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Optimization of Sowing Time of Kabuli Type Chickpea (Cicer Arietinum L.), Under Rectangular Planting Geometry In Rainfall Deficit Areas of Eastern Amhara

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BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM IN AGRONOMY

OPTIMIZATION OF SOWING TIME OF KABULI TYPE CHICKPEA (*Cicer arietinum* L.), UNDER RECTANGULAR PLANTING GEOMETRY IN RAINFALL DEFICIT AREAS OF EASTERN AMHARA

BY Sisay Bisetegn

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MSc. Thesis

BY Sisay Bisetegn wolie

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THESIS APPROVAL SHEET

As members of the board of examiners, we evaluated and examined this thesis entitled "Optimization of Sowing Time of Kabuli Type Chickpea (*Cicer arietinum* L.), Under Rectangular Planting Geometry in Rainfall Deficit Areas of Eastern Amhara by Sisay Bisetegn wolie. We here by certify that the thesis is accepted for fulfilling the requirements for the award of the degree of "Masters of science in Agronomy"

Board of Examiners

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DECLARATION

This is to certify that the thesis entitled, Optimization of Sowing Time of Kabuli Type Chickpea (*Cicer arietinum* L.), Under Rectangular Planting Geometry in Rainfall Deficit Areas of Eastern Amhara. submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy of Department of Plant Sciences, Bahir Dar University, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during the course of this investigation have been duly acknowledged.

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Dedication

I dedicate this thesis to my wonderful and lovely parents, Mr. Bisetegn Wolie, Miss. Etagen Bisetegn, workye Bisetegn and Elsa Dargie for their continuous support throughout my life.

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analyses of Variance
ANRS	Amhara Nation Regional State
CIMMY	International Maize and Wheat Improvement Center
CSA	Central Statistics Agency
DAS	Days after Sowing
EEPA	Ethiopian Export Promotion Agency
FAO	World Food and Agriculture Organization
GB	Gross Benefits
GDP	Gross Domestic Product
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPCC	Intergovernmental Panel on Climate Change
ISTA	International Seed Testing Agency
MRR	Marginal Rates of Return
NB	Net benefits
NGO	None Government Organization
RCBD	Randomized Complete Block Design
REP.	Replication
RKWAO	Raya Kobo Wereda Agricultural Office
SAS	Statistical Analysis Software
TVS	Total Variable Cost
USD	United States' Dollar
UTM	Universal Transverse Mercator
WP	Watiable Powder

"Optimization of Sowing Time of Kabuli Type Chickpea (*Cicer arietinum* L.), Under Rectangular Planting Geometry in Rainfall Deficit Area of Eastern Amhara",

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ABSTRACT

*Improved agronomic practices increases yield potential of chickpea in different agro ecology of the Country, Crop yield decline due to climate change and improper agronomic practices are the major bottlenecks to sustainable crop production in Ethiopia. "This field experiment was conducted with the objective of Optimization of Sowing Time of Kabuli Type Chickpea (Cicer arietinum L.), Under Rectangular Planting Geometry in Rainfall Deficit Areas of Eastern Amhara", during 2023/2024 main cropping season. 'Kabuli' type chickpea (variety harbu) was testing crop, the experiments involved a combination of three planting date (Agust10, 17 and 24), three Intra (5cm, 10cm and 15cm) and three Inter (20cm, 30cm and 40cm) row spacing, Laid out in a randomized complete block design with three replications. Nine populations ranging from 44 to 380 plants plot-^{1} were also included in the investigation. Data was, yield, and yield components were collected and analyzed using SAS-GLM software. statically analysis showed that most yield and yield related parameter's, (Number of branch plant-^{1},plant height, Number of pod plant-^{1}, Dry biomass yield, Seed yield, and vigority index had significance difference on the main effects of Planting dates, intra and inter row spacing's., similarly the two way interaction of intra and inter row spacing's significantly affects seed yields. Hundred seed weight and Harvest index are significant on the three way interaction of the test crop. The combination of treatments means also showed highly significantly difference (P < 0.001) on almost all agronomic attributes of testing crop, the highest grain yield,(3087kg/ha-1) was recorded in early planting (august10) and medium(10cm) intra row spacing and from the narrower inter row spacing (20cm), this treatments combination had also 61.45 % yield advantage than the lowest yield (1163.4kg/ha-^{1}) recorded from planting date august 24 with 15cm intra and 30cm inter row spacing's, similarly Highest yield (1673.5kgha-^{1}), (2072.3kgha-^{1}) and (2033.9kgha-^{1}), obtained from the main effects planting date 10Agust,10cm Intra row spacing and 20cm Inter row spacing's respectively Partial budget analysis results indicates that the highest net benefit, (313,547ETBha-^{1}) obtained from the two way interaction (10cm intra * 20cm inter row spacing's). Marginal Rate of Return between the two un-dominated treatments is 283.9%, which is well above the commonly accepted minimum threshold of 100% for investment in smallholder agriculture (according to CIMMYT, 1988) standards. In conclusion early planting medium (10cm) and narrower (20cm) Inter row spacing's can increases chickpea production and productivity in the study area and similar agro ecologies, however since the experiment was conducted for one season at one location, this research should be repeated over a season and location, to reach more conclusive recommendations.*

Key words: Kabuli type Chickpea, yield

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Chapter1. INRODUCTION

1.1. Background and Justification

Agriculture is the backbone of the Ethiopian economy, and more than 37.57% of the national growth domestic product of the country is derived from the agricultural sector (World Bank, 2021) and provides employment for 72.7% of the country (CSA, 2019). Crop production is a major contributor to GDP, accounting for approximately 28% of the sub-sectors of agriculture (Belay Duguma *et al*., 2012).

According to Getu Gemechu (2011), coffee, pulses, oilseeds, potatoes, sugarcane, vegetables and cereals are the principal crops grown in Ethiopia.

Chickpea, botanically called *Cicer arietinum* L. is an annual cool season plant belonging to the Fabaceae family; it originated in southeastern Turkey (Singh & Diwakar, 1995).

Chickpea (*Cicer arietinum* L.) is the third most important food legume after beans and peas, grown with more than 50 countries worldwide with area coverage of 89.7%, 4.3%, 2.6%, 2.9% and 0.4% in Asia, Africa, Australia, America and Europe, respectively (Raza *et al*., 2014) (Sheleme Beyene *et al*., 2015).

It was grown on about 11.98 million hectares (ha) worldwide and its annual production was 10.89 million tones (t) during 2010, (Khan and Hussain, 2010). India alone accounts for 68.5%of the total chickpea growing area with 68.7% of the total world production.

The major world producer of chickpea is India with over 5 million tonnes, Pakistanis is the second largest chickpea producer with an annual production of 673 thousand tons that contributes 8% to the worldwide production (Raza *et al*., 2014).

In Africa, Ethiopia stands first in area (213187 ha) and production (about 500,000 tons), but third in productivity (1335.2kgha-^{1}), after Egypt and Sudan (Agajie Melak, 2018).This clearly indicates the importance of chickpea in Ethiopian agriculture.

The country also having potential suitable land and water resources for irrigation-based chickpea production surpasses many thousand hectares (Sheleme Beyene *et al*., 2015), (Nigusie, *et al*., 2017).

Chickpea production in Ethiopia could be increased from its current level of about 500,000 tons to about 750,000 tons by improving technical efficiency while narrowing the yield gaps,

The largest growing regions of chickpea in Ethiopia are Amhara, Oromia and few districts of Tigray and SNNPR (EEPA, 2004), 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, Amhara region Account for about 80% of the country's chickpea production., (CSA, 2019).

In the present time in north wollo (Eastern Amhara region), the production increased due to the presence of irrigation technology from 27.000 tons to 28,000 tons annually (Endiris belay 2023. north wollo agricultural office).

There are two types of chickpea depending on seed color, shape, and size; desi and kabuli. According to Nigusie, *et al*., (2017) the kabuli type has large, round or ram head and cream-colored seeds, and is grown in temperate regions.in Ethiopia, among the two chickpea types, the Desi type is dominantly grown in Ethiopia.

Kabuli type of chickpea covered 25% of the whole area coverage (Asnake, 2014) (Sheleme Beyene *et al*., 2015) Mostly it produced based on as source of foreign currency or export purpose.

Chickpea, a multi-functional crop, has an important role in the diet of the Ethiopian small-scale farmers' households and serves as protein source for the rural poor who cannot afford to buy animal products.

The crop also serves as a source of cash income and plays a major role in Ethiopia's foreign exchange earnings through export to Asia and Europe.

It is Ethiopia's third most important export legume after faba bean and haricot bean, generating revenue of about USD 61 million annually by kabuli type chickpea, and making chickpea one of the main pulse crops in the country in terms of cropped area, total production and direct human consumption, (CSA ,2019).

The country is the largest consumer and exporter of chickpea in Africa and shares some 4.5% of global chickpea market and more than 60% of Africa's global chickpea market (Awel Mohammed et al., 2022).

Apart from being excellent sources of food, chickpea play a significant role in improving soil fertility by fixing the atmospheric nitrogen made it available for crop uptake. It meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg nitrogen per hectare from air. This indicates that how chick pea having significant economical important and for sustainable land use management. (Hbtu Mengesha, 2020).

After harvest, chickpea leaves substantial amount of residual nitrogen for subsequent crops and adds some amount of organic matter to maintain and improve soil health and fertility, this saves the fertilizer input cost not only for chickpea but also for the subsequent crops, (ICRISAT, 2010).

Its straw is also used for animal feed. In spite of all these virtues and benefits, while the productivity of this crop remains very low in Ethiopian agriculture (Hbtu Mengesha, 2020), though the potential yield of chickpea more than six-ton ha^{-1}, current chickpea productivity is only 1.6-ton ha^{-1} in Ethiopia, due to this and other reason chickpea is grown by subsistence farmers in several regions of the country under rain fed conditions with residual moisture. According to CSA (2019), this is mainly because of lack of adapted varieties suitable to growing conditions, poor crop management practices, and inappropriate seeding rates, traditional methods of tillage and conventional sowing dates, (Geletu and Abebe, 1982).

Furthermore, chickpea is seriously affected by time of sowing since it is commonly grown on residual moisture preserved in the soil (Summerfield *et al*., 1990).

Chickpea planted during rainy season suffers from water logging (high moisture stress) and soil borne diseases while when late planted it may suffer from low water moisture

Received high rainfall in the early time of crop growth, Cold temperature, low radiation and wet seedbeds are the major constraints during the vegetative period and drought during the reproductive period. However, winter-sown chickpea is exposed to relatively less favorable thermal and better moisture regimes than spring-sown chickpea (Saxena, 1981). Further, high evapotranspiration and scarcity of water have led to the depletion of the groundwater, hence creating problems of salinity. All considered, these factors have put a strong barrier to the progress of development of stress tolerant cultivars.

Climate change predictions over this century are for warmer (at least 1–2◦C) and drier conditions, with increased extreme weather events and increased CO2 levels, in the regions `where the principal temperate grain legumes of chickpea, lentil, faba bean and pea are mainly grown.

The most important global debate of this century is on climate change (Ramirez-Villegas & Thornton, 2015), it is predicted that by 2050 there will be significant impacts including rising temperature, increasing drought due to higher evaporation and changing rainfall distribution and increased levels of CO2 due to greenhouse and agriculture gas emissions (Ramirez-Villegas & Thornton, 2015), thus,

It is predicted that present levels of agricultural production and field crops productivity under different ecologies and regions will be affected in a big way (Ramirez-Villegas & Thornton, 2015Yield loss in chickpea can vary between 30% and 60% depending on genotype, sowing time, location, and climatic conditions during sowing season.

Some chickpea genotypes have capacity to tolerate drought and in that case sowing time can be delayed. However, earlier or late sowing caused drastic reduction in yield and net profit compared with timely sowing, (Saseendran *et al*., 2004).

Planting date usually has an important influence on yield, because it affects the crop's growing conditions and periods (Saseendran *et al*., 2004). Thus, in rain-fed agriculture, late-planted crops are usually subjected to heat and water stress in the later stages of growth, and are poor in yield. In most of the Mediterranean and Near East, chickpeas are traditionally planted in the early spring, near the end of the rainy season (Yau, 2005).

Seeding rates vary because of the variation in seed size, Seeding rates range from three to four seeds/sq ft. This is equivalent to 80 to 95 pounds per acre for the Desi types and 150 to 200 pounds per acre for the Kabuli types. Higher seeding rates (four to five seeds/sq. ft) can produce higher grain yields but may not be economically feasible (M. Corp *et al*., 2004), Plant the seed at a depth of 1.5 to 2.5 inches, packing the soil after seeding improves seed-to-soil contact and seed (Corp *et al*., 2004).

1.2. Statement of the problem

Yield potential of chickpea is as high as six ton/ha^{-1} (ICRISAT, 2010), while in Ethiopia Productivity is less than 1.9 tons/ha^{-1} due to: lack of high yielding varieties, Poor agronomic practice and biotic and abiotic factors.

Chickpea is a cool-season annual legume ', it is sowing at proper/optimum time is one of the important factors which affect crop yield (Yau, 2005)

Chickpea is seriously affected by time of sowing since it is commonly grown on residual moisture preserved in the soil (Summerfield *et al*., 1990).

Chickpea planted during rainy season suffers from water logging (high moisture stress) and soil borne diseases while when late planted it may suffer from low water moisture and heat stress (Summerfield *et al.*, 1990).

Sowing date had a significant effect on shoot yield, days to flowering and maturity, seed filling period, dry weight at flowering, leaf area index and plant height (Yau, 2005).

In rain-fed, semi-arid areas, there is a need to keep a balance between the amount of vegetative growth and the limited soil moisture to optimize grain yield.

One way to maintain this balance is through the adjustment of seeding rate, under irrigated or high-rainfall conditions, high seed rate may be used, but seed rate has to be decreased under rain-fed, semi-arid conditions (Saseendran *et al*., 2004), (Yau, 2005).

Higher seeding rates (four to five seeds/sq ft) can produce higher grain yields but may not be economically feasible (Corp *et al.*, 2004).

Seeding rates vary because of the variation in seed size, seeding rates range from three to four seeds/sq ft. This is equivalent to 80 to 95 pounds per acre for the Desi types and 150 to 200 pounds per acre for the Kabuli types, while, the national recommendation spacing's are similar for both types of chickpea (kabuli and desi) 10cm*30cm intra and inter row spacing's, but the seed size as well as their physiologically differ.

For the above problems (reasons) this proposal were written to optimize planting date and plant spacing for the test crop on the rain fall deficit eastern Amhara (Raya kobo district).

1.3. Objectives of the Study

1.3.1. General Objective

The overall objective of this study is to enhance the productivity of Kabuli Type Chickpea (Cicer arietinum L.) through agronomic crop management practices in Rainfall Deficit Areas of Eastern Amhara.

1.3.2. Specific Objectives

- ✓ To examine the effect of sowing time and Rectangular Planting Geometry (Intra- and inter-row spacing) on the agronomic attributes of Kabuli Type Chickpea (Cicer arietinum L.) in Rainfall Deficit Areas of Eastern Amhara,

- ✓ To determine the best sowing time and Planting Geometry that give maximum productivity and profitability of Kabuli-type chickpea (*Cicer arietinum* L.) in rainfall-deficit areas of Eastern Amhara.

Chapter2. LITERATURE REVIEW

2.1. Botany, origin and distribution of chickpea (*Cicer arietinum* L.)

The chickpea most probably originated in an area of present-day Southeastern Turkey and adjoining Syria. Three wild annual species of *Cicer*, closely related to the chickpea, are found there: *C. bijugum* K.H. Rec, *C. echinospermum*, P.H. Davis and *C. reticulatum* Lad. The latter, first described by Ladizinsky (1975), could also be classified as a wild variety or subspecies of *C. arietinum*. The former two were described recently (Rechinger 1952, Davis 1970), (van der Maesen, 1987), (Bürger & Bagheri, 2018)

Cicer reticulatum could be considered as a progenitor, or perhaps had a common ancestor with chickpea. Since early botanists did not recognize these (relatively rare) close relatives, various diffuse origins has been very helpful postulated for chickpea.

De Candolle (1883) traced the origin of chickpea to an area south of the Caucasus and northern Persia recently (Rechinger 1952, Davis 1970), (van der Maesen, 1987), (Bürger & Bagheri, 2018),

Vavilov (1926, 1949-50) designated two primary centres of origin (now centres of diversity), south-west Asia and the Mediterranean, and a secondary one, Ethiopia. He noticed that, like other grain legumes, large-seeded cultivars abounded around the Mediterranean basin, whereas small-seeded cultivars predominated eastwards recently), (van der Maesen, 1987), (Bürger & Bagheri, 2018),

Know a day it is distributed to in chick pea producing continents' Europe, Australia, South America and Africa, (Bürger & Bagheri, 2018),

Chickpea belongs to the Leguminosae family and is C3 crop with diploid chromosome number (2n=24) having self-pollination mode of reproduction. It is an herbaceous annual plant which branches from the base. It is almost a small bush with diffused, spreading branches. The plant is mostly covered with glandular or non-glandular hairs but some genotypes do not possess hair. Based on seed size and color, cultivated chickpeas are of two types, (Mazid & Amegbeto, 2022).

It is an annual legume that stands erect and its height ranging from 30 to 70 cm. The plant produces primary, secondary and tertiary branching, resembling a small bush. The plants are naturally resistant to lodging and have the inflated pods. Each pod contains 1 to 2 seeds that are formed several inches above the ground and are relatively shatter resistant, (Sheleme Beyene *et al*., 2015).

The seeds of the plant remain below the ground during germination, offering the plant some tolerance to cool soil and ability to regrow if the top growth is damaged in the seedling stage, (Tigabie Mesay *et al*., and 2020).

There are linguistic indications that the large-seeded, cream-coloured chickpea reached India only two centuries ago, apparently through Afghanistan, as its Hindi name is Kabuli chana (chana = chickpea), an allusion to the Afghanistan capital Kabul.

The small-seeded, dark-coloured chickpea is called Desi (local), and these denominations are now quite widely used to distinguish the two main groups of cultivars recently, (Bürger & Bagheri, 2018)

The most closely related wild species, *C. bijugum, C. echinospermum* and *C. reticulatum* would have attracted early food gatherers; the seed size of *C. bijugum* and *C. reticulatum* unlike other species, they do not shatter their seeds immediately upon ripening. Domestication and crop evolution followed the usual process, (Bürger & Bagheri, 2018).

2.3. Environmental requirements /adaptation /of Chickpea

There are wide variations in the agro climatic conditions under which chickpea are grown around the world. It is grown between 20°N and 40°N in the northern hemisphere. It is also cultivated on a small scale between 10°N and 20°N in India and Ethiopia at relatively higher elevations (Ewert *et al.*, 2015).

These environments differ in photoperiod, temperature, and precipitation there are wide variations in the agro climatic conditions under which chickpea is grown around the world, (Ewert *et al*., 2015).

It is also cultivated on a small scale between 10°N and 20°N in India and Ethiopia at relatively higher elevations the crop is grown on stored soil moisture, and drought and low temperatures are the primary factors limiting growth. In East Africa and the Indian plateau (8°N to 20°N), day length and temperature are relatively constant during the season, (Ewert *et al*., 2015).

The crop is raised essentially on stored soil moisture from preceding rain. High temperature and drought are the major constraints to chickpea production in these environments (Singh & Diwakar, 1995), (Ewert *et al*., 2015).

2.3.1. Soil Type

The plant requires fertile soil with good drainage system. Any waterlogged conditions can severely damage the crop. Chickpeas generally grow on heavy black or red soils and require a soil pH of 6.0 to 7.0. (Mazid & Amegbeto, 2022)

Chickpea prefer soil with good residual soil moisture content). Inoculating chickpeas with rhizobium, when planting first time in virgin sandy soils or in heavier soils can increase yield by 10-62%. In Ethiopia, chickpea is best adapted to the areas having Vertisols (Tigabie *et al*., 2020),

2.3.2. Temperature

Chickpea is a self-pollinated crop and usually grown as a rain-fed cool-weather crop or as a dry climate crop in semi-arid regions. The optimum daily temperature ranges from 18 to 29°C. Occurrence of frost and hailstones can severely damage the crop (Devasirvatham *et al.,* 2015).

Though sensitive to cold, some cultivars can tolerate temperatures as low as -9.5°C in early stages. A relative humidity of 21-41% is optimum for seed setting (Devasirvatham *et al*., 2015). The three major physical factors that influence the phenology, growth and productivity of chickpea are day length, temperature and water availability, of which the latter two are highly variable in these environments. The adaptation and productivity of chickpea is often limited by low and high temperatures. Cold stress generally occurs in the late vegetative and reproductive stages across the geographical areas of chickpea production (Devasirvatham *et al*., 2015).

High temperatures can cause cellular abnormalities such as oxidative stress, and denaturation of proteins and enzymes. Oxidative injury occurs as lipid peroxidation, and hydrogen peroxide content tends to increase in heat sensitive genotypes at day and night temperatures of over 40/30°C compared with heat tolerant genotypes) ABA remains high at 40/35°C but was observed to decline at 45/40°C (Kumar *et al*., 2012)

A Cold and freezing temperatures (−1.5°C to 15°C), are considered a major problem during the seedling stage of winter-sown chickpea in Mediterranean areas and autumn sown crops in temperate regions (Singh, 1993). South Australia and parts of north India are most affected by chilling temperatures at flowering (Berger *et al*., 2011).

On the other hand, high day and night temperatures (>30/16°C) may cause damage during the reproductive stage on winter sown chickpea in Mediterranean in season rainfall areas, south Asia and spring sown regions (Berger *et al*., 2011).

In chickpea, temperature is a major environmental factor regulating the timing of flowering thus influencing grain yield (Summerfield *et a*l., 1990; Berger *et al*., 2004)

Both low and high temperatures can limit the growth and grain yield of chickpea at all phonological stages. The FAO climate change technical paper and the Intergovernmental Panel on Climate Change (IPCC) have provided evidence of climate change linked to human activity (Devasirvatham *et al*., 2015).

Global temperature has been increasing at the rate of 0.74°C per 100 years (IPCC, 2007a). Over the past 50 years, the linear warming trend has been nearly twice the rate of the previous 100 years (FAO, 2009) (Devasirvatham *et al*., 2015).

Projections to the end of the 21st century estimate a rise in global mean temperature of between 1.8 and 4°C, depending on greenhouse emissions and changes in rainfall patterns (IPCC, 2007a,b). Such changes in climate will influence crop production and some estimates suggest a grain yield decrease of between 8 and 30% (ICRISAT, 2009),

Changes in seasonal temperature and rainfall patterns and their subsequent impact on yield may change the geographic distribution of chickpea production (Devasirvatham *et al*., 2015).

Chickpea could expand in new production areas where the frequency of low temperatures (<15°C) is higher during early crop growth). However, temperatures lower than 10°C at flowering can reduce grain yield by 15–20% In contrast, the frequency of high temperatures (>30°C) during the reproductive stage resulting yield reduction Effect of Drought on Chickpea. Drought is responsible for 40%–45% of chickpea yield losses across the globe (Chaturvedi *et al*., 2009)

High mean maximum temperature and low relative humidity in the Sudan led to excessive sodium accumulation in plant shoots and resulted in seedling death. Surviving plants sown outside of the optimum period showed poor vegetative and reproductive growth and thus gave low seed yield (Ram & Soltani, 2020).

2.3.3. Rainfall

The plants grow well in areas with annual rainfall of between 600 - 1000 mm. However, chickpea productivity under marginal rainfall conditions may be increased through genotype selection and manipulation of planting density, (Corp *et al.*, 2004), (Sheleme Beyene *et al.*, 2015). Owing to its deep taproot, chickpea is fairly drought tolerant as it is able to extract moisture from deep layers of soil profile, but its productivity is reduced by the recurrence of the terminal droughts. Thus, chickpea cultivation is solely dependent on soil moisture reserve where planting is made late during the recession of the main rainy season to escape the waterlogging condition.

