliable conclusion.

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7. APPENDICES

Appendix Table 1. Mean square values of ANOVA for Phenological parameters as affected by inter-row and intra-row spacing.

source of variation	D. f	Mean square	
		Days to 50% flowering	Days to physiological maturity
Replication	2	10.33	9.318
inter- RS	3	34.910**	16.408**
intra-RS	3	110.186**	20.076**
inter-RS x intra RS	9	4.484NS	4.484ns
Error	30	3.667	1.862
CV		3	1.3

Where: Inter RS = Inter-row spacing; Intra RS = Intra-row spacing; NS, = non- significant, d f = degree of freedom. * = significant ** = highly significant respectively

Appendix Table 2. Mean square values of ANOVA for growth parameters as affected by inter- row and intra-row spacing.

Source of variation	D f	Mean Square		
		Plant height (cm)	No. of primary branch/plant	No. of secondary branch/plant
Replication	2	7.4427	0.6533	1.971
Inter RS	3	40.0608**	2.1691**	23.696**
Intra RS	3	37.6302**	7.7080**	28.772**
Inter RS x Intra RS	9	6.3709*	0.2739*	0.365*
Error	30	0.8983	0.2862	1.135
CV (%)		2.0	12.6	12.1

Where: Inter RS = Inter-row spacing; Intra RS = Intra-row spacing; NS, S and HS = non- significant, significant and highly significant respectively; d f = degree of freedom.

Appendix Table 3. Mean square values of ANOVA for yield components and yield as affected by inter-row and intra-row spacing.

Source of variation	D f	Mean squares				
		Stand count at harvest (%)	Number of pods/plant	Number of seed/pod	Hundred Seed weight (g)	Seed yield in kg
Replication	2	12.12	49.82	0.1939	35.0373	8922
Inter RS	3	65.03*	715.19**	0.2347**	24.1271**	2276708**
Intra RS	3	105.83*	618.30**	0.09139**	4.2147**	453664**
Inter RS x Intra RS	9	8*	13.6**	0.00454NS	0.2490 NS	5376**
Error	30	15.89	45.99	0.01240	0.9389	12001
CV (%)		4.2	8.7	6.7	3.5	3.4

*Where: Inter RS = Inter-row spacing; Intra RS = Intra-row spacing; NS, = non-significant, *significant and ** highly significant respectively; d f = degree of freedom.*