The flowering and pod setting stages of chickpea appear to be the most sensitive stages to water stress (Nayyar *et al.,* 2006). Chickpea grows best on well-drained soils with a neutral pH. It is not well adapted to saline soils and does not tolerate wet or waterlogged soils.

2.4. Factors affecting chickpea production and its managements

2.4.1. Biotic factor

Chickpea is prone to damage by many diseases and insect-pests. In general, root diseases (fusarium wilt, collar rot and dry root rot) and foliar diseases (ascochyta blight, botrytis grey mold) are important diseases in Ethiopia (Sheleme Beyene *et al*., 2015).

Among the insect pests, infestation by pod borer (*Helicoverpa armigera*) is the most severe. The insect infestation is severe throughout the country and has been reported to significantly reduce the crop yield. Cutworm is next to pod borer in affecting chickpea. It is more common in the northern part of the country. Bruchids (Callosobruchus chinesis) is yet another insect that damages the seeds during storage (Sheleme Beyene *et al.,* 2015).

2.4.1. Chickpea diseases and its managements

Ascochyta blight (*Didymella rabiei* **L.)** : The fungus Ascochyta rabiei, also known as *Didymella rabiei* or *Phoma rabiei*, causes lesions to occur on all above- ground parts of the chickpea plant its major important pest warm and humid weather conditions, (Gaur *et al*., 2010).

Ascochyta blight is the foliar disease having the greatest potential to destroy chickpea crops. Symptoms include yellowing of infected plant parts and elongated, sunken, dark lesions on stems, leave, and pods, (Gaur *et al*, 2010).

The lesions weaken leaf stems and branches, causing them to drop off the plant. The pathogen is spread on seed and by rain splash, wind, infested residue, and volunteer plants. Cool, wet weather enhances infection and spreads the disease epidemic.

Yield losses from Ascochyta blight can be up to 100% in susceptible cultivars under favorable conditions for the disease, (Corp *et al*., 2004).

Management Ascochyta blight: Ascochyta blight is controlled by a combination of genetic resistance and crop husbandry, planting certified, disease-free seed of resistant varieties is critical to preventing and controlling the spread of Ascochyta blight, (Gaur *et al*., 2010).

i) Grow resistant varieties such as Kabuli type cultivars (Abad, Malhotra and Khalima).

Weed-infested chickpea crop severely attack. Then weed managements important.

ii) It is difficult to control once significant disease development has occurred; fungicide should be sprayed during early bloom.

2.4.1. Wilt *(Fusarium orthocerus L.)*

i) Treat the seed with Benlate or a mixture of Benlate of Thiram (1:1) at the rate of 2.5 g per kg of seed, (Gaur *et al*, 2010).

Sclerotinia Blight (*Scleritinia sclerotiorum*)

i) Use only healthy seeds free from sclerotia.

After harvest, the diseased plants should not be allowed to stand in the field but should be destroyed by burning. Treat the soil with a mixture of fungicides like Brassicol and Captan at a rate of 10 kg per hectare.

2.4.1. Rust (*Uromyces ciceris arietini*):

- Spray the crop with 0.2 percent Mancozeb 75 WP as the first symptoms appear, followed by two more sprays at 10 days intervals, (Gaur et al., 2010).

2.4.1. Insect pests

The leaves, stems, and pods of chickpea plants are heavily pubescent (hairy), and the glandular hairs secrete acids that are objectionable to insects. This natural protective mechanism is effective in controlling some insect pests of chickpea, (Gaur *et al*., 2010).

Cutworms, cabbage loppers, and army- worms cause damage in some years and require insecticide treatment, (Corp *et al.*, 2004)), (Gaur *et al.*, 2010)

Gram Pod Borer (*Helicoverpa armigera*): Gram pod borer is the major important insect pest, these insect 50 to 80 % economic damages, (Corp *et al.*, 2004).

Managements of gram pod borer by spray one of the following

i). Spinosad 45SC @ 0.1ml/l in water

ii). Indoxacarb 14.5SC @ 0.3ml/l in water

iii). Flubendiamide 48SC 0.1ml/l in water

iv). Novacuron 10EC 1ml/lit in water.

2.4.1. Weeds

Chickpea is not competitive with weeds. Weed problems have proven to be a major constraint to successful chickpea production, so weed management measures must be planned and implemented carefully, (Gaur *et al.*, 2010).

2.4.1. Crop Varieties

Most of the desi (with yellow to brown seed testa) chickpea is grown between 20°N and 30°N, while kabuli (with cream colored seed testa) types are grown above 30°N. There is a small area under this crop between 10°N and 20°N at relatively high elevations in India and Ethiopia (Khanna-Chopra and Sinha, 1987).

In the Mediterranean region (30°N to 43°N) both temperature and day length increase (9.4 to 13.4 h) from the time of sowing of spring chickpea. Most of the rainfall is received in the early part of crop growth.

Cold temperature, low radiation and wet seedbeds are the major constraints during the vegetative period and drought during the reproductive period. However, winter-sown chickpea is exposed to relatively less favorable thermal and better moisture regimes than spring-sown chickpea (Saxena, 1981).

2.4.2 Abiotic factors (stresses) for chickpea production in Ethiopia

2.4 2. Drought Stress

Drought is one of the most important abiotic stresses, which limits production in different parts of the world and has remained the most recalcitrant when attempted to address through traditional breeding approaches Abiotic stresses, (Tuberosa and Salvi 2006, Toker. 2007).

It is important to note that the water scarcity alone causes70% of agricultural yield loss across the globe (Boyer 1982). Moreover, in concern with drought, desiccation has been reported as the most severe form of drought that leads to loss of protoplasmic water (Yordanov *et al*. 2003).

Drought imposes negative effects on plant growth and development by impeding lipid biosynthesis and lowering the membrane lipid, which ultimately results in loss of membrane integrity (Pham-Thi *et al*. 1987, Monteiro de Paula *et al*. 1990, Gigon *et al*. 2004, Harb *et al*. 2010) and irreversible cell damage (Vieira da Silva et al. 1974).Further, the water deficit hinders the foremost biological process of photosynthesis and other metabolic activity of plant (Chaves 1991, Chaves et al. 2003, 2009, Pinheiro and Chaves 2011). Notably, almost 90% of chickpea is grown under rainfed conditions (Kumar and Abbo 2001) where terminal drought limits its productivity (Toker *et al.* 2007a).

The result of drought relies upon the water-holding capacity, evapo-transpiration and need of water for crop plants (Toker *et al.* 2007a).

Drought accounts for 40–45%yield losses in chickpea across the globe (Ahmad *et al*. 2005).

4.4.2. Terminal Heat Stress

Concerning heat stress, Wahid et al. (2007) reported that the risen temperature beyond certain optimum level is detrimental to the crop growth causing severe injuries that are collectively termed as ‘heat stresses.

Impact of high temperature on plant growth has been reported on various legume crops including dry bean (Prasad *et al*. 2002), groundnut (Prasad *et al*. 2003) and soybean (Baker *et al*. 1989). However, a significant progress has not been achieved in regard to the effect of heat on different morphological and physiological stages of chickpea (Wang *et al*. 2006). Being a cool season crop, chickpea is also susceptible to high temperature (30–35°) for few days at flowering stage and can cause substantial yield loss (Summerfield and Wein 1980, Saxena *et al*. 1988). Summerfield *et al*. (1984) found the negative relationship between the effect of high temperature at reproductive phase and yield in chickpea.

Evolution or more precisely the domestication of chickpea has enforced the selection of various phonological changes in accordance with the changes of habitats (Berger *et al.* 2011). In the Mediterranean region, chickpea confronts extremely low temperature in winter (Berger 2007) and tremendously high temperature during the reproductive stage (Iliadis 1990). While in case of Indian subcontinent condition, chickpea encounters day temperature of 5–10°C during vegetative stage and 20–27°C and even >30°C temperature during reproductive stage (Summerfield *et al*. 1984, 1990, Berger and Turner 2007). Exposure of various chickpea genotypes beyond 35°C temperature shows no pod setting (Basu *et al*. 2009).

The parentheses and an thesis stages are the stages that are most vulnerable to high temperature stress (Devasirvatham *et al, 2013*). High temperature hampers photosynthesis by damaging both structural and functional activity of chlorophyll and lowers the chlorophyll content (Xu *et al,*. 1995).

Temperature beyond 40°C causes disruption in photo system I and II (Baker 1991, Sharkey 2005) and also affects respiration (Kurets and Popov 1988), membrane composition and its stability (Levitt 1969), nitrogen fixation (Black *et al*. 1978) and water relation (McDonald and Paulsen 1997). High temperature stress exerts pronounced effect on reproductive phase, which leads to impairment in pre-an thesis, post-an thesis and fertilization processes ultimately resulting in loss of seed weight and yield (Nakano *et al*. 1997, 1998, Prasad et al. 2003, Upadhyaya *et al*. 2011).

In chickpea, high temperature stress also causes reduction in number of flowers, pollen production, pods/plant and most importantly, the filled pods/ plant (Wang *et al,*. 2006, Basu *et al,*. 2009, Devasirvatham *et al,*. 2012).

The sensitivity of chickpea pollen to high temperature is more than stigma, and this observation has been confirmed both in field as well as under controlled conditions using genotypes like ICC1205/ICC15614 (heat tolerant) and ICC 4567/ICC10685 (sensitive) (Devasirvatham *et al,*. 2012, 2013).

Heat stress marks noticeable effects in anther locale number, anther epidermis wall thickening and pollen sterility (Devasirvatham *et al,*. 2013). For instance, when ICC 5912 was kept at 35/20°C for 24 h before an thesis, the genotype became sterile, whereas the other genotype ICCV92944 produced fertile pollens (Devasirvatham et al. 2010)

2.4.2. Salt Stress

Chickpea production is adversely affected due to salinity in arid and semi-arid regions of world (Ryan 1997, Ali *et al*. 2002). Dua (1992) determined the threshold level of electrical conductivity (EC) of 6dS for survival of chickpea under salinity.

Salt stress (i) reduces water potential (Hayashi and Murata 1998, Munns 2002, Benlloch-Gonzalez *et al.* 2005), (ii) creates imbalance in ion (Hassanein 2000) and (iii) causes toxicity.

Salinity also imposes osmotic stress and ion toxicity (Munns 2005), ion imbalance and nutrient deficiency (Tejera *et al*. 2006) in plant. Millan *et al*. (2006) discussed the effects of soil salinity on anthocyanin pigmentation in foliage's of both desi and kabuli types chickpea. In addition to inhibiting growth, photosynthesis, energy and lipid metabolism (Ramoliya *et al*. 2004, Parida and Das 2005), salinity also restrains flower and pod formation (Katerji *et al*. 2001, Vadez *et al*. 2007, and 2012a).

Sohrabi *et al*. (2008) analyzed the effect of sodium (Na) salinity at different levels (0, 3, 6 and 9dSm-1) in kabuli ('Hashem' and 'Jam') and desi ('Kaka' and 'Pirooz') genotypes for growth and yield parameter suggested the plant growth, pod number, flower, seed weight and seed number get reduced due to the effect of salinity. Moreover, salinity also exerts negative effects on nodulation, nodule size and N2 fixation (Swaraj and Bishnoi 1999, Flowers *et al*,. 2010). Interestingly, Samineni *et al*,. (2011) declared that both growth stages, that is, vegetative and reproductive are equally sensitive to salinity.

2.4.2. Water Logging Stress

Excess moisture and water logging predispose plants to disease attacks and insect pests that finally affect the yield and quality of grains. Given the context, at flowering stage, water logging causes mortality in chickpea ranging from 10% (line 946-512) to 65% (cv. 'Amethyst') (Singh and Singh 2011).

The mortality of plants increased with water logging just before and after flowering of plant confirming 13% mortality of plants under water logging for 6 days before flowering. The mortality rates were recorded as 65% and 100% with water logging one day after flowering and 7.5 days after flowering, respectively (Cowie *et al*. 1995). Similarly, a set of 100 accessions was grown in excess of water for 50 days, and based on experimental results, it was noticed that 19 genotypes did not show any germination, five genotypes survived up to <20 days. Outstandingly, the progeny derived from the cross DZ10-4 9 JG9-2-3-88 had tolerance and survived for 45–60 days (Bejiga and Anbessa 1995). Further, the effects of water logging at various physiological stages were monitored by keeping the plants in waterlogged condition showed survival of plant decreases in water logging condition with increase in physiological stage (Cowie *et al*. 1996). The effect of water logging on root growth, plant biomass and seed yield was examined in two chickpea cultivars, 'Almaz' and 'Rupali' witnessing 54% and 44% yield reduction, respectively (Palta *et al*. 2010)

2.5. Importance and Utilization of Chickpea

Traditionally, chickpea is one of the most favored of all pulses in Ethiopian society. In Ethiopia, the chickpea grain is widely used in different forms as follows: green vegetable, kollo, nifro, dabo, genfo (porridge), kita, shimbra-asa, boklet, kik, mitad shiro, and shiro which is used to prepare the so-called "wot" (sauces) eaten with Ethiopian injera, (CSA2018).

It is 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 Beyene, *et al*., 2007), Chickpeas have several potential health beneficial effects on some of the important human diseases like cardiovascular diseases, type 2 diabetes, digestive diseases, and cancers.

Chickpea varieties have significant differences in the nutritional composition profiles between different varieties grown in Ethiopia and are an excellent source of micronutrients and macronutrients. 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, 0-225mg beta-carotene, 0.21-1.1mg thiamin, 0.12-0.33mg riboflavin and 1.3-2.9mg niacin (Duke, 1981; Huisman and van der Poel, 1994).the limiting amino acid concentrations are 0.52mg for methionine, 1.45mg for lysine and cysteine, 0.71mg for threonine and 0.16 mg for tryptophan (Million Eshete. 1994).

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.

Many smallholder farmers this meant improved income, food security, nutrition and investment in businesses such as seed production and livestock rising. Overall, the increased productivity and production have helped Ethiopia to increase its revenue and diversify exports, instead of relying totally on few exports cropping such as coffee (Tsedeke Abate, 2011).

Apart from being excellent sources of food, chickpea play a significant role in improving soil fertility by fixing the atmospheric nitrogen made it available for crop uptake. It meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg nitrogen per hectare from air.

It's leaves substantial amount of residual nitrogen for subsequent crops and adds plenty of organic matter to maintain and improve soil health and fertility. Because of its deep tap root system, chickpea can withstand drought conditions by extracting water from deeper layers in the soil profile; hence it is a drought hardy crop (Gaur *et al*., 2010).

Chickpea can tolerate cool temperatures and it is preferred to be planted during the winter than traditional spring in order to improve water use efficiency, better moisture conditions and increase yield (Rasool *et al*, 2015).

2.6. Types of Chickpea

There are two types of chickpea depending on seed color, shape, and size; desi and kabuli. According to Nigusie, *et al*., (2017), There are two different types of chickpea that grown worldwide Desi and Kabuli.

2.6.1. Microsperma (desi type)

Features of Desi types:-the seeds of this type are small and angular in shape. The seed color varies from cream, black, brown, yellow to green. There are 2-3 ovules pod-1 but on an average 1-2 seeds pod-1 are produced. The plants are short with small leaflets and purplish flowers, and contain anthocyanin (Singh & Diwakar, 1995), among the two chickpea types, the Desi type is dominantly grown in Ethiopia.

Desi chickpeas have colored and thick seed coat .The seed colors of Desi chickpeas are brown, yellow, green or black. The seeds are generally small and angular with a rough surface. The flowers are generally pink and the plants show various degrees of anthocyanin pigmentation, although some Desi types have white flowers and no anthocyanin pigmentation on the stem. The Desi types account for 80-85% of world's chickpea area. The splits (dal) and flour are in variably made from desi type.

2.6.2. Macrosperma (kabuli type)

Features of Kabuli:-White or beige colored seed with ram-head to rounded shape characterizes the Kabuli type chickpeas; the seed coat is thin with smooth seed surface.

The flowers of Kabuli type are white and lack anthocyanin pigmentation on the stem. As compared to Desi type, the Kabuli type has higher levels of sucrose and lower levels of fiber, The plant is medium to tall in height, with large leaflets and white flowers, and lacks anthocyanin .(Singh & Diwakar, 1995)

The Kabuli type generally has large seed size (100-seed mass >25 g), and receive higher market price than Desi type. The price premium in Kabuli type generally increases as the seed size increases.

2.7. Chickpea Production Potential and Constraints in Ethiopia

2.7.1. Chickpea production potential in Ethiopia

Agro-ecological suitability in the cultivation of chickpeas and high revenue gotten from export its cultivation practice and chickpea improvement program in Ethiopia made considerable efforts to overcome the aforementioned constraints and developed 27 improved varieties and management technologies coupled with their dissemination to farmers.

It is Ethiopia's third most important export legume after faba bean and haricot bean, generating revenue of about USD 61 million annually by kabuli type chickpea, and making chickpea one of the main pulse crops in the country in terms of cropped area, total production and direct human consumption, (CSA, 2019).

It plays a crucial role in food security and poverty reduction in Ethiopia, (MoA, 2018),the country is the largest consumer and exporter of chickpea in Africa and shares some 4.5% of global chickpea market and more than 60% of Africa's global chickpea market (CSA (2019), (Awel Mohammed *et al*., 2022)

Plant genetic resources and genetic diversity present in them provide assurance for future genetic progress and insurance against unforeseen threats to agricultural production (Hari *etal*, 2018).

Genetic diversity of plants is very important for developing high-yielding varieties and for maintaining the productivity of such varieties in the plant breeding strategies. In the studies of Ethiopian chickpea morphological characters, the landraces showed considerable variability within and between chickpea populations (D. Melese, 2005). Now a day established three local chickpea seed producers and marketing cooperatives with a member of 505 farmers were established,(Shiferaw Bekele, *etal* 2007)..

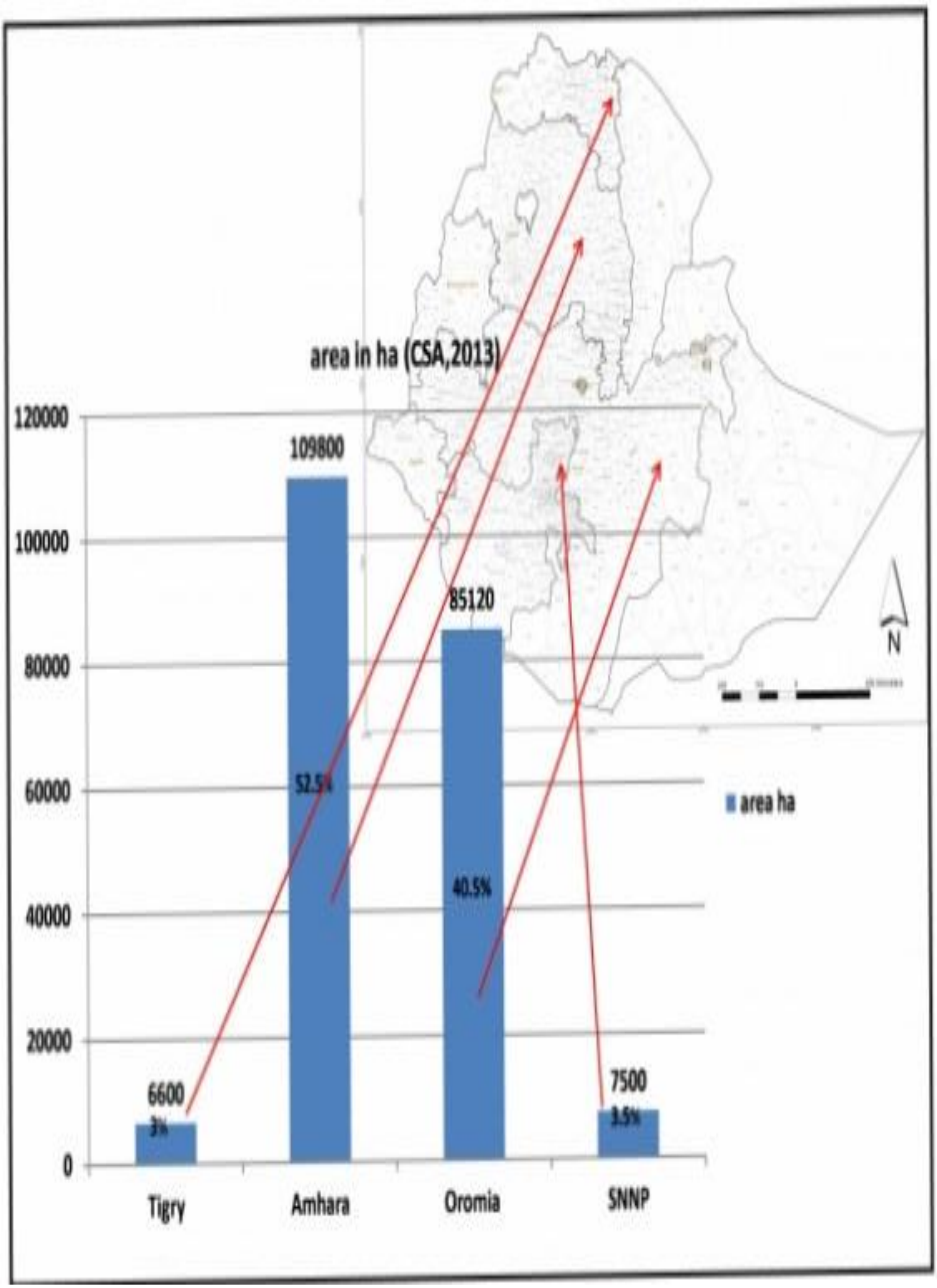


Figure2.1. Chickpea producing regions in Ethiopia,

(CSA, 2013)

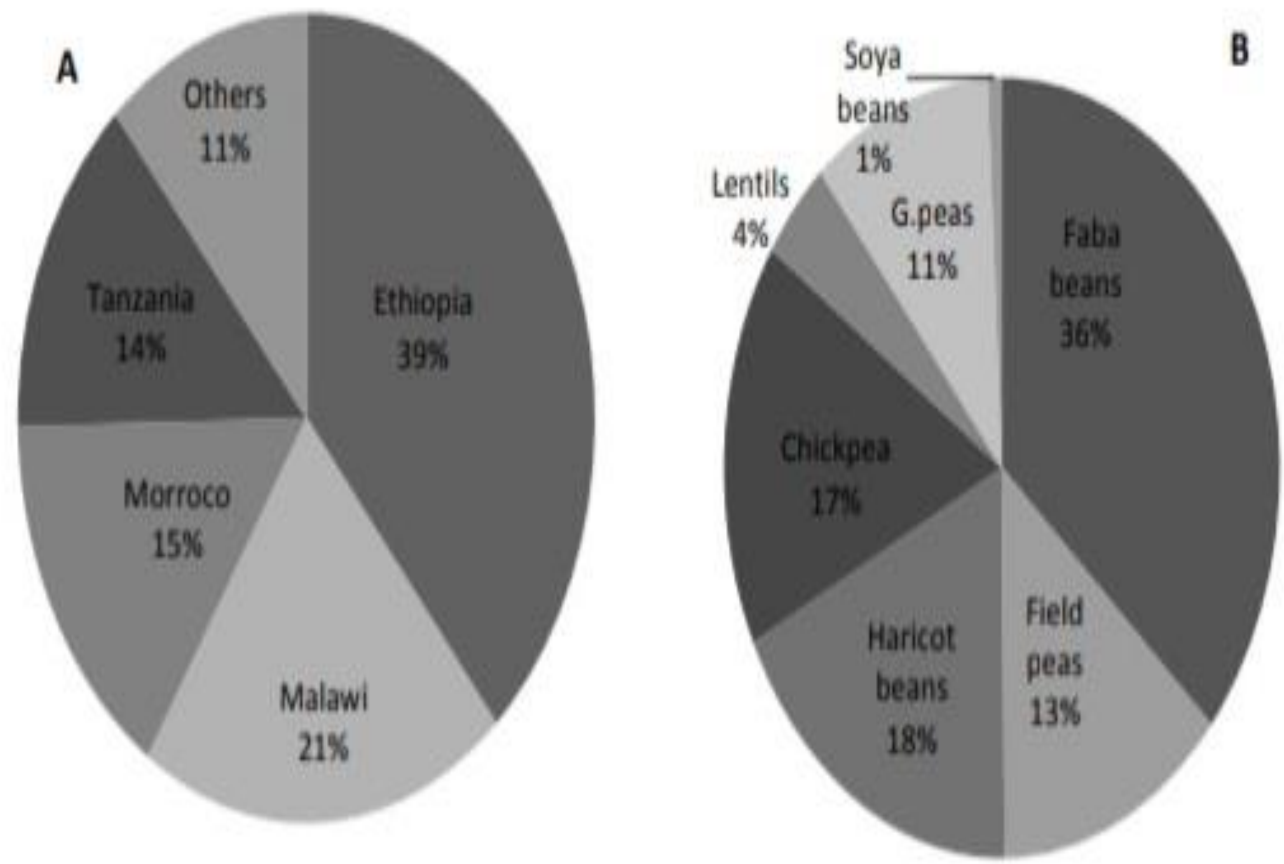


Figure2.2.major chickpea producer African countries and chickpea production status from other legume crops, in Ethiopia

Source (CSA, 2013).

2.7.2 Chickpea Production Constraints in Ethiopia

The major limitation to chickpea adoption is lack of seed systems, shortage of quality seed and lack of timely delivery, and insufficient access to production credit to farmers. More than 90% of the annual seed demand for chickpea production was covered by the informal seed system either by own saved seed or through farmer to farmer seed exchange system, (Bishaw and Van Gastel, 2008, Atilaw and Korbu, 2011).

The formal seed system of the country supplies below 10% of the seed demand and when disaggregated over 90% was focused on maize and wheat seed production. As of the forgoing gaps in the formal seed system, this scaling up activity was done to promote improved chickpea technologies coupled with seed multiplication and delivery. Therefore, to expand the area coverage of improved seed, to ensure its sustainability and market participation of smallholder farmers establishing farmer seed producer and marketing cooperative is the best alternative.

The production and market participation of smallholders in Ethiopia is not satisfactory and below the available potential (Shiferaw Bekele etal, 2007).

Market imperfections have led to a stagnation of the sector with producers remaining in subsistence production (Shiferaw Bekele etal, 2007).

The performance of chickpea is affected by abiotic and biotic factors. Abiotic factors such as soil salinity, extremes of temperatures and flooding. Abiotic factors affect water relations of the plant, both at cellular level as well as at the whole plant level, causing both specific and non-specific reactions, damage and adaptation reactions (Potters *et al*., 2007).

Rasool *et al*, (2015) states that yield performance of chickpea is also influenced by deficiencies in some elements in agricultural soils such as nitrogen, phosphorus and the presence of heavy metals such as arsenic which is found in the oxidized state as arsenite (As (III)) and arsenate (As (V)).

Biotic factors such as diseases, insects, pests and plant parasitic nematodes affect chickpea productivity (Beyene *et al*., 2015). Castillo et al. (2008) identified chickpea parasitic nematodes that are estimated to cause annual yield losses of 14% as reniform nematode (*Rotylenchulus reniformis*), root-knot nematodes (*Meloidogyne spp.*), root lesion nematodes (*Pratylenchus spp*.) and cyst-forming nematodes (*Heterodera spp*). Root diseases (fusarium wilt, collar rot
And dry root rot) and foliar diseases (ascochyta blight, botrytis grey mold) also threaten chickpea production. Insects pests such as pod borer (Helicoverpa armigera),
Cutworm and bruchids significantly reduces chickpea yield (Beyene *et al.*, 2015).

Factors such as low yield potential of local cultivars, for example the Ethiopian Desi chickpea types, with small seed size and undesirable texture, are low in productivity.
Moreover, poor cultural practices and susceptibility of landraces to biotic and abiotic stresses are also issues of concern in Africa. Unavailability of improved seed also contributes to low productivity and some high-yielding varieties with market-preferred traits have not reached farmers on a large scale. Farmers are growing local landraces,

which do not meet the quality and quantity requirements preferred by the domestic and international markets.

2.8. Effect of crop management practices on the yield and yield component of Chickpea

2.8.1. Sowing date

Chickpea is a cool-season annual legume originated in the 'Fertile Crescent',(Saseendran et al.,2004), (Yau, 2005). The purpose of determining the planting date is to find the best time for germination, establishment and survival seedling of seed using environmental factors that affected plant development growth.

In general, any delay because some part of sun light is not received by canopy (Jose, F *et al* ,2004), Delay in planting result in decrease of dry matter, grain yield and its quality due to reduction of mount of received sun radiation by canopy Jose, F *et al* ,2004),. Ozer .H, 2003), related the low grain yield of safflower in late planting date to reduced number of sheath in plant and harvest index.

Among other important reasons for reducing grain yield in delayed planting date are reduction of canopy area and short length of vegetative period, (Hocking *et al*, 2001), Robertson *et al*, 2004), that delay in planting date reduced the 1000- grain weight and its yield.

The response of concluded grain yield components to density plant is varied and is relatively compensable in a way that increase in density is accompanied by decreasing in grain number and weight of 1000- grain per head, Although, increase of plant population resulted in increasing number of head per area unit which ultimately leads to high yield, (Ferreira *et al* 2001).

To achieve the highest yield, in addition to optimum density, consistent distribution of plants and consequently the structure of plant canopy are great importance (Egli, *et al*, 1991].

Chickpea sowing at proper/optimum time is one of the important factors that affect crop yield (Ewert, 2017)

Sowing before or after the optimum date considerably decreased the crop yield of soybean (Rehan, 2002). Calvino *et al*, 2003) stated that planting date has a major consequence on yield of the crop. Sowing date is an excellent loom to augment both yield and monetary profit if administration is done perfectly.

Sowing date also affects photoperiods, which regulates time taken to commence flowering as well as time to continue growth and developmental phase (Berger-Doyle *et al*., 2014).

Planting date usually has an important influence on yield, because it affects the crop's growing conditions and period.

In Mediterranean environments, precipitation occurs mainly in the winter, and summers are usually hot and dry (Saseendran *et al*., 2004). Thus, in rain-fed agriculture, late-planted crops are usually subjected to heat and water stress in the later stages of growth, and are poor in yield.

In most of the Mediterranean and Near East, chickpeas are traditionally planted in the early spring, near the end of the rainy season, (Saseendran *et al*., 2004), (Yau, 2005), this means that the crop depends largely on residual soil moisture, which can limit yield potential. Farmers' reluctance to plant in autumn or winter cannot be attributed to a lack of cold tolerance in chickpea, because in relatively mild areas of the region, practically all chickpea lines have sufficient cold tolerance to survive the winter.

The main reason for farmers not to practice autumn planting is the greatly increased risk of a severe epidemic of ascochyta blight disease (caused by Ascochyta rabiei) that may wipe out the crop (Raza *et al.*, 2014).

In rain-fed, semi-arid areas, there is a need to keep a balance between the amount of vegetative growth and the limited soil moisture to optimize grain yield. One way to maintain this balance is through the adjustment of seeding rate. Under irrigated or high-rainfall conditions, high seed rate may be used, but seed rate has to be decreased under rain-fed, semi-arid conditions (Saseendran *et al*., 2004), (Yau, 2005).

Sowing date had a significant effect on shoot yield, days to flowering and maturity, seed filling period, dry weight at flowering, leaf area index and plant height (Yau, 2005).

There are many factors responsible for the low yield of chickpea. The use of traditional or low yielding varieties and adoption of poor management practices are of great importance. Amongst the agronomic practices, sowing methods and proper spacing are of great importance Sowing time had a marked effect on growth and development of crop (Reddy *et al*. 2003).

Optimum sowing time provides more time for growth and development of plant that is favorable for higher yield whereas both early and late sowing hinders the growth and development with lowering seed yield, (Gurung, *etal*.1996).

Chickpea is normally sown during second fortnight of October to first fortnight of November in Chhattisgarh. Studies have shown that early winter sowing (mid-October to mid-November) is the optimum period (Saxena, 1987), Late sowing, after November 18 reduced yields by 28 per cent for every 10-day interval delay sowing time.

Number of pods Plant-^{1} a significant reduction was recorded in number of effective pod plant-1 with successive delay in sowing time after 3rd week of November. Among different sowing time, 3rd week of November sown crop with significant difference followed by 1st week of November (76.31) sowing. The lowest number of pods was recorded in 3rd week of December sown crop with significant difference to others.

The reduction in number of pods plant-^{1} was 8.59, 31.7 and 46.68 % in 1st week of November, 1st week of December and 3rd week of December sowing respectively, over 3rd week of November sowing. Optimum weather condition favours growth and development of plants, which leads in more number of pods plant compared to un favorable condition occurred under delayed sowing resulting in lesser growth and developmental period.

The beneficial effect of early sowing on pods plant-^{1} was also reported by Sharma *et al.* (1988), Dixit *et al*., (1993a) and Prasad *et al.* (2012) Regarding effect of spacing, closer spacing of chickpea exhibited lesser number of pods plant-^{1} as compared to wider row spacing of 50 cm. Significant maximum number of pods plant-^{1} was noted under 50 cm (74.21) with significant difference followed by 40 cm (65.14). The lowest number of pods plant-^{1} was recorded under 30 cm row spacing (56.65) with significant difference to other spacing. Increase in row spacing resulted in increasing number of pods plant-^{1} in general. Wider spacing had 14.99 and 31.0% higher number of pods plant-^{1} under 40 cm and 50 cm spacing, respectively, as compared to closer spacing of 30 cm. This is because of efficient utilization of nutrient, water and solar radiation at wider row spacing as compared to narrow row spacing.

Increase in pods plant-[1] with increase in row spacing had also been reported by Sonboir *et al.* (2017) .As concerned to effect of nipping on number of pods, nipping of chickpea exhibited more number of pods plant-[1] compared to no nipping. Significantly, maximum number of pods plant-[1] was recorded less than one nipping at 40 DAS (66.78) which was at par with one nipping at 30 DAS (66.70). The lowest number of pods plant-[1] was recorded under no nipping (62.51) with significant difference.

The average increase in number of pods plant-1 was 6.77 % due to nipping over no nipping. Nipping at 40 DAS and 30 DAS recorded 6.83 and 6.70 % higher number of pods plant-[1] as compared to no nipping. The nipping is known to accumulate more photosynthesis which are utilized for development of higher number of pod (Singh and Devi, 2006) One nipping at 30 to 45 DAS recorded higher number of pods plant-1compared to no nipping (Sonboir *et al*., 2017 and Sujatha *etal*, 2016) .

The interaction effect of sowing time and spacing exhibited that 50 cm spacing recorded higher number of pods plant-[1] at all sowing time with significant difference to other spacing, however it was at par with 40 cm spacing in 1st week of December and 3rd week December sown crop. Among all the combination, 3rd week of November with 50 cm spacing recorded highest number of pods with significant difference to other. Similarly lowest number of pods was recorded in 3[rd] week of December with 30 cm spacing which was at par with 3rd week of December 40 cm spacing. The interaction effect of sowing time and nipping showed that one nipping at 40 DAS recorded maximum number of pods plant-[1] in 1st and 3rd week of November sowing which was however at par with nipping at 30 DAS. Moreover in 1st and
3rd week of December sowing, maximum number of pods was noted in no nipping with significant difference. The nipping in December sown crop exhibited reduction in number of pods plant-[1]. Among all combinations, the higher number of pods was recorded in 3rd week of November sowing with nipping at exhibited significantly number of pods plant-1 (83.48 0 DAS which was however, at par with nipping at 30 DAS on same date of sowing. The least number of pods was noted in 3rd week of December sown and nipping at 40 DAS, which was at par with nipping at 30 DAS on the same time of sowing only.

Development of pods in chickpea depends on vegetative growth and number of branches flavored by sowing time, spacing and nipping. Due to this, lesser number of pods in December sown may have been observed.

Number of seed pods^{-1} Maximum number of seed pod^{-1} was recorded in 3rd week of November (1.75) sowing which was however at par with 1st week of November sowing. The lowest number of seed pods^{-1} was observed under 3rd week of December sowing with significant difference to other sowing time. The seed pod^{-1} was favorably influenced due to sowing time.

Delayed sowing of chickpea in December resulted in lesser seed pod^{-1}. This may be due to increased temperature in delayed sowing at flowering and maturity. This is in agreement with the findings of Rajput *et al.* (1986), who observed higher values of pods plant^{-1} with the 15th November sowing.

The beneficial effect of early sowing time on seed pods^{-1} was also reported By Sharma *et al*. (1988), Nipping of chickpea exhibited higher number of seed pods^{-1} as compared to no nipping. Significantly maximum number of seed pods^{-1} was recorded fewer than one nipping at 40 DAS (1.67) which was at par with one nipping 30 DAS (1.64). The lowest number of seed pods^{-1} was recorded under no nipping (1.62) which was at par with one nipping at 30 DAS.

100-seed weight (g) among different sowing time, that 100 seed weight was recorded higher in 3rd week of November (24.01) sowing with significant difference followed by 1st week of November (22.35). Minimum 100 seed weight was observed in 3rd week of December sowing with significant difference to other sowing time.

The yield Parameter of chickpea i.e. 100-seed weight was favorably influenced due to sowing time. Timely sowing provides favorable weather condition for growth and development of seeds leading to bolder seeds.

Delayed sowing coincides with higher temperature at grain development stage that leads to more small sized grain. Rajput *et al*. (1986) who observed higher values of 100-seed weight with 15 November sowing. Sharma *et al*. (1988) also reported the beneficial effect of early sowing time on 100-grain weight, the 100 seed weight was noted higher in wider spacing and it decreased with lower in spacing. Maximum 100 seed weight (21.45) was recorded under spacing of 50 cm that was at par with 40 cm spacing (21.40). Minimum 100 seed weights were observed under 30 cm spacing (20.96) with significant difference.

Increase in row spacing resulted in increasing 100- seed weight in general. This is because of efficient utilization of nutrient, water and solar radiation at wider row spacing as compared to narrow row spacing. Saini and Faraday (1997), Thakur *et al*. (1998), and Mondal (2000) have also reported increase in yield attributing characters with increase in row spacing, Nipping of chickpea exhibited more 100 seed weight as compared to no nipping. Significantly, maximum 100 seed weight was recorded fewer than one nipping at 40 DAS (21.50) which was at par with one nipping 30 DAS (21.32).

The lowest 100 seed weight was recorded under no nipping (20.98) with significant difference. The higher seed quality parameters noticed with nipping at 40 DAS may be due to increase in photosynthetic area leading to higher photosynthetic rate, better assimilation and accumulation of more photosynthesis resulting into better seed development as evident with higher 100-test weight observed by Gnyandev (2009) in chickpea.

Sujatha *et al.* (2016) also reported that the nipping at 45 DAS recorded higher 100-seed weight.

2.8.2. Row spacing (intra and inter)

One of the main reasons of low yield of Chickpea (*Cicer arietinum* L.) is improper population. Too low and high plant population beyond a certain limit often adversely affects the crop yield. Number of plants per unit area influences plant size, yield components and ultimately the seed yield (Beech and Leach, 1989). Moreover, plant spacing in the field is also very important to facilitate aeration and light penetration in to plant canopy for optimizing rate of photosynthesis.

There is very little information available on the relative contribution of various plant spacing towards yield and yield components and their interaction. Both over and under plant densities resulted in significant yield decrease (Ashour, *et al.* 1995).

Panwar *et al*. (1980) and Singh *et al*. (1994) reported row spacing of 45 cm increased chickpea yield compared to 30 and 50 cm spacing while Parihar (1996) indicated that row spacing had no significant effect on seed yield. Nawaz *et al.* (1995) and Felton *et al*. (1996) concluded that dry matter production and plant height were higher in higher plant populations (60 plant m-^{2}), and a population of 40 plants per square meter gave the maximum grain yield.

Khan *et al*. (2001) concluded that narrow row spacing of 30 cm produced significantly maximum yield than at of wider row spacing of 70 cm. But Barary *et al*. (2002) observed the effect of row and plant spacing on seed yield was non-significant. Seed rate of 40-50 and 75-100 kg ha-^{1} was found sufficient for small seeded and bold seeded varieties, respectively (Faroda and Singh, 1979) but Javadi *et al.* (2004) achieved more yield at 75 kg than that of 100 kg seed rate ha-^{1}.

Yield increased with increase in plant population up to 50 plants m-2 for irrigated and population of 23 plants m-2 was ideal for rain fed chickpea (Saxena, 1979 and Lather, 2000). Contrary to this Karawasra and Faroda (1979), McKenzie, and Hill (1995) reported that seeding rate (30, 45 and 60 kg ha-^{1}) and row spacing (20, 30 and 40 cm) did not affect gram yield though higher plant population intercepted more solar radiation.

Arshad *et al*. (2008) narrated that maximum seed yield was harvested at 75 kg seed rate ha-^{1}. Among the yield components, number of pods plant-1 and number of grains pod-^{1} and 1000 seed weight decreased with increasing seed rate (Aziz *et al.*1988 and Komatsu *et al*.1989).

Tripathi and Singh (1989) and Abbas (1990) stated that different seeding densities affected number of branches plant-^{1}, pods plant-^{1}, seeds pod-^{1}, 1000 seeds weight, total dry matter, did not significantly influence different seed rates while Zahoor (1991) reported that 1000 seeds weight, biological yield, seed yield and harvest index and seed yield significantly.

Machado *et al.* (2006) narrated that row spacing did not affect yield but higher seeding rates increased yields in late seeded chickpea when moisture was not limiting.

Machado *et al*. (2003) revealed that biological and grain yield was increased when the seeding rate was increased from 17 to 33 seed m-2, no further response was obtained by increasing seeding rates to 50 seeds m-2 and observed that row spacing did not influence grain yield but more yield was reported by Corp *et al.* (2004) at seeding rates of 44-55 seeds m-^{2} than lower seeding rates of 33-44 seeds m-^{2}.

Regan *et al*. (2003) and Gan *et al*. (2003) recommended optimum plant population density for higher seed yield from 40 to 45 plants m-2 for Kabuli chickpea and from 45-50 plants m-2 for desi chickpea.

Pu-hai Liu *et al*. (2003) concluded that as plant population increased from 20 to 50 plants m-^{2}, seed yield m-^{2} increased by 20% for desi and 27% for small seeded Kabuli chickpea.

Lines *et al*. (2008) reported 70 % reduction in grain yield, when plant density was increased from 15 to 90 plants m-^{2}.

Keeping in view the contradictory findings about the spacing of crop, there is a dire need to find out appropriate row spacing and seed rate to harvest maximum yield of good quality chickpea.

Munir *et al*, 1987), reported that biological yield decreased with wider row, which is due to decrease in number of plants in area in wider planting row spacing.

Optimum row spacing plays an important role in contributing to the high yield because thick plant population will not get proper light for photosynthesis and can easily be attacked by diseases.

On the other hand, very small population will also reduce the yield (Pookpakdi and Pataradilok, 1993). Due to this reason, normal population is necessary for high yield.

Denmead *et al*. (1962) estimated that 60 cm inter row spacing might increase the energy available for photosynthesis 15-20%, compared with 100cm spaced row in corn. Uniform spacing generally gives a greater yield than hill groupings under favorable moisture conditions. However when moisture is a limiting factor, the advantage may be small or mild (Dungan et al., 1958).

Donald (1963) suggested that the advantage of uniform spacing under irrigated conditions is due to reduced competition for light because when the moisture is lacking, light is no longer the limiting factor and the advantage of uniform spacing is lost.

Singh and Singh (1990) reported that seed yield was highest in CV. UMP 79-1-2 (1.21 kg haG1) and lowest in CV. Type-11 (1.06 t), while plant population did not affect seed yield. Pookpakdi and Pataradilok (1993) conducted study in the 1989 wet and dry seasons and the 1990 dry season.

Mungbean yield was highest in the 1989 wet season, whereas black gram produced higher yields in the dry seasons. Yield of both crops generally decreased with decreasing plant density, while pod number/plant increased with decreasing density. For commercial cultivation of row spacing of

30cm with plant spacing of 10 cm is generally used to obtain 320,000 plants haG1 (Bashir, 1994).. Kumar and Sharma (1989) who reported higher biological yield at narrow row spacing, but don’t confirmed by Soni *et al.* (1991), who reported non-significant effect of row spacing on biological yield. Different row spacing, have different yield i.e., 921, 818.8, 727 kg yield haG1 for row spacing of 20, 30 and 43 cm, respectively.

Ali-khan and Kiehn (1989), Kler *et al*. (1991), Singh *et al*. (1991) and Board *et al*. (1992), who reported that narrow spacing's resulted in higher grain yields in food legumes..

2.9. Interaction effect of crop management practices on the yield and yield component of Chickpea.

2.9.1. Interaction effect of sowing date, inter- and intra-row spacing

The low yield of crops has been partly attributed to inappropriate plant density, planting time, and pest pressure (weeds, diseases and insect pests) (Gebre-michael, 2011). Tolossa Amenu *et al* 2020 reported that plant height, ear height, stem diameter, leaf area, and number of ear per plant, 100-seed were significantly influenced by only main effect of intra and inter row spacing, except leaf area, which was affected by interaction of intra and inters row spacing's.

Munir *et al*, 1987, Biological yield influenced by interaction effect of planting date × row spacing was significant. As interaction effect of planting date × row spacing, Biological performance decrease with delay in planting and wider row spacing. 6 December planting date at row spacing of 30 cm and 5 January at row spacing of 60 cm had the highest and lowest biological performance respectively. Planting date and row spacing have significant influence on radiation distribution in plant population as well as photosynthesis, (James, *etal*, 1994).

Chickpea late sowing in narrow rows however cannot recover yield but it reduces loss up to 16 %(Weaver et al., 1991), Further experiments indicated similar outcomes with narrow rows by providing yield advantage of 244 and 120 kg ha-^{1} compared to wide rows keeping the sowing dates constant. Same yield response has been reported from chickpea varieties, which mature early, when they are late sown.

Early maturing soybean cultivars sown in narrow rows take yield advantage over wide rows (Sweeney *et al*., 1995).

Amrinder Singh *et al*, 2019 number of grains/pod found significantly higher in D2S2 (date of sowing of chickpea on Oct 25th with seed rate at 62.5 kg/ha). The interaction effect between date of sowing and seed rate on 1000-grain weight was significant in chickpea. The interaction effect of date of sowing and seed rate on harvest index was significant

The yield reduction under late sowing dates have been similar results were also reported by also Srivastava *et al*., (1990), Paikaray and Misra (1992), Singh and Dixit (1992), Dixit *et al*., (1993) and Singh *et al*., (1988). Singh and Sharma (1988) reported that, there was appositive correlation between plant height and the number of plants per unit area due to more competition for light. Comparing various planting dates showed that planting date of November 6th had the highest plant height because of the increase in duration of the period of plant growth.

Rezvani and Sadeghi (2005) had stated that plant height increase as the duration of growth period increases. In this connection, Rahemi and Soltani (2005), Rezvani and Sadeghi (2005) and Goldani *et al*. (2000) observed plant height increase with high densities and early planting dates in their experiments.

According to Rahemi and Soltani (2005), the height of the first pod to soil surface increases with earlier planting dates as well as with the increase in density. There was a significant difference (p = 1%) between density and different planting dates in terms of the number of sub branches, but not between interaction of density × planting dates in this respect. The maximum number of sub branches was related to row 40 cm space and the minimum of it was related to row 20 cm space.

The highest number of sub-branches (4.2) was also associated with planting dates of November 6th and the lowest one (2.2) was associated with December 6th. Goidani *et al*. (2000), Jalilian *et al*. (2005), Shams et al.(2005) and Singh *et al*. (1988) have examined the effects of density and planting date on the number of sub-branches and stated that the number of sub-branches decreases with the increase in density and with delayed planting. For the number of pods per plant , a statistically significant difference (p = 1%) was observed between density and different planting dates.

2.9.2. Interaction effect of sowing date and intra row spacing

The difference among the inter row spacing in response to intra row spacing on number of pods might be due to the fact that, as the plant population increased there was high competition for the growth factors as compared to wider spacing which had an impact on adjacent chickpea plants could have enabled the plants grown at wider spacing to utilize its energy for more branch and subsequently, the greater number of pods plant-^{1}. In agreement to the present result, Khan *et al*. (2010) reported higher number of pods plant^{-1} in the wider inter row spacing of chickpea.

Keyvan Shamsi ,2010) reported that row 20 cm spacing had the highest biological yield (2,857 kg ha^{-1}) followed by row 30 and 40 cm spacing (2,582 and 1,673 kg ha^{-1} repeatedly). Among various treatments, the highest and lowest biological yields were respectively obtained from planting date of November 6th × row 20 cm spacing and planting date of December 6th × row 40 cm spacing. Experimental results showed that although one plant-weight decreased with high densities, this weight reduction was made up by increasing the number of plant per unit area and biological yield per unit area was higher in high densities than low ones.

Rastegar *et al. (*1998) reported similar results. According to the results of this research, planting date and density as well as their mutual effects had no significant impact on harvest index. Bagheri *et al*. (1997) argued chickpea harvest index was obtained at a spectrum from 20 to 47%, having a positive direct relation with grain yield. Pezeshkpur P, *etal*,2005) proclaimed in his report that, harvest index decreases with high densities because of delayed formation of sub-branches which have high share of plant dry weight per unit area.

2.9.3. Interaction effect of sowing date and inter row spacing

Optimal planting date and row spacing are the most significant cultural decisions a farmer makes (Board and Kahlon, 2013). Analyses of crop growth dynamics and yield components have given a wide-ranging picture of how sowing date and lines pacing impinge on soybean production (Lobell *et al*., 2009).

Loomis and Connor (1992) stated that growth energetic parameters are light interception, Leaf area index, rate, and level of total dry mass. Some others that develop yield of soybean and all crops are, Crop growth rate and Date of maturity producing parameters like Harvesting index [(yield dry matter per area/total dry matter per area) x 100]. Seed counting per area, seed mass (grams per seed), number of pods per area, number of seeds per pod, number of pods per reproductive node and total reproductive nodes per area are the yield gears, which have potential to manipulate chickpea yield. Non-optimal sowing date and row spacing minimize seed yield by declining the number of seeds and number of seeds per area (Kahlon and Board, 2012). Ferreira and Abreu [5] stated effects of planting date and row spacing on yield, yield components and related traits in fall safflower under rain fed condition.

Morrison *et al*., 1997 reported interaction effect of planting date × row spacing. Showed that delay in planting, increase in row spacing decreases the number of head per plant, the maximum and minimum number of head per plant was obtained in 6 December, 5 January, and row spacing 30cm and 60cm respectively 6 December.

2.9.4. Interaction effect of inter- and intra-row spacing

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, Shamsi and Kobraee (2009) who worked 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.

Aziz *et al*, 1988) and Abbas (1990), reported decreased number of pods plant-1 and 100 seed weight with increasing seed rate. The interaction of row spacing and seed rates was significant for number of pods plant–1 and their average ranged from 28.94 to 45.61. The highest number of pods plant–^{1} (45.61) was recorded in 45 cm row spacing cum 75 kg seed rate ha–^{1}. The lowest number of pods plant–^{1} (28.94) were recorded in the treatment with 15 cm row spacing x 100 kg seed rate ha–^{1} (RS1 x S4) closely followed by treatment combination of RS2 x S4 and RS5 x S4 with 29.73 and 30.10 pods per plant and these treatments were non-significant statistically.

Whenever the seed rate was increased to 100 kg ha–^{1}, planting geometry was shifted to 15 cm single rows or 15/45, and 15/75 cm paired rows, number of pods plant–^{1} decreased and were less from 45 cm single rows and 75 kg seed rate ha-^{1}. It might be due to greater number of plants per unit row length, which might have adversely affected the pod development, hence, pods formation were comparatively less than that of low seeding rate which resulted in greater competition for light, space and nutrients. Nazir *et al*. (1991), who reported that all the yield-contributing characters were favorably affected by planting geometry obtained similar results.

Biabani (2011) reported higher grain yield of chickpea at average (45cm×7.5cm) spacing combination than 35cm×5cm and 55cm×10cm spacing combinations. Singh and Singh (2002) who reported that the yield per unit area was increased with increasing plant density due to efficient utilization of growth factors. The highest mean harvest index (45.45%) of chickpea was obtained from the interaction of 40 x 15 cm inter and intra row spacing, the lowest harvest index (42.08 %) of chickpea was obtained with the narrowest inter- and intra- row spacing, *i.e*. 20 × 10 cm. this reduction in harvest index in narrower spacing might be due to the higher plant population per unit area, which might have increased the flower abortion due to competition for nutrients, moisture and solar radiation. Similarly, Chala *et al*, 2020 reported that the maximum harvest index (34.03%) in the widest row spacing (40 cm) of chickpea than 20 cm row spacing. Khan *et al*. (2010) reported higher hundred seed weight (29.87g) in the wider inter row spacing of 45 cm than 30 cm inter row spacing of chickpea.

Recently, (Attia, A. *et al* 2012) reported that maize plants sown in line having (60 cm) row to row distance had heavier 1000 grains weight and highest grain yield. Leilah A.A. *et al* (2013) point out that planting maize in ridges 80 or 90 cm apart produced the highest values of yield and yield components and planting maize in ridges 70 cm apart gave the lowest values of yield and growth parameters. According to the recent investigation, (Gobeze, Y *et al* 2012) the highest number of the ear, stem diameter and cob length were recorded at 8 plants /m^2, while the highest values of plant height were recorded at 12 plants/m2. Similarly, Darwich M. (2009) reported that increasing maize distance between rows from 60 to 70 and 80 cm lead to a significant increase in growth character, grain and its components due to better interception and utilization of solar radiation and the increase in photosynthetic processes.

Population above the optimum has resulted in lodging that has caused a reduction in maize production. Sharifai A, *et al*., (2012) reported that increase in intra-row spacing from 20 to 25cm significantly increased number of row per cob, cob diameter, 100-grain weight and grain yield. The earlier crop cover provided by smaller / narrow intra row is instrumental to enhance soil protection, diminishing water runoff and soil erosion (Sangoi *et al*., 1998, and Mureithi, *et al*, 2012).

Row spacing is one of the important characters, which can be manipulated to attain the maximum production from per unit land area. The optimum row spacing with proper geometry of planting is dependent on variety, its growth habit and agro climatic condition. The seed yield of chickpea is highly dependent on plant population. Seed yield increases with decreased row spacing up to an optimum limit which changes according to genotypes.

Goyal *et al* (2010) Studied on growth and yield of kabuli chickpea (*Cicer arietinum* L.) genotype under different plant densities and fertility levels. Sharma and Dadheech (1986) reported higher seed yield (15.69 q/ha) with 30 cm row spacing while 45 cm row spacing reduced the yield (12.79 q/ha).

Beech and Leech (1989) studied growth and yield of chickpea at row spacing of 18,36,53 and 71 cm. Row spacing had only a small effect on ground dry matter production and yield. There was no significant difference in yield at different row spacing. Brhanu Challa *et al* ,2020), reported that desi type (var. Marye) (bold seeded), chickpea Significantly higher (248 g) 1000 grain weight was recorded under 40 cm with 20 cm spacing and lowest (165 g) 1000 grain weight under 30 cm x 5 cm row spacing. The highest (1625 kg ha-1) seed yield of chickpea was obtained from 30 cm x 15 cm and the lowest seed yield (1096 kg ha-1) was recorded from 20 cm x 5 cm row spacing. The highest harvest index (34.03%) was achieved for the interaction of 40 cm inter- and 20cm intra-row spacing and the lowest harvest index (12.14%) under 20 cm x 5 cm row spacing. 30 x 10 cm.

2.9.5 Method and rate of seeding

Seeding rates vary because of the variation in seed size. Seeding rates range from three to four seeds/square ft. This is equivalent to 80 to 95 pounds per acre for the Desi types and 150 to 200 pounds per acre for the Kabuli types. Higher seeding rates (four to five seeds/ square ft) can produce higher grain yields but may not be economically feasible (M. Corp *et al.,* 2004).

Plant the seed at a depth of 1.5 to 2.5 inches. Packing the soil after seeding improves seed-to-soil contact and seed (Corp *et al*., 2004), (Loria *et al*., 2021). It is one of the most essential legume food plants in sustainable agriculture system due to its low production cost, wider adaptation, ability to fix atmospheric nitrogen which fits in various crop rotations and existence prolific tap root system (Yadav *et al*. 2020), (Loria *et al*., 2021).

Chickpea play significant role in maintaining the fertility of soil by fixing nitrogen up to 140 kg ha-^{1} per year (Flowers *et al*. 2010), (Loria *et al*., 2021). Chickpea provides low inputs of nitrogen through biological nitrogen fixation and allows benefits to other cereal crops (Siddique *et al*. 2005), (Loria *et al*., and 2021).

Reported that the chickpea also provides significant amount of residual nitrogen to the soil and adds chickpea has high economic and nutritive importance but its yield is comparatively low in India. The main reason of low yield is improper population that too low or too high plant population adversely affects the yield of crop.

An optimal plant stand is required for the desired yield level. A lower seed rate or poor-quality seed can result in poor plant stand. Poor plant standing can also result in deeper seeding than normal depth, poor soil health or soil moisture deficit.

Seed yield decreased from 270 to 206 g/m2 as sowing date was delayed The significant differences in final yield were closely associated with the variation observed in the vegetative growth which in turn had a considerable effect on the components of yield (Loria *et al.,* 2021).

Almaz Meseret, *et al* ,2022) reported Chickpea Plants were grown in wider spacing (15 cm intra row and 20 cm inter-row spacing) matured earlier than the rest of the spacing . In contrast, the narrowest spacing or highest plant density (100 plants m−2) was found to delay the time needed for maturity. & is effect can be due to the fact that the crop growth rate increased as plant density increased, (Morrison *et al.*, 1990) & is result is in line with Agajie Melkamu .2018), who reported prolonged maturity of chickpea in narrower intra row spacing due to high competition for existing resources in the soil, low light interception, and poor air circulation in the canopy.

Gezahegn Kelemu *et al*, 2016), found longer physiological maturity of faba bean recorded at narrower spacing. Abeje Melkamu ,2020), also reported that soybean planted at narrower inter-row and intra row spacing (40 cm × 5 cm) matured earlier than wider spacing (80 cm × 15 cm).

2.9.6. Harvesting

The crop becomes ready for harvest when leaves turn reddish-brown and start shedding Plants are either plucked out by hand or cut with a sickle or machine harvested with a combine.

It hand-harvested, the crop is allowed to dry in the sun on threshing floor for about five to six days. Thereafter, the threshing is done either by beating the plants with sticks or by using a stationary threshing machine or combine.

Harvesting and storage Seed color is of utmost importance to buyers. They prefer a light yellowish-cream color as opposed to greenish or brown seeds, so monitor seed color carefully.

Harvesting could be accomplished by either direct combining the crop or swathing before combining, depending on uniformity of maturity. Swath when most of the plants are yellow and pods appear nearly matured.

To reduce seed loss, swath at night or at dawn when plants are slightly damp, when the vines, pods, and seeds in the windrow have dried down to about 13 percent moisture content, the crop is ready to combine.

Adjust screen sizes and concave clearance when combining to accommodate larger seeds. Adjust cylinder and fan speeds to obtain undamaged seeds and best separation, starting at the lowest speed and increasing speed as necessary. Chickpeas are prone to shatter and header harvesting losses. Using sickle sections equipped with double-density knife guards can substantially reduce losses.

Attachments that extend knife finger length and headers equipped with air-reels also have been shown to reduce seed loss. .

Store seeds at a moisture content of 10 to 12 percent to prevent disease and insect outbreaks, (Corp *et al*., 2004).

It is important to harvest chickpeas at the right stage of maturity and not delay harvesting to avoid shattering. Substantial grain losses can occur due to shattering at the time of harvest, if the harvested crop has to be taken out of the field and moved to a distant threshing floor, the harvested plants should be placed inside sacks to avoid grain loss during transportation.

Chapter3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Northeastern part of Amhara National Regional State of Ethiopia (Figure 3.1). This field experiment was conducted on Eastern Amhara in north wollo district in Raya Kobo at Abure kebele 10km apart from south wards from the district , in one year, during the main crop growing season in 2024 E.C. it has an elevation, lies at 450 NE, 110 North & 390 Easts latitude with an elevation of 1450 to 1500 meters above sea level, The study area is one of the eight rural districts in North Wollo Zone and lies about 54 Km North to the zonal town Woldia, 189 km South of Mekele ,570 km from Addis Ababa and 410 km far away from the regional head quarter City of Bahir Dar town,. Raya Kobo is bordered in the North by Tigray Region, in the South by Gubalafto and Habru district, in the East by Afar Region and in the West Gidan distric. The agro-climatic feature of the districts is tropical as 9.3%, 35% and 55.7% are Dega, Weyna Dega and Kola, respectively.

The topography of the districts consists of 65% plain and the rest 20%, 6%, 5%, and 4% as mountainous, rugged, gorges and swampy. The principal feature of rainfall in the area is bimodal, characterized by seasonal, poor distribution, and erratic with a mean annual rainfall of 670mm that ranges from 500-850mm. (RKWAO, 2015). Based on 2023 years of climate data collected from the Northeastern Ethiopia meteorology at Kobo agricultural station, the mean minimum and maximum annual temperatures of the study area were 10.1 and 25.1 °C, respectively (Appendix table10). Moreover, the study area was receives 683.3 mm of mean annual rainfall with a mean monthly precipitation of 59.98 mm. The rainfall distribution of the area is bimodal, and the main rainy season from June to August (Fig. 3.1).

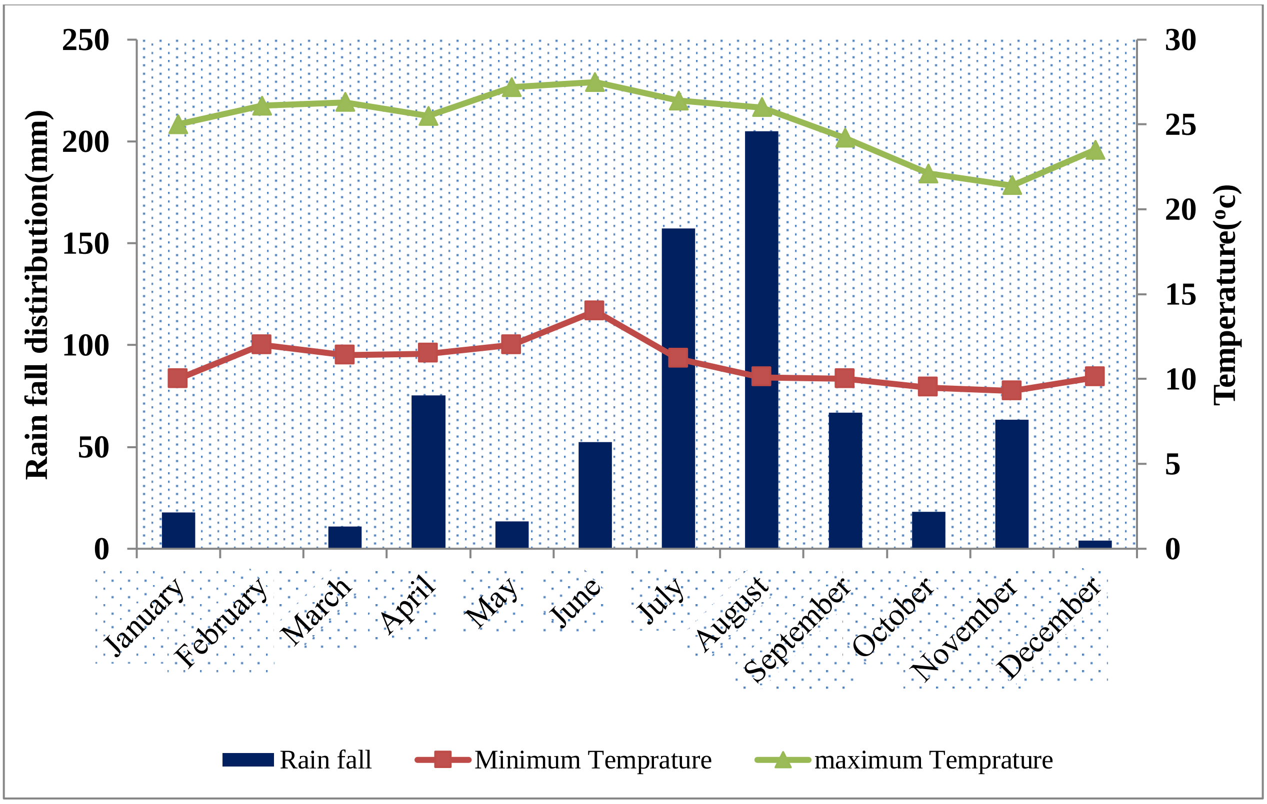


Figure3.1. Rain fails (mm), minimum and maximum temperature (°C) data during study year and location (2023/2024 E.C).

In Raya Kobo district, there are 43 rural and six urban kebele administrations. The total population of the district in 2017 is estimated to be 275,981 (138,726 male and 137,165 female). Out of the total population 218,102 (108,737 male and 109,365 female) live in rural areas whereas 57,789 peoples (29,361 male and 28,428 female) live in the urban area of the district (CSA, 2013). In addition, according to RKWAO (2015) there are 49,841 rural households in the study area. The study area represents an agriculturally potential area with high livestock population density. Mixed farming system is practiced in the area with crop production dominating livestock rearing. Despite the fact that the area is potential for cop production, however agricultural productivity is generally low and it is subsistence oriented. Livestock and its product contribute a significant proportion of cash income for households. The livestock population of the district is estimated as 242621 cattle, 32602 sheep, 118375 goats, 13863 camels, 21611 donkeys, 674 mules, 44 horses and 156126 poultry (RKWAO, 2018).The total-cultivated land of the district is 47,784 hectare. the major crop production are produced in the low land part of the district are Teff, sorghum, Mung bean and chick pea respectively and among this 15,728.25 hectare is cultivated for Teff production.11, 0100 hectares sorghum, and the remain is different types of high land crops like wheat, barely lentil, pea and chickpea and other cops .The average productivity of Teff during 2019 production year is 1.5tone/ha-[1]. The average-cultivated land size is 0.75 ha and the average fragmentation is 3 plots. The source of labor for crop production is both family and hired labor. Different types of local Teff varieties are cultivated in the district such as Magna, Tikurie, Bunign, Sergegna, and improve variety such as Zoble, Quncho and Boset. This woreda also known by the major and one of sorghum belt area in Ethiopia .The farmers was produced long cycle high yielding local sorghum varieties like Abola , Jigurte, Dagalet, Abaere etc. But know a day it is difficult produced those cultivars do to environmental change and low and an erratic rain fall. Know a day this area produced high yielding, short season improved sorghum varieties. Due to the cause of potential land and shortage of rain fall in the locality the regional Government built ground water for irrigation, then the farmers produced horticultural and other crops 3 times in a year on more than 12,000 hectares of land. Then know a day Chickpea and Mungbean is the major pulse crop used as rotational with the main crop and horticultural crops and as means of income (cash) for local and national market and for local consumptions practiced by farmers both rainfall and irrigation conditions.

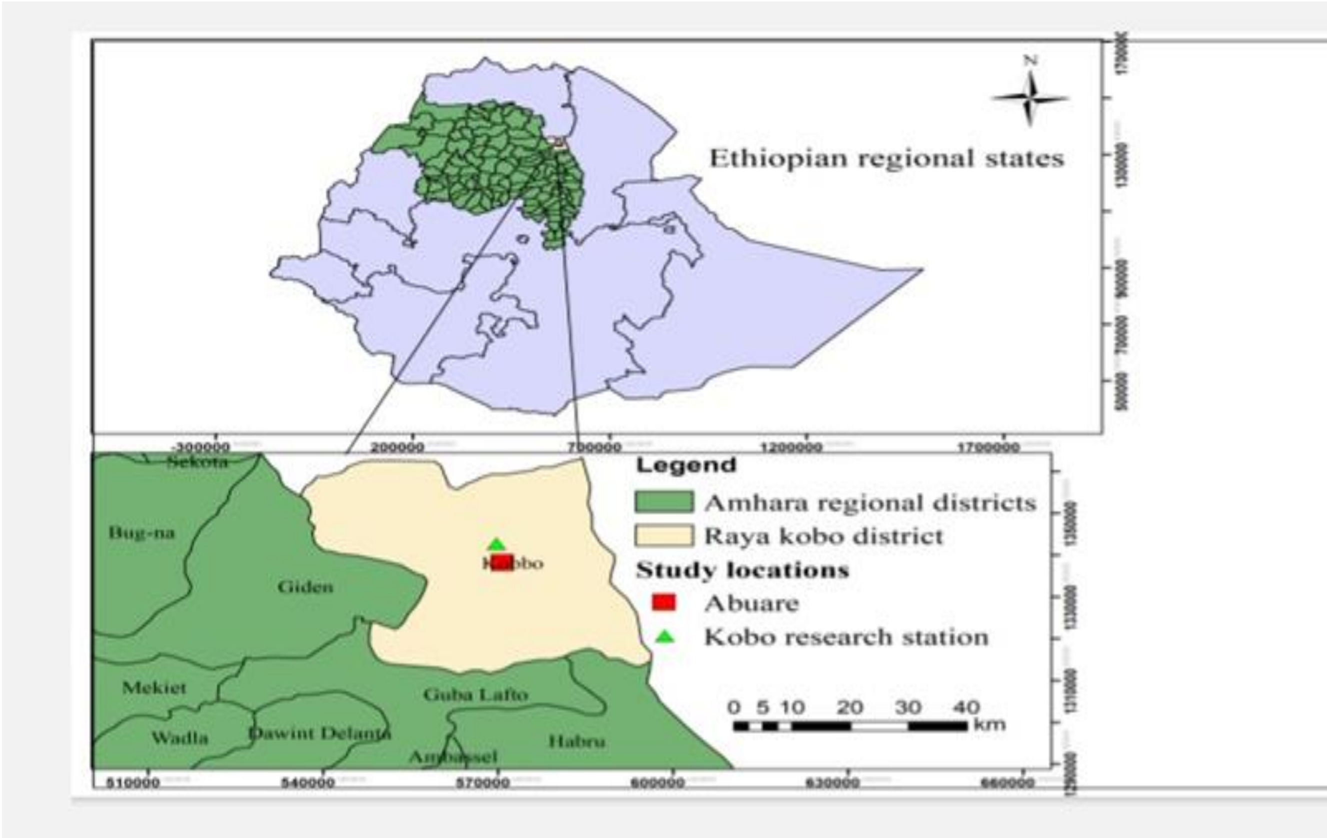


Figure3.2. Map of study area

3.2. Soil Sampling and Analysis

A soil sample was taken of 0- 20cm soil depth from 5 random spots of the experimental site with a zigzag method by using Ogre and a composite was made before planting, composite sample was taken to Debre-brihan Agricultural research center soil laboratory and analyzed for selected physic-chemical properties mainly textural analysis (percent sand, silt and clay), soil pH, total nitrogen, organic matter content, available phosphorous (P), exchangeable potassium (K+) and cation exchangeable capacity (CEC), Analysis of organic matter content of the soil in a laboratory was determined by Walkley and wet oxidation method as described by Jackson (1958) and total nitrogen by Kjeldhal method as described by (Beech, D. F, 1989), the pH of the soil was measured in water at soil to water ratio of 1:2.5, and cation exchange capacity was determined using Kjeldhal procedure as described by Page, A. L . 1982, Ranist V. E, *etal* 1990), Available phosphorous was determined according to the methods of Olsen and Dean and exchangeable potassium by flame photometer (Soil texture analysis could be performed by Bouyoucous hydrometer method (Day, P. R. 1965)

According to the laboratory analysis, the soil texture of the experimental area was clay (Table 3.1). The soil texture (proportion of sand, silt and clay in the soil) controls water contents, water intake rates, aeration, root penetration, and soil fertility. The experiment was practiced on the textural class of the soil, which is clay (Weil and Brady 2016; USDA, 2017), with a textural proportion of 42.2% sand, 13.6% silt, and 51.1% clay contents (Table 3.1). The pH of the soil was 6.2, According to Ethiosis (2016), the study soil was moderately acidic (6.2), Chickpea grows well under the pH range of 6.0 to 8.0 (ICRSAT, 2010), (Mazid & Amegbeto, 2022), reported that chickpea is best adapted to, clay loams, and clay soils. This indicates that the soil texture of the study area is suitable for chickpea production, and likewise, the content of Soil Organic Carbon (2.56%) was good (Landon 1991). Table 3.3 shows that the Total nitrogen (0.18%) and Available Phosphorus (2.3 mg kg^{-1}) were found in low (Landon, 1991) and very low (Hazelton and Murphy, 2016) ranges, respectively. the CEC of the soil of the experimental site was analyzed to be 32.4cmol/kg According to the rating made by Landon (1984), this value lies in the above meddle range (15-25cmol/kg), which means the soil, is satisfactory for agricultural production.

Table3.1. Major physic-chemical properties of the experimental site

Properties	Soil characters	Values	Method of soil analysis
BD	Bulk density	1.35	Core sampler method (Blake and Hartge, 1986)
pH	2.5:1 (S/L)	6.2	Potentiometric pH meter (Anderson and Ingram, 1993)
SOC	(%)	2.56	Wet, digestion method (Walkley and Black, 1934)
TN	(%)	0.18	Micro-Kjeldhal method (Bremner, 1982)
AvP	mg Kg-1 (ppm)	2.30	Bray 2 method (Bray and Kurtz, 1945)
Ex. Ca2+	(Cmol(+) Kg-1)	32.4	
Ex. K+	(Cmol(+) Kg-1)	0.1543	
	Soil texture:		
7	Sand (%)	42.2	
8	Silt (%)	13.6	
9	Clay (%)	55.1	
10	Textural class	Clay	

BD= bulk density, pH = soil reaction, SOC= soil organic matter, TN = total nitrogen, AvP = available phosphorus Ex. Ca2+ = cation exchange capacity, Ex. K+ = potassium exchange capacity

3.2. Experimental Material

Chickpea (Harbu Variety) was used in the experiment as test crop. The selection criteria's are, it is adapted the locality both rain fed and irrigation condition and it is less sustainable to ascochyta blight than other chick pea varieties. Adaptability work both rain fed and irrigation done by Sirinka agricultural research center and this variety were well performed than other nine cultivars of kabuli type chickpea on study area.

Table.3.2. Experimental material (variety)

Crop	Variety name	Center released	Year of released	Maternity date	100seed Weight(g)	Seed rate kg/ha-1	Altitude Require ments	Rain fail(mm)	Productivity(k-ha-1)	
Crop	Variety name	Center released	Year of released	Maternity date	100seed Weight(g)	Seed rate kg/ha-1	Altitude Require ments	Rain fail(mm)	Research center	Farmer field
Chickpea	Harbu	Debre-zeyit ARC	2004	90-150	31	110-140	800-2600	600-1200	20.-24	18-22

Source Chickpea production guideline in Ethiopia, 2015

Different herbicides and pesticides chemical's (2.4 D, highway, Indosulfan, karate) in order to control weeds before planting and after plantings insect pests controlling of chickpea.

For measuring, handling, and proper data recording activities, I were also used the following materials like Meter, Rope, Peg, Plastic bag, Tagging paper, Notebook. Data sheets, Sensitive balance, and also pen and pencil and other materials' for the success of data record and management.

3.3. Experimental Treatments and Design

The treatments was factorial combinations of were having three planting date's, early planting, medium planting and late planting on seven days interval (August 10, 17, and 24 in Ethiopian colander respectively), three-intra spacing (5cm, 10cm, and 15cm), three inter row spacing (20cm,30,cm and 40cm that have 27 treatments. Planting date August 15- 20 is the present days of farmer practice without recommendation on the study area, The experiment was laid out in 2.4m width and by 2m length with factorial arrangements in randomized complete block design (RCBD) with three replications. The distance between adjacent plots and replications (blocks) were 0.5m and 1m, respectively. The total size of each plot are 2 × 2.4m (4.8m2), the net harvestable plot size 1.8m length times each harvestable row/plot(3.6m^2) and the total experimental area will be 54m*9.2m equals to 616.4m2.

3.4. Experimental Procedure

The experimental field were plough-using tractor, disk harrow and the oxen plow to make the soil fine tilts for sites , and I were removed the weed by using herbicide chemicals and hand weeding before seeding, leveling operations done by using human labor in order to reduce heterogeneity of experimental area within blocks.

Seed and seeding:- The physical purity of the seed were maintain properly, under sized and shriveled seeds as well as broken seeds would be removed, uniform and sound seeds will be select for germination test .were the germination capacity of the seed at hand below hundred percent (100%) I was adjusting seed rate based on the treatment setups of by one of the following adjustment methods.

Amount of seed were required for each treatment:-.

$$\text{Seed rate (kg/ha)} = \frac{\text{1000 grain weight (g) x number of seedlings per hill}}{\text{Spacing (cm2)}} \times 100 \quad \text{(iii)}$$

$$\text{Seed rate after correction for germination} = \frac{\text{Actual seed rate}}{\text{Germination \%}} * 100 \quad \text{(iv)}$$

Seed rate after allowance for risk (20% extra) = calculated seed rate + (calculated seed rate * extra germination %).

Seeding method:- After the accomplishments of physical purity and germination tests the required amount seeds were weighed by using sensitive balance based on each treatment requirements by doubled amounts for using two seeds per hole to 3-5 cm deep by using hand seeding (Deepings) with seven days intervals from August 10 up to August 24 Ethiopian calendar.

Other agronomic practice: Expect the treatments each agronomic practice was treated equally as farmers practice in the study area, (example weeding, diseases and insect pest management practices was done properly and equally by using effective chemicals like highway, karate, indosulfan for the control of insect pests like boll worm, cut worm and others and 2-4D chemical were used the controlling broad leaves before planting and using manuals weeding after planting as farmers practice.

Harvesting**:-** is done by hand picking by excluding border rows in each direction and the area will be convert in hectare bases. Manual labor forces using peg like stick on clear and wide canvas do threshing properly.

3.5. Data collected

3.5.2. Crop phenology and growth parameters

Days to emergence (days); it was record by counting the number of days starting from the time of sowing up to when 50 % of the plants emerge from each plot by visual observation.

Days to flowering (days); it was be record by counting the number of days starting from the time of sowing up to the time when 50 % of the plants in the plot flowering.

Plant height (cm); this refers plant height (cm) from the ground level to the tip of main stem at harvesting, it was measured by using a pocket tape on five plants randomly select from the three middle rows and the means were record as plant height.

Days to physiological maturity (days); this refers duration from sowing up to the time of attaining 90 % maturity and it was record as the number of days from sowing to the time when about 90 % of the plants in a plot have mature pods in their upper and lower parts of the plants changing color to yellow. Hence, the physiological maturity will be determining by the yellowness and dryness of leaves and as a whole plant.

Numbers of branches per plant; this refers the numbers of primary branches on the main stem per plant was harvested at maturity. It was obtained by counting the branches from ten randomly sampling plants from the three middle rows and the means will be record as number of branches per plant.

3.5.3. Yield and yield components

Number of productive pods per plant; it will be determined by counting average number of pod of five random sample plants in each plot (total number of pods of five randomly select plants were divide by five).

Number of un productive Pod per plant (cm); this refer to the pod remain unproductive due to any stress that was measured by taking five plants randomly in from net plot during the time of counting productive pods and the mean data were recorded.

Above ground dry biomass yield (kg ha^{-1}):- this refers to the dry weight of above ground biomass. It was obtained by rejecting out of quadrant and measure by using spring balance, and subtracts the bag and record the net weight of dry biomass.

Nodulations' count:- Chickpea is legumes crop that fix nitrogen in order to enhance soil fertility then I wear count number of nodules from randomly selecting plant roots and take the means of each treatments.

Grain yield (kg ha^{-1}); It was obtained by separating from total dry biomass yield by threshing and weighting, then were convert in kilogram hectare basis. The moisture content of grain yield were adjusted to 10 % by sun drying for two weeks to attain maximum complete dry weight near complete drying of straw with minimum moisture content. Crinkled, shriveled and un-matured seeds were discarded.

$$\text{Adjusted Yield} = \frac{100 - \text{Measured moisture content }\%}{100 - 12.5\%} \qquad (1)$$

Harvest index; It is a ratio between economic character (seed yield) and total plant dry weight (seed yield + straw weight) which was showed the proportion of seed yield and straw weight. The yield data wear taken from each entire net plot of the experiment.

$$\text{Harvest index }(\%) = \frac{\text{Economice yield}(\text{t/ha} - 1)}{\text{Total biological yield }(\text{t/ha} - 1)} * 100 \qquad (2)$$

3.5.4. Chickpea seed quality measurements

Thousand (1000) seed weight (g): This refers the weight of hundred seeds. It was be determined by weighted the weight of 1000 seeds using electronic sensitive balance in which samples were taken from each plot.

Standard Germination: Germination testing is designed to estimate the maximum number of seeds that was produced a normal seedling.

$$\text{Germination }(\%) = \frac{\text{Number of seeds germinated}}{\text{Number of seeds tested}} \times 100$$

Vigor Index: ten normal seedlings were taken randomly from each replication of germination test.

Vigor index-I: Vigor index-I is the percent germination x the sum average of shoot length and root length.

Vigor index-Il Vigor index-Il is the percent germination x average seedling dry weight.

Speed of germination: 100 seeds were counted at random from the working seed sample. Four replicates of 25 seeds were counted at random from the well-mixed pure seeds. This test was carried out according to ISTA (2004). For each treatment, then, 25 seeds were planted from each replication in sterilized sand media. The planted seeds germinated in seed germinator at a temperature of 25°C for 6 to eight days. After eight days, normal, abnormal and diseased seeds were sorted. Then, speed of germination (SPG) was calculated following procedures described by Maguire (1962).

$$SPG = \frac{\text{Number of normal seeding}}{\text{Days of final count}} + \frac{\text{Number of normal seeding}}{\text{Days of first count}}$$

$$SPG = \frac{\text{No of seed germinated}}{\text{Time taking for germination}}$$

Moisture content test (14%):- 5g of the prepared seed placed in the oven dry at 101-105 $_{o}$c, after 16 -17 hours, out the seed from oven dry and place them in a desiccator to cool at room temperature and or by calculating by using the following formula.

$$\frac{\text{Wt. of fresh seeds - wt. of dry seeds \% of moisture content}}{\text{Wt. of fresh seeds}} \times 100$$

Seeds determine whether a seed is healthy or diseased.

3.7. Partial Budget

To determine economically profitable treatment (s), partial budget analysis was performed following the procedure of the International Maize and Wheat Improvement Centre (CIMMYT, 1988). Since yields of experimental plots are usually higher than that of farmers, yields of the treatments were adjusted down to 90% to reduce the yield gabs between experimental plots and farmers. Gross benefits (GB) of the treatments were estimated by multiplying of yields with their market prices at East Amhara local/cooperative based market. Similarly, variable costs due to the treatments will be estimated with the surrounding market prices and summed up to get total variable costs (TVC). Net benefits (NB) due to the treatments were obtained by deducting TVC from GB at hectare basis. Then, treatments will be ranked in ascending order to total variable costs (TVC) and dominance analysis will used to exclude dominated treatments from further analysis of those treatments costing more but producing a lower net benefit than the next lowest cost treatment. Marginal rate of return (MRR %) were eventually being estimated as the percentage ratio of the change in net NB to change in TVC. Seed price, were considered variable costs. Other production costs, such as land renting, labor for land seeding, weeding, harvesting, trashing, and cleaning, were considered fixed costs across treatments. Grain and straw yields were considered the output yields, and the cost is output cost.

All costs were calculated as the average value of the months of August to February during 2023/24. The local costs of kabuli type chickpea seed were 80 birr/ kg^{-1}- and straw yield were 11800 birr ton/ha , Labor costs for each treatments were calculated according to the World Food Program, where standards of 1100 Birr, 2200 Birr, and , were used to estimate total variable costs . The grain yield was adjusted downward to 12.5% to reduce the yield gap between experimental plots and farmers. Finally, total variable cost (TVC), gross benefit (GB), net benefit (NB), and marginal rate of return (MRR) were calculated as follows:

(i), Total variable cost (TVC): Total costs that vary for each treatment is the sum of the individual costs that vary.

$$\mathrm{TVC\ (ETHB)} = \sum_{i=1}^{n} C1 + C2 + C3 \ldots\ldots\ldots\ldots\ldots Cn \qquad (3)$$

Where, C1, C2, C3….. Cn, are variable costs during the experimental years

(ii), Gross benefit (GB): The gross field benefit for each treatment was calculated by multiplying the field price by the adjusted yield.

$$\mathrm{GB\ (ETHB)} = \sum_{i=1}^{n} U1 + U2 + U3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots Un \qquad (4)$$

Where, U1, U2, U3….. UN is field benefits obtained in experiment (iii), Net benefit (NB): This is calculated by subtracting the total costs that vary from the gross field benefits.

$$\mathrm{NB\ (ETHB) = GB - TVC} \quad (5)$$

(iv), Marginal rate of return (MRR): Which is the marginal net benefit (i.e. the change in net benefits) divided by the marginal cost (i.e. the change in costs), expressed as a percentage. After treatments were arranged in ascending order by TVC value, treatments with high NB and lower TVC than the preceding treatment were selected for further analysis. Thus, treatments with a lower NB value and a greater TVC than the preceding were excluded (dominated). Selected treatments were subjected to MRR analysis, which was calculated by the following formula:

Where T2 and T1 are consecutive treatments, (T) arranged in ascending order based on their TVC after excluding treatments with low NB and high TVC.

$$\mathrm{MRR\ (\%)} = \frac{\mathrm{NBT2 - NBT1}}{\mathrm{TVCT2 - TVCT1}} \mathrm{x100} \quad (6)$$

3.8 Statistical Data Analysis

All agronomic and selected pre-harvest soil data from the experimental field were collected and entered into Microsoft Office Excel. The same software was used for data editing and management. Data were subjected to analysis of variance (ANOVA) using statistical procedures as described by Gomez and Gomez (1984) with the help of SAS-JMP17 software (SAS, 2022). Before analysis, the data were checked for normal distribution following the scatter plot technique. The data were analyzed with planting date, intra and inter row spacing's as fixed effects and replication as random effects. When the analysis of variance showed significant differences among treatments at any level of probability, mean separation was conducted using Tukey-kramer HSD. Using the same software, a simple linear regression analysis was conducted to determine the association between (i) grain yield and other agronomic attributes and (ii) agronomic attributes with planting dates, intra and inter row spacing's. A simple correlation analysis was also carried out to investigate the strength of the associations among grain yield and yield traits of kabuli type chick pea (variety harbu). The value of r (correlation coefficient) lies within the range of -1 and +1; a value close to +1 or -1 represents a strong linear relationship, a value of r close to zero means the linear relationship is very weak; and an intermediate value of r indicates the portion of variation in one variable that is accounted for by the linear function of the other variable.

Chapter4. RESULTS AND DISCUSSION

4.1. Phonological Parameters

4.1.1. Days to 50% flowering

The main effect of intra row spacing's, were showed extremely highly significant difference ($p<0.0001$), while the main effects of inter row spacing's, the two way interaction (planting date* inter, and, intra*inter as well as the three way (date*intra*inter) interaction and also replications was not significant ($p>0.05$) on Days to 50% flowering (Appendix table1).

The mean value of the two way interactions (planting date* intra row spacing) result indicates that the earliest (51.33, and 52.11DAS) obtained insignificantly from planting date August17*5cm intra row spacing's and agust24*5cm intra row spacing's respectively, while the longest day (63.67DAS) obtained from the interaction of planting date august 17* 15cm intra row and followed (62.67DAS) recorded from planting date august 10*15cm (statically same to 63.67DAS) (table 4.1).

The mean value of the main effects of inter row spacing result indicates that the earliest (55.9DAS) 50% flower sets observed on 20cm inter row spacing's, while the later (58.6DAS) recorded on 40cm row spacing's, (table4.1), and also treatments combination effect results showed that the earliest (47.6DAS) recorded from planting date August 17 with 5cm intra and 20cm inter row spacing's, this had not significant differences (48DAS), planting date August 24 with 5cm intra and 20cm inter row spacing's, while the longest day Days to 50% flowering (64 DAS) recorded from planting day of August 10 with 15cm intra and 40cm inter row spacing's, (appendix Table3). In contrast with this result, Turk *et al.* (2003) found that the denser plant population has extended days to flowering in lentils. This might be in contrary to the fact that wider inter -row spacing had a better light interception as compared to the narrower row spacing resulting in less number of days to flower as chickpea needs direct sunlight coverage for their various physiological processes. Therefore, the result suggests that days to flowering vary from crop to crop as well as the prevailing environmental conditions under which the crops are grown. The adequate amount of soil moisture during planting might have triggered the seeds to germinate and emerge from the soil uniformly this result was in agreement with a report Where seed germination and establishment and flowering of faba bean were not affected by the sowing date (Abdel, L. Y. I. 2008).

4.1.2. Days to physiological maturity

Days to physiological maturity affected by the main effect of planting date, and intra row spacing and replication and the two way interaction of planting date and intra row spacing's were significant at (P<0.05), while, main effects of inter row spacing and the two way (planting date*inter row spacing's) and the three way interaction effect was not significant for this parameter (P>0.05) (appendix table1).

The value of main effect planting date results showed that the earliest (101.1.DAS) recorded from on planting date august 24, while longer days of physiological maturity (106.9DAS) was recorded from the earlier planting date of august 10 (Table 4.1). in argument this (Mittel and Srivastava, 1964) stated sowing time had a marked effect on growth and development of crop similarly those researchers (Berger, Doyle *et al*., 2014) was observed sowing date affects photoperiods, which regulates time taken to commence flowering as well as time to continue growth and developmental phase.

The mean value intra row spacing result showed that, the shortest days of physiological maturity, (96.2DAS) was recorded from 5cm intra row, while the longest days of physiological maturity, (110.4DAS) was recorded from 15cm intra row spacing's. similarly the mean value of interaction effects of planting date and intra row spacing results showed that the longest days of maturity(111.9DAS) was recorded from planting date august10 with 15 cm intra row spacing's, while the shortest days of maturity(91,8DAS) was recorded from planting date august with 5cm intra row spacing's (table4.2).

Significantly higher days to physiological maturity (113DAS) was recorded from the mean value treatments combination of planting date August 17 with 15cm intra and 30cm inter row spacing's while, the earlier days to physiological maturity (90DAS) was recorded from planting date August 24 with 5cm intra 30cm inter row spacing's similarly no significant difference with (92DAS) planting date August 24with 5cm and 40cm inter row spacing's and (93DAS) planting date August 24 with 10 cm intra and 20 cm inter row spacing (appendix Table 5.4), this may be disagreement with the fact that 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 inter- row spacing.

Table4.1. Mean comparasin of main effect on Phonological Parmeters.

Treatments	Days to 50% flowering	Days to physiological maturity
planting dates		
August 10	58.a	106.9a
August 17	58a	104.2b
August 24	56a	101.8c
Sig. level ($P < 0.05$)	Ns	**
Intra-row spacing(cm)		
5 cm	52.4a	96.2a
10cm	57.9a	106.3b
15cm	62a	110.4c
Sig. level ($P < 0.05$)	Ns	***
Inter row spacing(cm)		
20 cm	55.9a	103b
30 cm	57.9ba	104.3ba
40 cm	58.6b	105.7a
Sig. level ($P < 0.05$)	**	**
CV (%)	6.1	4.1
EMS	12.4	18.5

Sig .level = probability level (p.> 0.0001) ***highly significant<0.05)**,p>0.05) non-significant ,the same letters indicate non-significant between treatments CV (%) = Coefficient of variations, EMS = error mean square= days of flowering (50%), DM = days of physiological maturity.

Table4.2. Mean comparison of interaction effects between planting date and intra row spacing on days to physiological maturity

Planting dates	Intra row spacing		
	5cm	10cm	15cm
Augest-10	102.3bc	108.7b	109.7b
Augest-17	94.6cd	106.2bc	**111.9a**
Augest-24	**91.8cd**	103.9bc	109.8b
Significant level (<0.05)	**		
CV (%)	4.1		
EMS	18.47		

4.3. Growth Parameters

4.3.1. Plant height

Environmental factors play an important role in determining the crop growth. Data given in Table 4.4 showed that the main effect of planting date, intra row spacing and replication had shown significant difference ($p<0.05$), while the main effect of inter row spacing's, the two way interaction of planting date intra , planting date inter row spacing's, and the three way interaction effects were not significant effects on plant height ($p>0.05$) (Appendix table 5.1), Shamsi and Kobraee (2009) who worked on spacing experiment on soybean observed that increasing the density of plants led to significant increases in plant height.

Mean value of main effect planting date results showed that the tallest (38.8cm) was recorded from planting dates of august 10 while the shorter plant height (36.6 and 37.1cm) recorded from planting date august 24 and planting date august 17 respectively and no significant between the two, in argument this (Yau, 2005) stated that Sowing date had a significant effect on shoot yield, days to flowering and maturity, seed filling period, dry weight at flowering, leaf area index and plant height (Berger, Doyle *et al.*, 2014) sowing date affects photoperiods, which regulates time taken to commence flowering as well as time to continue growth and developmental phase. Similarly the mean value intra row spacing result showed that the shortest plant height (36cm) from 5cm intra row spacing's, while the longest (38.8cm) plant height recorded from 15cm intra row spacing's (table4.4). 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, Shamsi and Kobraee (2009) who worked on spacing experiment on soybean observed that increasing the density of plants led to significant increases in plant height. Rezvani and Sadeghi (2005) had stated that plant height increase as the duration of growth period increases. In connection this, Rahemi and Soltani (2005), Rezvani and Sadeghi (2005) and Goldani *et al*. (2000) observed plant height increase with high densities and early planting dates in their experiments. According to Rahemi and Soltani (2005), the height of the first pod to soil surface increases with earlier planting dates as well as with the increase in density. Mean value of treatments combination result showed that the longest plant height (44.5 and 44cm) recorded from the treatments combination of planting date August 10 with 5cm intra and 20cm inter row spacing's , and planting date August 17 with 15cm intra and 40cm inter row spacing's , respectively but had no significant difference, while, the shortest in height was recorded (33.2.5cm) and (33.5cm) from planting date August 17 with 15cm intra and 40cm inter row spacing's and planting date August 24 with 15cm intra and 40cm inter row spacing's respectively and are not significant difference, (appendix table4). In argument this findings Rezvani and Sadeghi (2005) and Goldani *et al*. (2000) observed plant height increase with high densities and early planting dates in their experiments. 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, Shamsi and Kobraee (2009) who worked 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. Felton *et al*. (1996) concluded that dry matter production and plant height were higher in higher plant populations on chick pea.

4.3.2 Number of branch per plant

The analysis of variance results showed the two way interaction (planting date *inter row spacing's) had significant at (p<0.05), similarly the main effects of planting dates and intra row spacing's are significant at (P<0.05) and extremely highly significant (P<0.0001) respectively, replications were also shows extremely highly significant difference (p<0.0001), While the main effect of inter row spacing's, the tow way interaction effects of planting date* intra, planting date* inter row spacing's and the three way interaction effects (date *intra *inter) were not significant on number of branch per plant (appendix table1).

The two way interaction (planting date *inter row spacing's) result indicated that the highest number of branches (13.78) were recorded from planting date August10*15cm inter row spacing's, while the lowest number of branches (7 and 7.22) in-significantly recorded from planting date August 24* 20cm inter and August 17*20cm inter row spacing's(table4.3). The mean value of the main effects results showed that highest number of branch plant-^{1} (11.5) recorded from the mean value of planting date august 10,while the lowest number of branches (9.2 and 9.3) from planting date August 24 and august 17 respectively similarly the highest number of branch per plant (12.6) recorded from the main effects 15cm intra row spacing's and the lowest (5.4) recorded from 5cm intra row spacing's, (Table4.5), (However the interaction had no significant effect on the number of branch plant-^{1} (appendix table 5.1). Mean value of treatments combination result showed the highest number of branch plant-^{1} (17) was recorded planting date August 10 with 15cm intra and 40cm inter row spacing's and next highest number of branch plant-^{1},(16) was recorded from planting date August 10 with 10cm intra and 40cm inter row spacing's, while the lowest number of branch plant-^{1} (4), were recorded from planting date August 24 with 5cm intra and 30cm inter row spacing's, (appendix table4). Yet, whole plant growth and competitive ability depends not only on the photosynthetic rate of individual leaves, but also on the geometry and dynamics of a plant's canopy, and the pattern of energy allocation among all organs (Bange and Caton, 2006).in similar argument of this result Goidani *et al*. (2000), Jalilian *et al*. (2005), Shams *et al*.(2005) and Singh *et al*. (1988) have examined the effects of density and planting date on the number of sub-branches and stated that the number of sub-branches decreases with the increase in density and with delayed planting

Table4.3. Mean comparison of interaction effects between planting date and Inter row spacing on number of Brach per plant

Planting dates	Intra row spacing		
	20cm	30cm	40cm
Augest-10	9.33bc	11.44ab	13.78a
Augest-17	9.11bc	10.22bc	10.22bc
Augest-24	7c	7.22c	11.67ab
Significant level (<0.05)	**		
CV (%)	35		
EMS	1.652		

4.3.3. Logging percentage

Logging is the dawn fall of plants due to over (abnormal) growth (over population and resource usage and/or physical damage of plants may the cause of logging on crops, that affect the productivity of crops negatively, The main effect of intra row spacing's has extremely highly significant deference (p<0.0001) on logging percentage, while main effect of planting date and intra row spacing's, the two way as well as the three way and also replications had not significant effect on logging percentage (p>0.05) (Appendix table1). The highest logging percentage (4.4%) was recorded from 5cm intra row spacing's and the lowest logging percentage (1.2%) from 15cm intra row spacing's (table4.4), similarly, highest logging percentage, (5.3,4.7,4.7,4.3,4.3, recorded from planting dates August 17 with 5cm and 20cm inter row spacing's, planting dates August 10 with 5cm and 30cm inter row spacing's, August 17 with 5cm and 30cm inter row spacing's , planting dates August 10 with 5cm and 40cm inter row spacing's, planting dates August 17 with 5cm intra and 40cm inter row spacing's ,while the lowest logging percentage,(1,1,1,1,1,1.3,1.7,1,7) from planting dates August24 with 15cm and 40cm inter row spacing's planting dates August 24 with 15cm and 30cm inter row spacing's, planting dates August 24 with 15cm and 20cm inter row spacing's, planting dates August 24 with 10cm and 30cm inter row spacing's planting dates August 17 with 15cm and 30cm inter row spacing's, planting dates August 10with 15cm and 40cm inter row spacing's ,was recorded on 15cm intra and 30cm inter row spacing's respectively. planting dates August 17 with 15cm and 20cm, planting dates August17 with 15cm and 40cm inter row spacing's, and planting dates August 24 with 10cm and 40cm inter row spacing's.(appendix table4).

4.4. Mean comparsion of main effect on growth parameter.

Treatments	PH	NBPP	L%
planting dates			
August 10	38.8a	11.5a	2.4a
August 17	37.1b	9.3b	2.7a
August 24	36.6b	9.2b	2.2a
Sig. level (P < 0.05)	**	**	Ns
Intra-row spacing(cm)			
5 cm	38.8a	5.4b	4.4a
10cm	37.6b	12a	1.8b
15cm	36.6c	12.6a	1.2c
Sig. level (P < 0.05)	**	***	***
Inter-row spacing(cm)			
20 cm	37.26a	10.4a	2.59a
30 cm	37.67a	9.3a	2.3a
40 cm	37.5a	10.3a	2.5a
Sig. level (P < 0.05)	Ns	Ns	Ns
CV (%)	7.7	35	45.6
EMS	8.2	12.3	1.3

Sig .level = probability level (p.> 0.001) highly significant (p.> 0.0001) *** extremely highly significant *** extremely highly significant<0.05)**,p>0.05) non-significant ,the same letters indicate non-significant between treatments CV (%) = Coefficient of variations, EMS = error mean square= days of flowering (50%), DM = days of physiological maturity

4.4. Yield components

4.4.1. Plant Stand count at emergence.

Analysis of variance revealed that the two way interaction effects of intra * inter row spacing were extremely highly significant difference on plant stand count at emergence (p<0.0001) ,similarly main effects of, and also planting date significant at(p<0.05) and intra and inter row spacing's, were extremely highly significant difference (p<0.0001) while the two way interaction effects of planting date * intra, planting date* inter row spacing's and the three way interaction had not significant on Plant Stand count at emergence (appendix table1). The two way interaction effects between intra and inter row spacing result showed that the days of physiological maturity had extremely highly significant difference ($p<0.0001$), the highest (218.3plant - plot) was recorded from 5cm*20cmand the lowest (40.7plant- plot) was recorded from15cm* 40cmintra and inter roe spacing's (Fig.4.1) The highest number of plant population (144.4) was recorded from the main effects of planting date august 10,and the lowest plant stand, (141) recorded from planting date of august 24,similarly the highest number of plant stand (245.7) recorded from the main effects of intra row spacing and the lowest plant stand (64.4) recorded from 15cm intra row spacing's and also the highest mean plant stands (210.4) obtained from 20cm inter row spacing, while the lowest stand count, (87.9) recorded from 40cm inter row spacing's.(table4.7), more over the heist stand count 374.5, 371 and 365) from the treatment combination of planting dates August 10 with 5cm intra and 20cm inter row spacing's, planting dates August 24 with 5cm intra and 20cm inter row spacing's ,and planting dates August 17 with 5cm intra and 20cm inter row spacing's while the lowest stand count at emergency, (43.7,44.7and 50) were obtained from the treatments combination planting dates August 24 with15cm intra and 40cm, planting dates August 17 with 15cm intra and 40cm inter row spacing's and planting dates August 10 with 15cm intra 40cm and inter row spacing's those are statically no significant difference (appendix table1) of The dense plant population was obtained from the lowest inter- and intra-row spacing's (20 cm inter and 5 cm intra) ,generally, plant population at emergence increased as the intra- and inters row spacing decreases (fig4.1).

4.4.2. Plant Stand count at harvest

The two way interaction effects between intra * inter row spacing and the main effects of intra and inter row spacing's had showed extremely highly significant difference on Plant Stand count at harvest ($p<0.0001$), while the main effects of planting dates, interaction of planting date intra, planting date inter row spacing's and the three way interaction and replications were not showed significant difference ($P>0.05$) on stand count of chickpea at harvest (appendix table1). The highest (218.3plant - plot) was recorded from 5cm*20cm and the lowest (40.7plant- plot) was recorded from 15cm * 40cm intra and inter roe spacing's (Fig.4.1). The mean of the main effect intra and inter row spacing's result showed that the highest stand count(206 .9) obtained from 5cm intra row spacing's while the lowest stand count at harvest (64.4) from 15cm intra row spacing's. Similarly the highest stand count (210.4) obtained from 20cm row spacing and the lowest stand counts (87.9) obtained from 40cm inter row spacing's.(fig 4.1). The higher plant stand count (373) was recorded from the treatment's combination of planting date august 10 with 5cm intra and 20cm inter row spacing's while the lower stand count (42) was recorded from planting date august 24 with 15cm intra and 40 cm inter row and similarly (42), (62), (65), (84) plants recorded from planting date august 24 with 10cm intra and 40cm row spacing's, planting date August 24 with 5cm 20cm row spacing's and planting date August 24 with 15cm*30cm row spacing's respectively has on significant on stand count at harvest,(appendix table4).This might indicate uniformity in stand establishment of chickpea might be influenced by planting date,Intra and inter row spacing's.

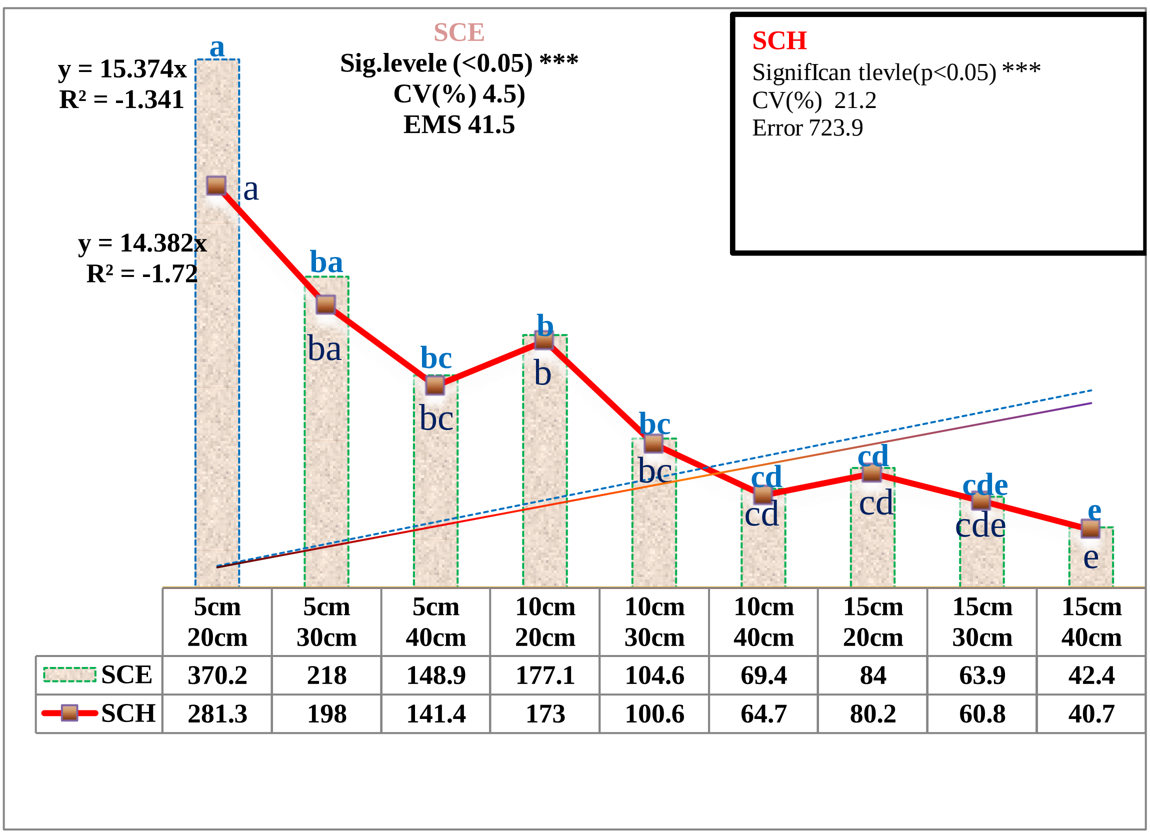


Figure4.1. Mean Comparison of the effects of interaction of Intra and inter row spacing's on stand count at emergence and at harvest.

Sig .level = probability level (p.> 0.001) ***highly significant (p.> 0.0001) *** extremely highly significant <0.05)**,p>0.05) non-significant ,the same letters indicate non-significant between treatments CV (%) = Coefficient of variations, EMS = error mean square= SCE =stand count at emergence,= SCH= stand count at harvest.

4.4.3. Number of pods per plant

Number of pods plant–^{1}, an important primary yield component, the main effect of Intra row and replications had extremely highly significant difference ($p<0.0001$), while the main effects of planting date and inter row spacing's, the three way interaction effects (date* intra *inter) and the two way interaction effects (planting date *intra, planting date inter , intra inter row spacing's) had not significant deference on number of pods plant-^{1} ($P>0.05$), (appendix table1). The highest mean value (72.4, and 72.3) number of pod plant-^{1} obtained from the main effects of 15cm and 10 cm intra row spacing's respectively and there are no significant difference between 72.4 and 72.3 statically, while the lowest mean value (23.5) pod plant-^{1} obtained from 5cm intra row spacing's, (table 4.7), In agreement to the present result, Khan *et al*. (2010) reported higher number of pods plant–^{1} recorded from in the wider inter row spacing of chickpea, The beneficial effect of early sowing on pods plant-1 was also reported by, Prasad *et al*., (2012) Regarding effect of spacing, closer spacing of chickpea exhibited lesser number of pods plant-^{1} as compared to wider row spacing of 40 cm, Significant maximum number of pods plant-^{1} was noted under 40 cm (74.21) with significant difference followed by 30 cm (65.14). The lowest number of pods plant-1 was recorded under 30 cm row spacing (56.65) with significant difference to other spacing, wider spacing had 14.99 and 31.0% higher number of pods plant-^{1} under 30 cm and 40 cm spacing, respectively, as compared to closer spacing of 20 cm. This is because of efficient utilization of nutrient, water and solar radiation at wider row spacing as compared to narrow row spacing. Increase in pods plant-^{1} with increase in row spacing had also been reported by Sonboir *et al*. (2017) similarly Among the yield components, number of pods plant-^{1} and number of grains pod-^{1} and 1000 seed weight decreased with increasing seed rate (Aziz *et al*.1988 and Komatsu et *al*.1989).

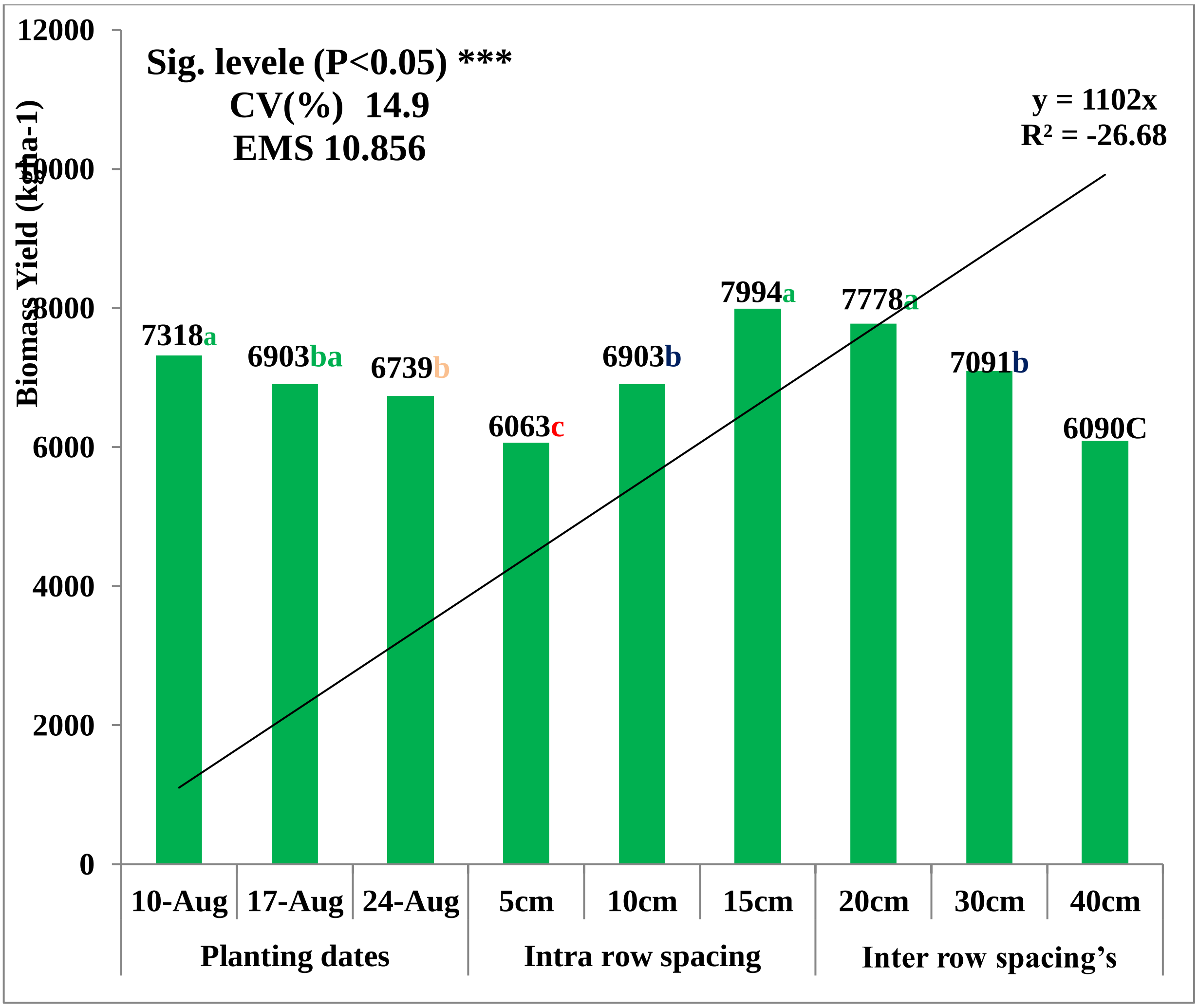
In treatment combination the highest number of pods per plant (98) was recorded from planting date August 10 with 10cm intra and 40cm inter row spacing's. Planting date August 17 with 15cm and 20cm inter row spacing's. Lowest number of pods per plant (18.3, 18.7,. 18.7, 21, 22.7, 22.8 and 24) on Planting date August 24*5cm*40cm inter row spacing's, on Planting date August 24 with 5cmintra and 30cm inter row spacing's, on Planting date August 24 with 5cmintra and 20cm inter row spacing's, Planting date august 10 *5cm *20cm inter row spacing's, on Planting date August 17 with 5cm intra and 40cm inter row spacing's, on Planting date August 10 with 15cm intra and 40cm inter row spacing's and on Planting date August 10 with 15cm intra and 30cm inter row spacing's respectively even though not statically differ . The lowest number of pods plant-^{1} was found in the closest spacing, *i.e*. 5 cm intra-row spacing which was significantly lower than the other interactions (appendix Table4).in argument this findings Morrison *et al*., 1997 reported interaction effect of planting date × row spacing. Showed that delay in planting, increase in row spacing decreases the number of head per plant in fall safflower under rain fed condition, The difference among the inter row spacing in response to intra row spacing on number of pods might be due to the fact that, as the plant population increased there was high competition for the growth factors as compared to wider spacing which had an impact on the number of pods per plant. The reduced competition for light and reduced overlapping from adjacent chickpea plants could have enabled the plants grown at wider spacing to utilize its energy for more branching and subsequently, the greater number of pods plant-^{1}. In agreement to the present result, Khan *et al*. (2010) reported highest number of pods plant–^{1} in the wider inter row spacing of chickpea.

4.4.4. Hundred Seed weight

Among various parameters contributing towards final yield of a crop, 100 seed weight is of prime importance. Data given in Table 4.5, Showed that, the three way interaction (planting date * intra * inter row spacing's) had shown extremely highly significant difference ($P<0.0001$) while reparations were not significant ($p>0.05$) on the hundred seed weight of chickpea, (appendix table1). The heaviest mean value (57.97g) had obtained from the interaction of planting date of Augest-10 * 15cm intra * 30cm inter row spacing's, while the lighters hundred seed weight (28.6g, 28.7g and 29.3g/100 seeds) recorded on from Planting dates august 24 * 5cm intra * 20 cm inter , Planting dates august 17 * 5cm * 20cm and planting date 10 august * 5cm *20 cm inter row spacing's this indicates narrower spacing and late planting affect the seed weight of chick pea in the study area in argument this, Robertson *et al*, 2004), that delay in planting date reduced the 1000- grain weight and its yield..) similarly, (Ferreira *et al*,. 2001) concluded grain yield components to density plant is varied and is relatively compensable in a way that increase in plant density is accompanied by decreasing in grain number and weight of 1000- grain per head, Although, increase of plant population resulted in increasing number of head per area unit which ultimately leads to high yield.), this contrary with Tolossa Amenu *et al* 2020), He reported that the interactions effects of planting date plant height, ear height, stem diameter, leaf area, and number of ear per plant, 100-seeds and grain yield were significantly influenced by only main effect of intra and inter row spacing, except leaf area, which was affected by interaction of intra and inters row spacing's Similarly. Brhanu Challa *et al* ,2020), reported that desi type (var. Marye) (bold seeded), chickpea Significantly higher (248 g) 1000 grain weight was recorded under 40 cm with 20 cm spacing and lowest (165 g) 1000 grain weight under 30 cm x 5 cm row spacing. The highest (1625 kg ha-1) seed yield of chickpea was obtained from 30 cm x 15 cm and the lowest seed yield (1096 kg ha-1) was recorded from 20 cm x 5 cm row spacing's.

4.4.5. Biomass yield (kg ha-^{1})

Biological yield is sum total of all dry matter produced through physiological and biochemical processes occurring in the plant system. Data given in figure4.2 showed that the main effects of planting date, inter- row and intra- row spacing showed extremely highly a significant ($P<0.0001$) and replication also significant effect at ($p>0.005$) on dry biomass. While, the three way (date * intra * inter) and the two way (date*intra, date *inter and intra inter) interaction effect had not significant ($P<0.05$) (appendix table1). The mean value of intra row spacing results showed that the heaviest (7994kg/ha-^{1}). Obtained from 15cm intra row and the lighters (6063kg/ha-^{1}) obtained from 5cm intra row spacing. Similarly the mean value inter row spacing result showed that the heaviest, (2033.9kg/ha-^{1}) obtained from 20cm inter row spacing, while the lighters, (6090kg/ha-^{1}) dry biomass yield obtained from 40cm inter row spacing (appendix table1), in argument this Munir *et al*, 1987), reported that biological yield decreased with wider row, which is due to decrease in number of plants in area in wider planting row spacing. The heaviest above ground dry biomass (9815kg/ha-^{1}) was recorded at planting date August 17 with 5cm intra and 30cm inter row spacing's and the lighters dry biomass (5277.8 kg/ha-^{1}) was recorded at planting date august 24 with 15cm intra and 40cm inter row spacing's, (Fig.4.2). For all of the inter row spacing, the highest number of above ground dry biomass were recorded as the intra- row spacing decreased.in argument this Solomon (2010) reported that dry biomass ha-^{1} was significantly increased with increased plant density (40 cm ×10 cm) on haricot bean. Similarly, Jose, F et *al,*. 2004), reported that increment of total dry biomass yield with increasing plant population of soya bean up to a certain point and subsequently no addition in biological yield can be obtained decrease in economic yield. Delay in planting result in decrease of dry matter, grain yield and its quality due to reduction of mount of received sun radiation by canopy.



(Sig .level = probability level (p.> 0.001) ***highly significant< extremely highly (p<o.ooo1), (p<0.05)** significant, (p>0.05) non-significant ,the same letters indicate non-significant between treatments CV (%) = Coefficient of variations, EMS = error mean square

Figure.4.2. Mean comparison of main effects of planting date, Intra and Inter row spacing's on Dry biomass yield of test crop.

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4.4.6. Seed yield (kg ha^{-1})

Seed yield is ultimate outcome of various physiological, biochemical and phonological processes occurring in the plant system. The two way interaction of intra *inter row spacing's and the main effects of planting date, intra and inter row spacing's had extremely highly significant difference ($P<0.0001$), similarly replications were significant at $p<0.05$), while the two way (planting date* intra and planting date* inter) and the three way (date* intra inter) interactions were not showed significant difference on seed yield ($p>0.05$) (Appendix table 1). In argument this Tolossa Amenu *et al* 2020 reported that plant height, ear height, stem diameter, leaf area, and number of ear per plant, 100-seeds and grain yield were significantly influenced by only main effect of intra and inter row spacing, except leaf area, which was affected by interaction of intra and inters row spacing's.

The mean value of the two way (intra * inter) interaction effects result showed that the highest yield (2655kgha^{-1}) were obtained from the medium intra row spacing (10cm) with the narrower inter row combinations, while the lowest yield (1310kgha-1) were obtained from the interaction of widest intra and inter row spacing's (15cm intra*20cm inter row spacing's) (Fig4.4), similarly the mean value of the main effect planting date result showed that the highest grain yield, (1906.7kg/ha^{-1}) obtained from the planting date of agust10 while the lowest grin yield (1603kg/ha^{-1}) obtained from the planting date of august 24.

reducing grain yield in delayed planting date are reduction of canopy area and short length of vegetative period, Robertson *et al*, 2004), concluded that delay in planting date reduced the 1000- grain weight and its yield.

The highest mean value of the main effect of intra row spacing result showed that the highest,(2072.3kg/ha^{-1}) obtained from 10cm intra row spacing, while the lowest grain yield, (1578kg/ha^{-1} and 1532.9kg/ha^{-1}) obtained from 5cm and 15 intra rows respectively, even though 1578kg/ha^{-1} and 1532.9kg/ha^{-1} are not statically differ) (Fig4.3).

Number of plants per unit area influences plant size, yield components and ultimately the seed yield (Beech and Leach, 1989). Moreover, plant spacing in the field is also very important to facilitate aeration and light penetration in to plant canopy for optimizing rate of photosynthesis. In argument this Khan *et al*. (2001) concluded that narrow row spacing of 30 cm produced significantly maximum yield than that of wider row spacing of 70 cm, respectively, both over and under plant densities resulted in significant yield decrease (Ashour, *et al*. 1995). Denmead *et al*. (1962) estimated that 60 cm inter row spacing might increase the energy available for photosynthesis 15-20%, compared with 100cm spaced row in corn. The mean value of main effect of inter row spacing results showed that the highest, (2033.9kg/ha-^{1}), while the lowest mean value, (1485.82kg/ha-^{1}) obtained from 40 cm inter row spacing, (Fig.4.3), Singh *et al*, (1991) and Board *et al*. (1992), who reported that narrow row spacing's resulted in higher grain yields in food legumes. He also concluded that row spacing of 20 cm (with plant to plant distance was 15 cm) is *the best*. The combination treatments of planting date August 10 with 10cm intra and 20cm inter row spacing resulted in the highest grain yield (3087kg ha-^{1}). The lowest grain yield (1163kg/ ha-^{1}) was recorded with the combination planting date August 24 with 15cm intra and 30cm inter row spacing's this result had no significant difference with Planting date August24with 15cm intra and 40 cm inter row spacing's, (1185.8kg/ha-^{1}) (appendix Table4). Biabani (2011) reported higher grain yield of chickpea at average (45cm×7.5cm) spacing combination than 35cm×5cm and 55cm×10cm spacing combinations. This result was also in agreement with Singh and Singh (2002) who reported that the yield per unit area was increased with increasing plant density due to efficient utilization of growth factors. The possible reason could be that, when inter-and intra- row spacing was decreased, with aducate moisture the number of plants per unit area increased, resulting in higher yield. Biabani (2011) reported higher grain yield of chickpea at average (45cm×7.5cm) spacing combination than 35cm×5cm and 55cm×10cm spacing combinations. This result was also in agreement with Singh and Singh (2002) who reported that the yield per unit area was increased with increasing plant density due to efficient utilization of growth factors. Chickpea late sowing in narrow rows however cannot recover yield but it reduces loss up to 16 % (Weaver *et al*., 1991).

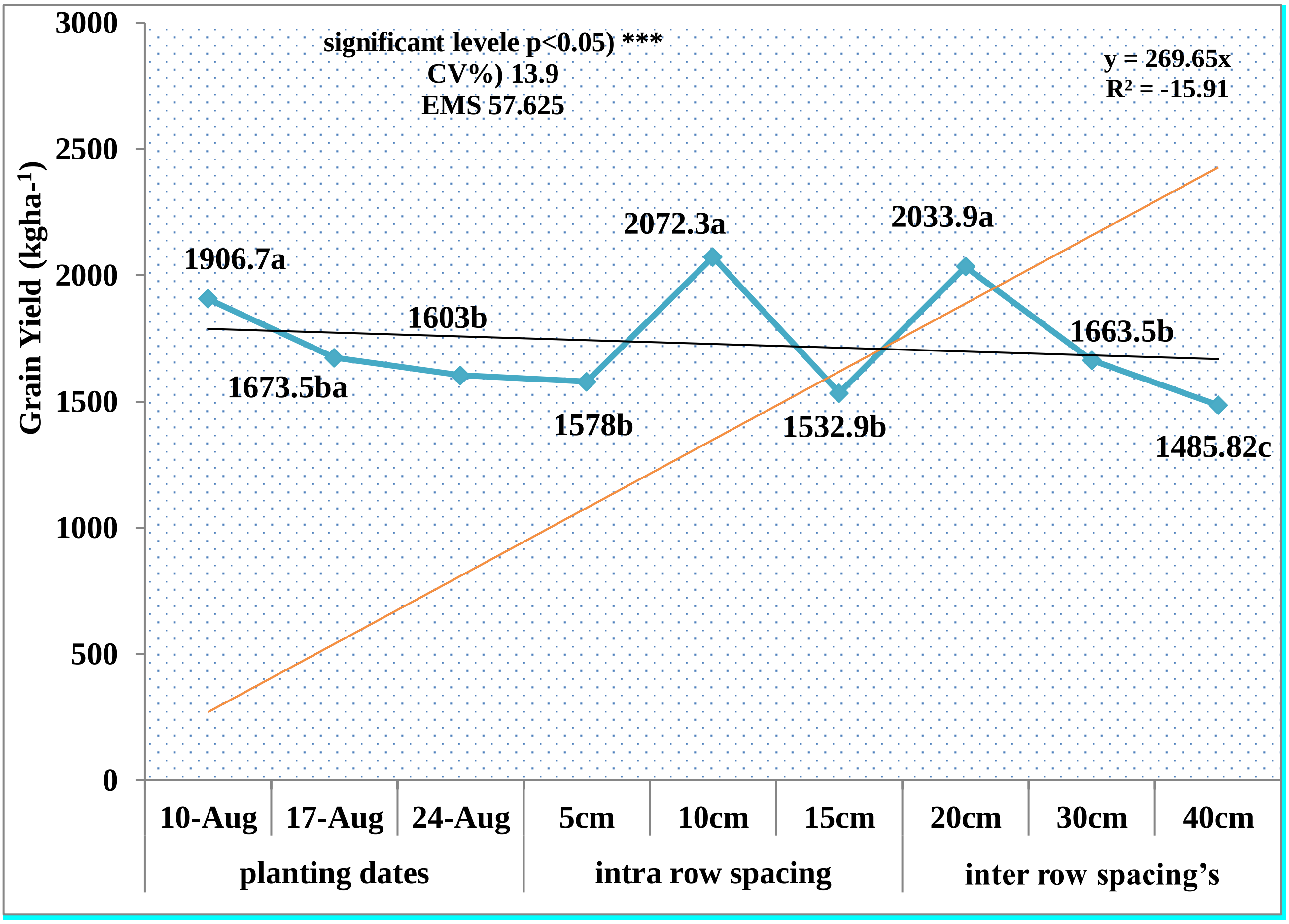

Figure4.3. mean comparison of main effects of planting date, intra and inter row spacing on grain yield of kabuli type chickpea.

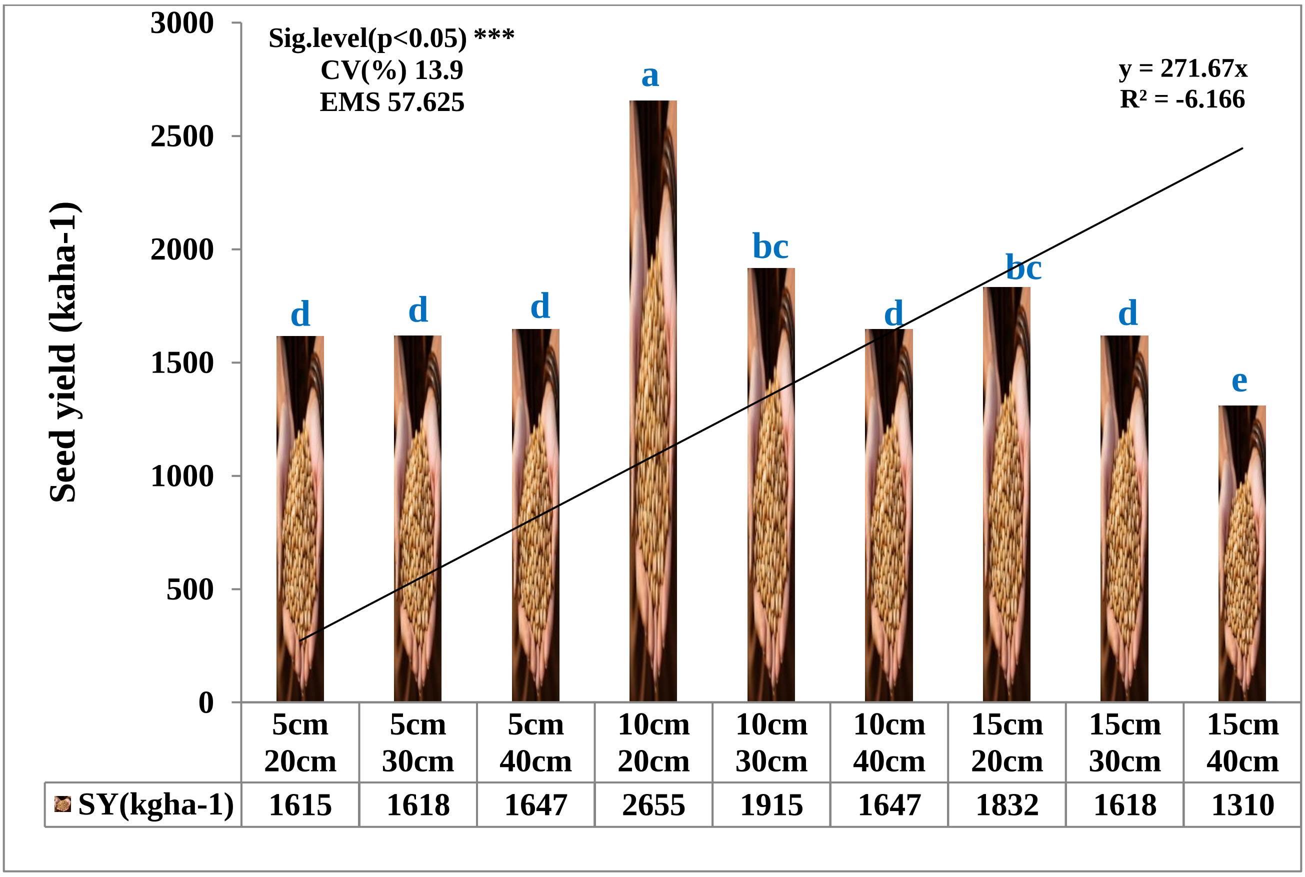

Figure4.4. Mean comparison of interaction effects of intra and inter row spacing's on seed yield of test crop.

4.4.7. Harvest Index

Harvest index is a measure of physiological productivity potential of a crop variety under favorable environmental conditions. It is the ability of a crop plant to convert the dry matter into economic yield. The three way interaction effects had shown significant differences ($p < 0.05$) on mean harvest index of chick pea (appendix Table1). The highest mean harvest index (59.09%) of chick pea was obtained from the interaction of early planting dates (agust10), 15cm intra and 30cm inter row spacing. The lowest harvest index (17.08 %) of chick pea was obtained from the late planting date (Augest-24) with 15cm intra and 40cm inter row spacing's (table 4.5). This reduction in harvest index in narrower intra spacing might be due to the higher plant population per unit area which might have increased the flower abortion due to competition for nutrients, moisture and solar radiation. Similarly arguments, Chala Birihanu *et al*, 2020 reported that the maximum harvest index (34.03%) in the widest row spacing (40 cm) of chickpea than 20 cm row spacing.

Table4.5 Mean comparison the three way interaction on hundred seed weight and harvest index

Treatments	HSW(g)	HI (%)
Augest-10 5cm 20cm	29.3fhijk	17.08l
Augest-10 5cm 30cm	29.9fghijk	21.5fghijk
Augest-10 5cm 40cm	31.4fghijk	22.54fghijk
Augest-10 10cm 20cm	34.83defghi	39.09a
Augest-10 10cm 30cm	34.83defghi	25.2cdefghi
Augest-10 10cm 40cm	35.4cdefghi	27.98abcdefg
Augest-10 15cm 20cm	36.6abc	28.7abcde
Augest-10 15cm 30cm	57.97 a	25.48cdefghi
Augest-10 15cm 40cm	37.23ab	33.74abc
Augest-17 5cm 20cm	28.6kl	19.54jjik
Augest-17 5cm 30cm	29.67fghijk	17.83kl
Augest-17 5cm 40cm	31.3fghijk	22.51fghijk
Augest-17 10cm 20cm	33.87efghi	22.55fghij
Augest-17 10cm 30cm	34.53efghi	34.25ab
Augest-17 10cm 40cm	35.73abcdefgh	28.94abcde
Augest-17 15cm 20cm	36.17abcde	23.5defghi
Augest-17 15cm 30cm	35.9abcdefg	28.87abcde
Augest-17 15cm 40cm	36.53abcd	28.8abcdefgh
Augest-24 5cm 20cm	28.67kl	23.18efghi
Augest-24 5cm 30cm	31.87fghijk	19.04jkl
Augest-24 5cm 40cm	32.13fghij	22.6efghi
Augest-24 10cm 20cm	35.5bcdefgh	21.16fhijk
Augest-24 10cm 30cm	35cdefghi	30.32abcd
Augest-24 10cm 40cm	35.87abcdefg	28.6abcdef
Augest-24 15cm 20cm	35.7abcdefgh	26.34abcdefgh
Augest-24 15cm 30cm	36.17abcde	25.56bcdefgh
Augest-24 15cm 40cm	36.17abcde	21.32fghijk
significant level(P<0.05)	**	**
CV (%)	10.1	12.7
LSD	5.727	5.289

Table4.6 Mean table for three way interaction (planting date, intra and inter row spacing on handred seed weight and Hharvest index (%)6.

Source of variation	Df	Sum square HSW(g)	Mean square	Sum square HI (%)	Mean square
REP.*Units* stratum		6.5	3.25	118.2	59.08
Pdate	2	108.58	54.29	91.61	45.81
Intra	2	1050.87	525.44	1264.18	632.09
Inter	2	125.73	62.86	87.94	43.97
Pdate.Intra	4	274.15	68.54	81.23	20.31
Pdate.Inter	4	180.06	45.02	41.02	10.26
Intra.Inter	4	205.68	51.42	309.59	77.4
Pdate.Intra.Inter	8	427.69	53.46	219.28	27.41
Residual	52	635.34	12.22	541.8	10.42
significant level(P<0.05)			***		**
CV (%)			10.1		12.7
LSD			5.727		5.289
EMS			2.018		1.864

CV (%) = coefficient of variation, LSD = list significant difference, EMS = error mean square, Df = degree of freedom, HSW(g) = hundred seed weight in gram, HI(%) = Harvest index(%) .

4.4.8. Vigor index

Vigority is the normal physical appearance of plants or seeds in optimum environmental condition and vigority index- is obtained from is the percent germination times (*) average seedling shoot and root length /100, Thus the highest vigor index indicate the more the vigor of the plant. The mean value of main effects The main effects of planting date intra and inters row spacing had significant difference while there interaction are not significant differences on mean vigority index of chick pea, (P<0.01)(, (appendix table1).

The mean value the main effect planting date result showed that the highest mean of vigor index (36.7%) obtained from planting date august 10, the lowest vigor while lower vigor index, (27.2% and 26.7%) from august 24 and august 17 planting dates, even though 27.2% and 26.7% are not statically differ, similarly the mean value of main effect intra row results showed that the highest mean value of vigority index (40.9%) obtained from 15cm intra row spacing and the lowest mean value of vigor index (20.1%) obtained from 5cm intra row spacing, and also the mean value main effect of inter row result showed that ,the highest vigor index(31% and 30.9%) obtained from 30 cm and

40cm inter row spacing's, even though 31% and 30.9% are not statically differ, while the lowest vigor index (28.2%) from 20cm inter row spacing, (table 4.7) and also the mean value of treatments combination result showed that the highest vigor index (55.4% 54%, and 51.6 %) obtained from the planting date August10 with 15cm intra and 30cm inter row spacing's ,the planting date August 10 with 15cm intra and 40cm inter row spacing's, and the planting date August 10 with 15cm intra and 20cm inter row spacing's, even though (15.8%, 16% 16.8% are not statically differ), while the lowest vigor index, obtained from the planting date August 17 with 5cm intra and 20cm inter row spacing's, the planting date August 24 with 5cm intra and 40cm inter row spacing's and August 10 with intra 5cm and 30cm inter row spacing's, even though (15.8%, 16% 16.8%) are not statically differ, (table4.7)

Table4.7. Mean comparison of main effect on yield component parameter.

Treatments	SCE	SCH	NPPP	HSW(g	DBM(kg/ha	SY(kg/ha	HI	VI
planting dates								
August 10	144.9a	132.9a	63.4a	36.2a	7318a	1906.7a	26.8a	36.7a
August 17	140.6ba	119.8a	52a	33.4b	6903ba	1673.5ba	25.1b	26.7b
August 24	141.7b	128.2a	52.9a	34.1b	6739b	1603b	24.3b	27.2b
Sig. level (P < 0.05)	**	ns	ns	**	**	***	**	***
Intra-row spacing(cm)								
5 cm	245.7a	206.9a	23.5b	29.9c	6063a	1578b	20.4c	20.1c
10cm	117b	112.8b	72.3a	35.1b	6903b	2072.3a	30.1a	29.1b
15cm	64.4c	61.2c	72.4a	38.7a	7994c	1532.9b	25.7b	40.9a
Sig. level (P < 0.05)	***	***	***	***	***	***	***	***
Inter-row spacing(cm)								
20 cm	210.4a	178.2a	59a	33.1b	7778a	2033.9a	26.9a	28.2b
30 cm	128.8b	119.8b	48.6b	36.1a	7091b	1663.5b	24.4b	1a
40 cm	87.9c	82.9c	60.6a	34.5ba	6090c	1485.82c	24.96b	30.9a
Sig. level (P < 0.05)	***	***	ns	**	***	***	**	**
CV (%)	4.5	21.1	38.1	10.1	14.9	13.9	12.7	14.6
EMS	41.1	723.9	456.8	12.3	10856.	57625	10.4	19.2

CV(%) = coefficient of variation, EMS = error mea square, SCH =stand count at emergency, SCH= stand count at harvest, DF = date of flowering, PH= plant height ,DM =date of maturity, LG=logging percentage NPBPP= number of primary branch per plant, NSBPP =

number of secondary branch per plant, NNPP=number of nodule per plant, NRPP= number of reproductive pod per plant, NUPPP= number of un reproductive pod per plant, TPPP= total pod per plant, HSW= hundred seed weight, BMT= dry biomass yield ton /ha, ASY= adjusted seed yield, AMC= adjusted moisture content ,HI= harvest index, ,VI= vigority index, SG =speed of germination, STG= standard germination

4.5. Correlation and Regression Analysis

4.5.1 Correlation

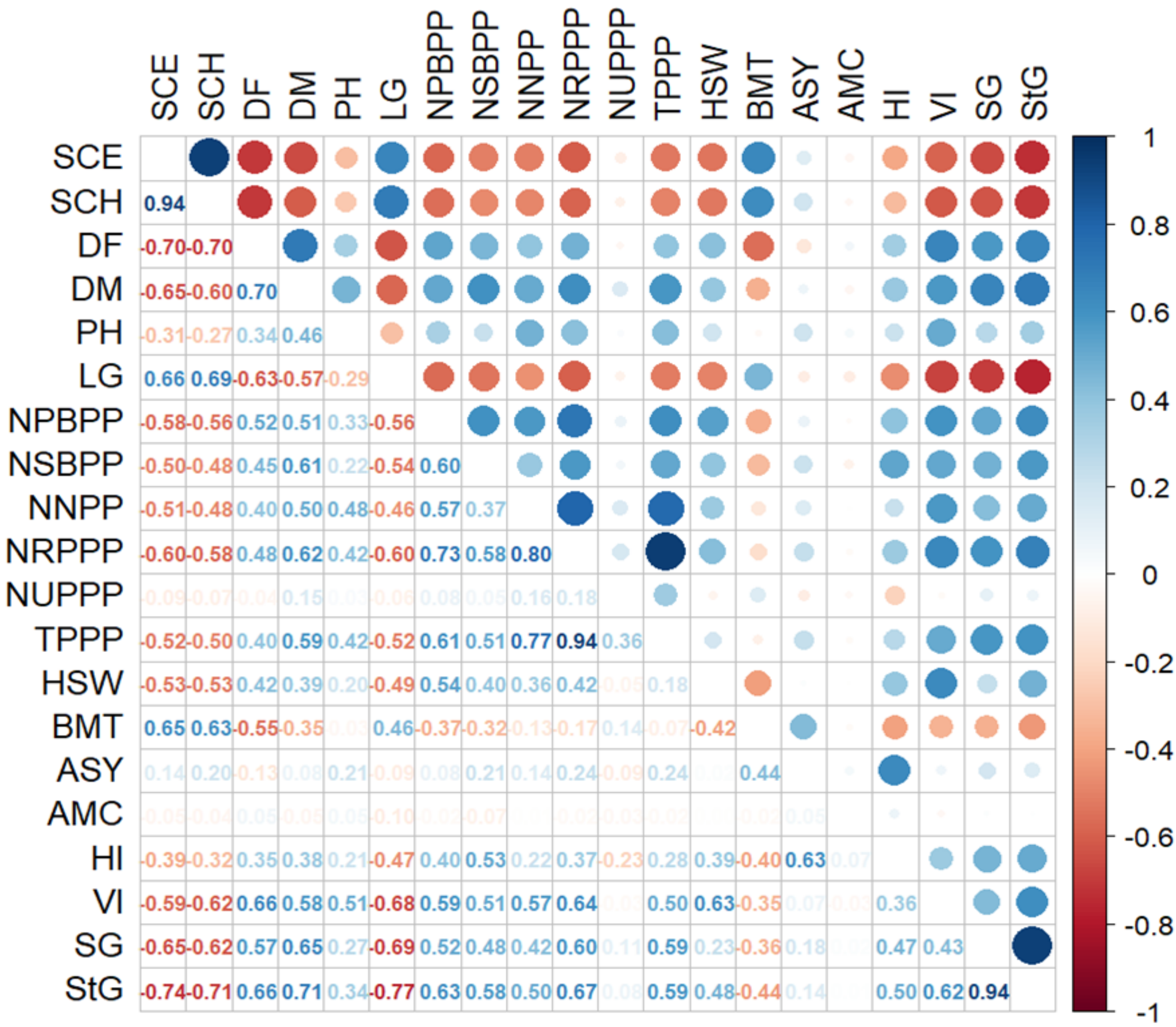

Figure4.5. Correlation matrix (Pearson) between some parameters.

SCE =stand count at emergency, SCH= stand count at harvest, DF = date of flowering, PH= plant height ,DM =date of maturity, LG=logging percentage NPBPP= number of primary branch per plant, NSBPP = number of secondary branch per plant, NNPP=number of nodule per plant, NRPP= number of reproductive pod per plant, NUPPP= number of un reproductive pod per plant, TPPP= total pod per plant, HSW= hundred seed weight, BMT= dry biomass yield ton /ha, ASY=

adjusted seed yield, AMC= adjusted moisture content ,HI= harvest index, ,VI= vigority index, SG =speed of germination, STG= standard germination.

Interpretation of the Correlation Matrix

Overview

The image is a correlation matrix visualizing the relationships between different variables (likely crop traits or parameters). The matrix uses colors and circle sizes to represent the strength and direction of correlations:

•Blue circles: Indicate positive correlations, the larger and darker the circle, the stronger the positive correlation.

Red circles: Indicate negative correlations, the larger and darker the circle, the stronger the negative correlation.

•No circle: Indicates a correlation close to zero.

The color bar on the right indicates the correlation coefficients, ranging from -1 to 1.

Key Observations

•Strong Positive Correlations: stand count at emergency and Stand count at harvest have a very strong positive correlation (0.94), indicated by a large, dark blue circle. This suggests that these two variables tend to increase or decrease together.

•Number of reproductive pod per plant and total pod per plant also show a strong positive correlation (0.94).

- Speed of germination and standard germination have a very strong positive correlation (0.94)

•Strong Negative Correlations: stand count at emergency and date of flowering have a strong negative correlation (-0.70), meaning that as one increases, the other tends to decrease. The same applies to Stand count at harvest and date of flowering (-0.70).

•logging percentage and standard germination have a strong negative correlation (-0.77)

•Other Notable Correlations: DM and StG show a positive correlation of 0.71.

•NRPPP and NNPP exhibit a strong positive correlation (0.80)

Detailed Breakdown

- ❖ Stand count at emergency vs. Other Variables: Strong positive correlation with Stand count at harvest (0.94), Strong negative correlation with date of flowering (-0.70) and date of maturity (-0.65)
- ❖ Stand count at harvest vs. Other Variables: Strong positive correlation with stand count at emergency (0.94).Strong negative correlation with date of flowering, (-0.70) and date of maturity, (-0.60).
- ❖ Date of flowering vs. Other Variables: Negative correlation with stand count at emergency (-0.70) and Stand count at harvest (-0.70), Positive correlation with date of maturity (0.70)
- ❖ Number of reproductive pod per plant vs. Other Variables: Strong positive correlation with number of nodules per plant (0.80) and total pod per plant (0.94).
- ❖ Speed of germination vs. Other Variables: Strong positive correlation with StG (0.94).StG vs. Other Variables: Strong positive correlation with SG (0.94). Strong negative correlation with logging percentage (-0.77).

Inferences

•Stand count at emergency and Stand count at harvest seem to measure similar aspects, given their high positive correlation.

•date of flowering and date of maturity may be related to factors that are inversely related to Stand count at emergency and Stand count at harvest.

•Number of reproductive pod per plant, number of nodule per plant, and total pod per plant could be part of a related set of traits or parameters that influence each other positively.

•Speed of germination and Standard germination also appear to be closely related.

Hypothesized Patterns:

Variables like stand count at emergency, Stand count at harvest, hundred seed weight, or vigority index might show strong positive relationships with DM or others in Group 2, implying they increase together.

Variables like date of flowering, date of maturity, or PH could inversely relate to others (e.g., higher DF associates with lower DM).

Parameters like dry biomass yield, seed yield, or adjusted moisture content may have little to no correlation with others.

Cluster Analysis: Variables like number of primary branch per plant, number of secondary branch per plant, Number of reproductive pod per plant; number of un reproductive pod per plant, and total pod per plant (possibly related to nutrient or particle parameters) might cluster together, showing similar correlation patterns with DBY. Vigority index and Speed of germination could correlate strongly with DBY

Outliers/Anomalies: Acorrelation of -0.8 (if present) between date of flowering / date of maturity and (e.g., dietary factors affecting intake). Unexpected neutral values (e.g., dry biomass yield ton /ha near 0) might indicate variables with no practical impact. Stand count at harvest and stand count at emergency have strong negative relation with all parameters except Logging percentage and dry biomass yield ton /ha, date of flowering and date of maturity have strong positive relations with vigority index, speed of germination and standard germination, but they have negatively correlation with Logging percentage and dry biomass yield ton /ha. plant height weak positive correlation with all parameters except weak negatively correlated with logging percentage , stand count at harvest and stand count at emergency , logging percentage has strong negative relation with all parameters except dry biomass yield ton /ha^{-1}, having weak positive relation , number of primary branch per plant, and number of secondary branch per plant have positive strong correlation with most parameters except weak negatively correlated with dry biomass yield ton /ha,, stand count at harvest and stand count at harvest , number of nodule per plant positively correlated with all parameters except logging percentage , stand count at harvest and stand count at emergency number of reproductive pod per plant has strong positive relation with most parameters except logging percentage , stand count at harvest and stand count at emergency, number of un reproductive pod per plant, has weak relation with all parameters total pod per plant has strong positive relation with vigority index, speed of germination, standard germination, number of reproductive pod per plant, number of nodule per plant, number of primary branch per plant,, number of secondary branch per plant and date of maturity , hundred seed weight has weak positive relation with all parameters except logging percentage , dry biomass yield ton /ha,, stand count at harvest and stand count at emergency dry biomass yield ton /ha, has negatively correlation with all parameters except stand count at harvest and stand count at emergency, adjusted seed yield has strong positive relation with harvest index, but weakly correlated with other parameters harvest index, speed of germination and standard germination have positive correlation with all parameters except dry biomass yield ton/ha-^{1},logging percentage , stand count at harvest and stand count at emergence\

4.5.2. Regression Analysis

The regression Analysis seed yield by intra row spacing result showed that the higher seed yields about 2600kg ha-^{1} were observed at medium intra-row spacing's (10cm) (Fig4.8), this boxplot showed how seed yield (ASY) varies with in different intra-row spacing's and the distribution and median yield for each spacing level, making it easy to spot which spacing tends to produce higher yields and how much variability exists within each group, similarly the highest seed yield above 3000kgha-^{1} could be obtained from the narrower inter row spacing's (20cm) (Fig4.9). Here's what's happening in boxplot does the same for intra-row spacing, for compare yield distributions across the different inter-row treatments. The interaction plot displays the mean seed yield for every combination of intra- and inter-row spacing.

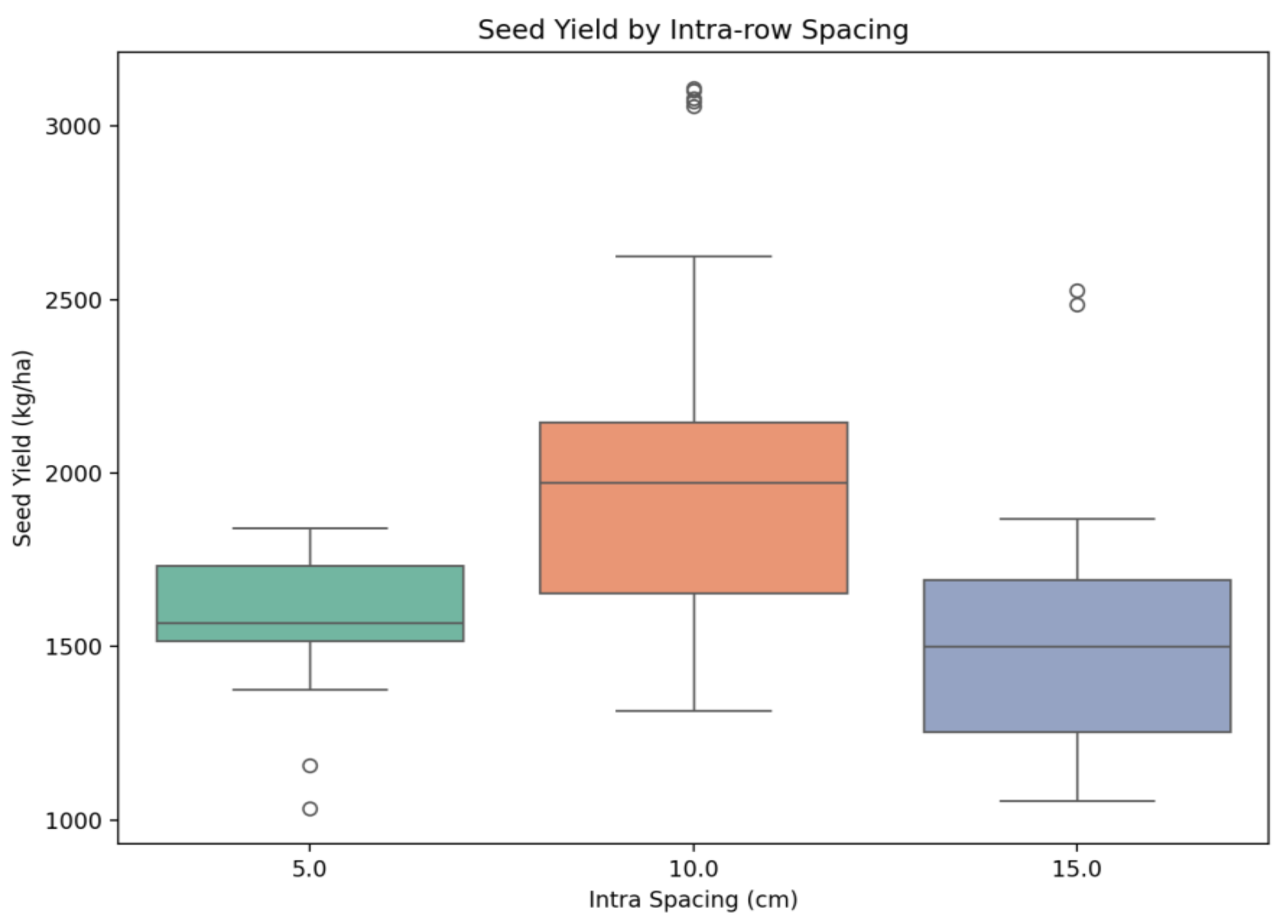

Figure 4.6 Regression between seed yield and intra row spacing's

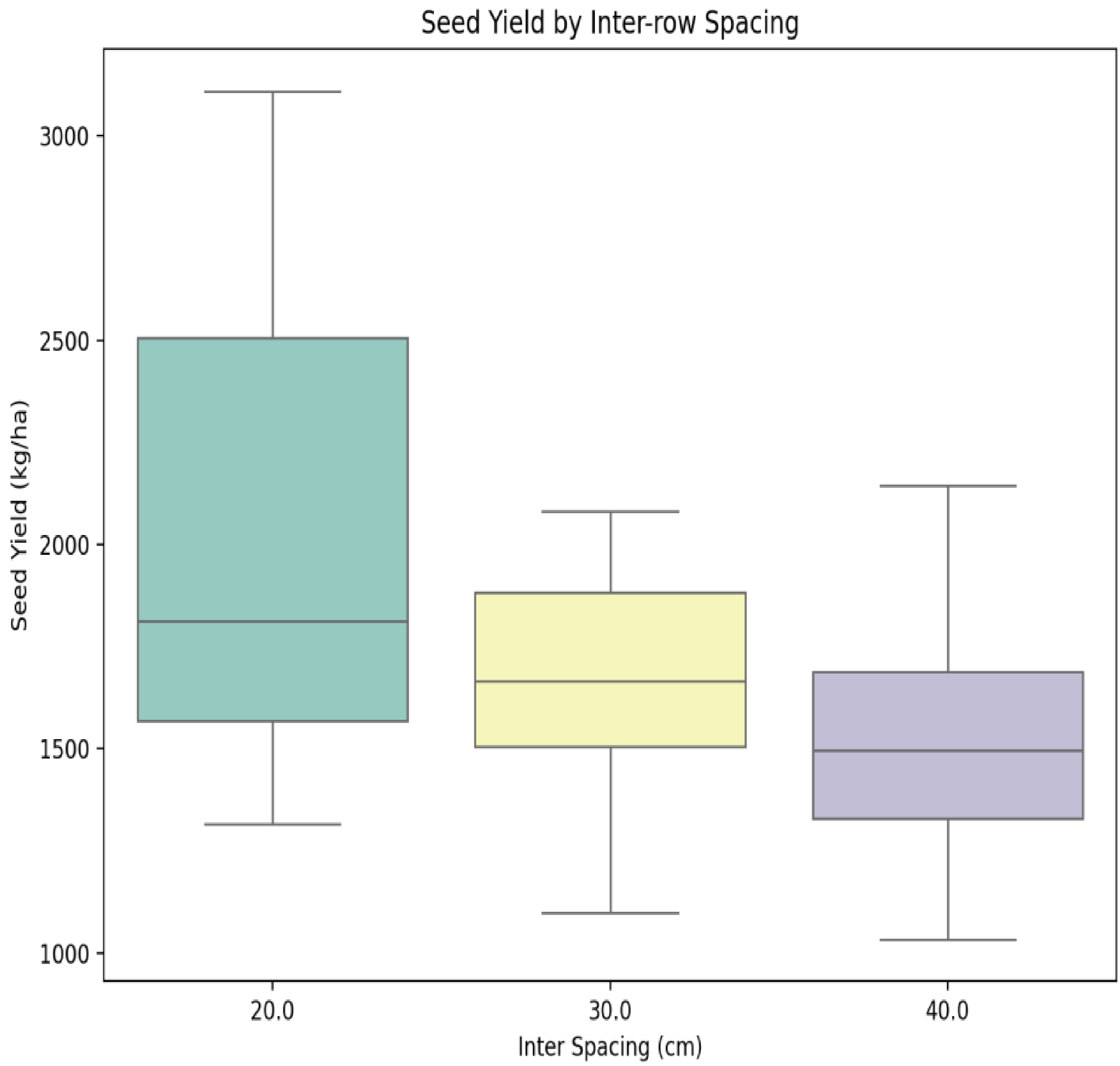

Figure4.7. Regression between seed yield and Inter row spacing's .

The 3D scatter plot (Fig4.10) result showed that the relationship between intra-row spacing, inter-row spacing, and seed yield (ASY). The colored points represent actual data, while the red surface and wireframe show the regression model's predicted yield across the range of spacing's. The regression equation and R^2 value are provided, indicating that both intra and inter spacing negatively affect yield, with inter spacing having a stronger effect. Closer spacing generally results in higher seed yield. The scatter points showed observed seed yields, while the red surface and wireframe represent the regression model's predictions. This visualization helps see how yield changes across the specific spacing treatments tested. The interaction plot displays the mean seed yield for every combination of intra- and inter-row spacing, each line represents a different inter-row spacing, and i can see how the effect of intra-row spacing changes depending on the inter-row spacing, this helps identify if there's a combined effect (interaction) between the two factors.

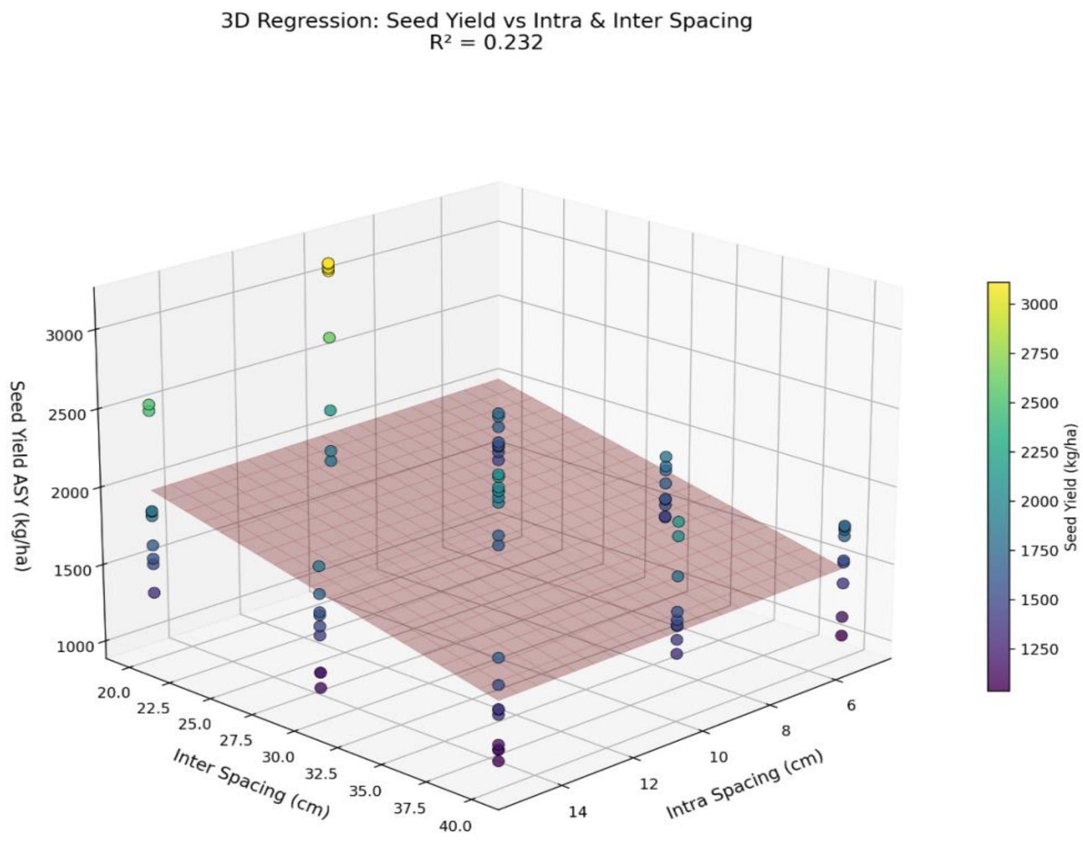

Figure4.8. seed yield verses intra and inter row spacing's

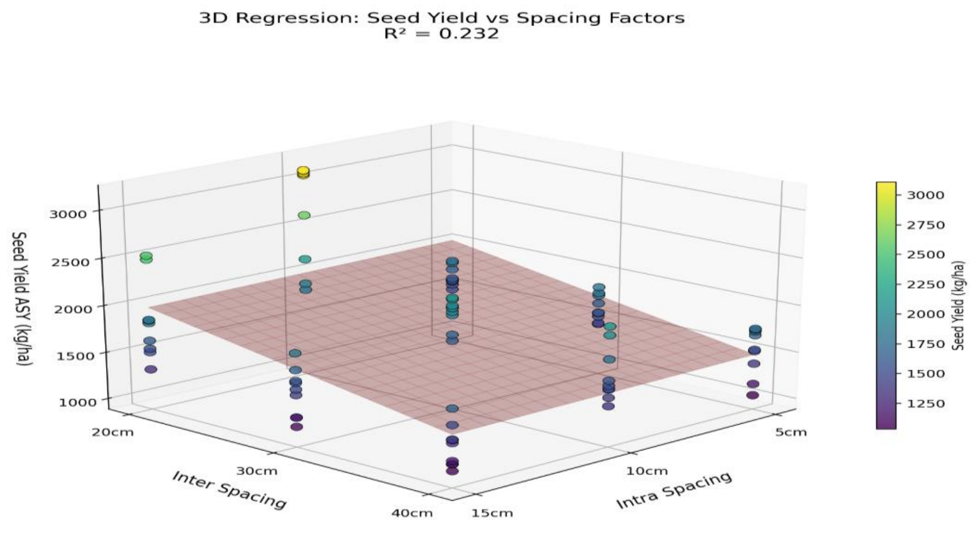

Figure4.9. Regression between seed yields verses spacing factors.

Regression equation: ASY = 2594.9 - 4.51*Intra - 27.4*Inter, R-squared: 0.232,
Interpretation: Both intra and inter spacing have negative effects on seed yield; with inter spacing having a much stronger impact. Closer spacing generally leads to higher yields. Here is a 3D scatter plot showing the relationship between intra-row spacing, inter-row spacing, and seed yield (ASY). The colored points represent actual data, while the red surface and wireframe show the regression model's predicted yield across the range of spacing's. The regression equation and R^2 value are provided, indicating that both intra and inter spacing negatively affect yield, with inter spacing having a stronger effect. Closer spacing generally results in higher seed yield.

The scatter points showed observed seed yields, while the red surface and wireframe represent the regression model's predictions. This visualization helps see how yield changes across the specific spacing treatments you tested. The interaction plot displays the mean seed yield for every combination of intra- and inter-row spacing. Each line represents a different inter-row spacing, and you can see how the effect of intra-row spacing changes depending on the inter-row spacing. This helps identify if there's a combined effect (interaction) between the two factors.Overall, these graphs show that both intra- and inter-row spacing influence seed yield and their effects can interact. Generally, closer spacing (both intra and inter) tends to result in higher yields, but the exact pattern can depend on the combination of spacing's used. This helps identify the optimal spacing strategy for maximizing yield in this experiment.

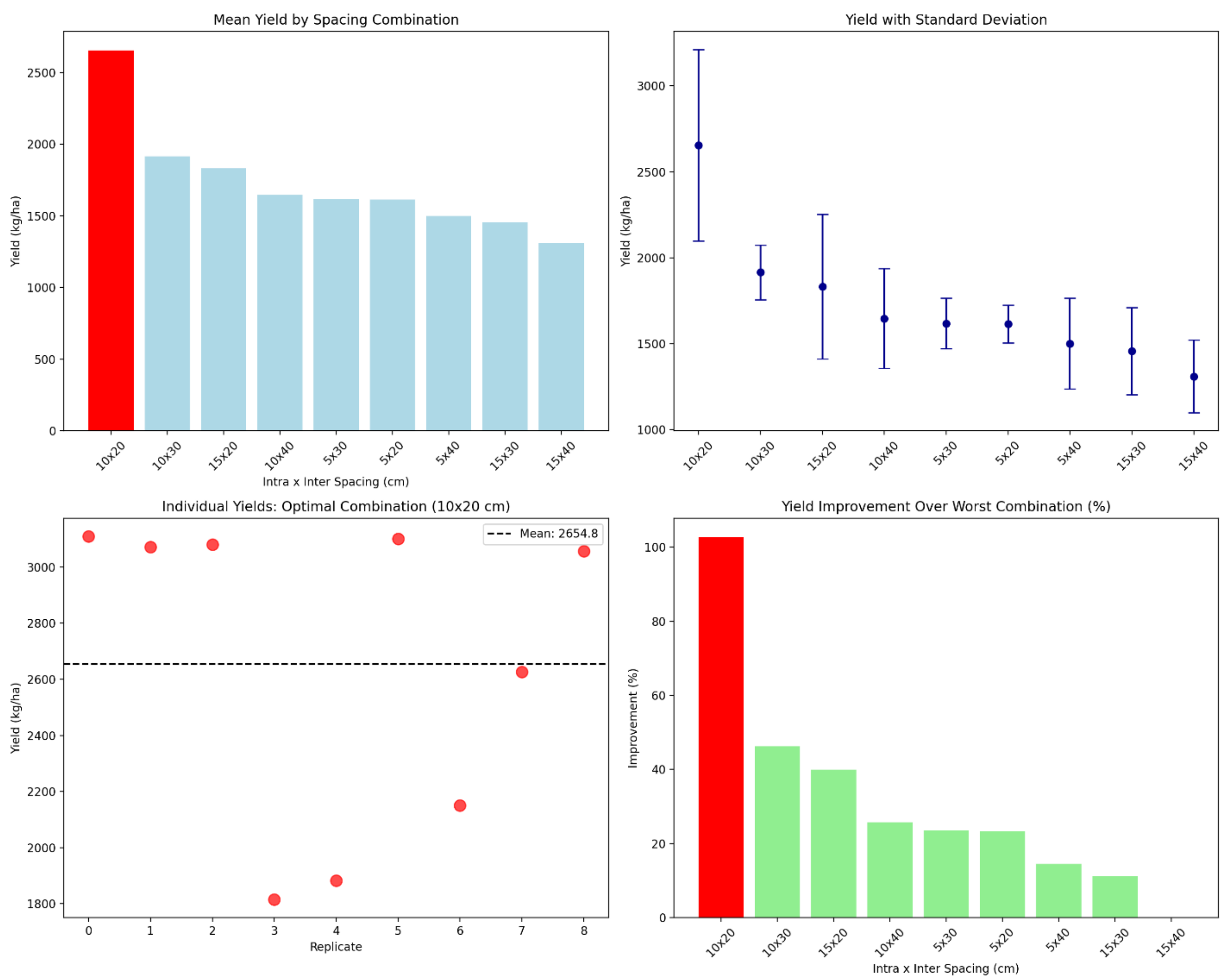

Figure4.10. Mean yield, individual yield and improvement over worst combination

Summary: Optimal spacing is 10cm intra x 20cm inters were gives 2654.78 kg/ha mean yield, this represents a 102.7% improvement over the worst combination (5cm x 40cm), the difference is statistically significant ($p < 0.001$).

The bar and scatter plots visually highlight the optimal combination (10 cm intra-row × 20 cm inter-row), which produced the highest average yield of 2654.78 kg/ha. This combination outperformed the lowest-yielding treatment by over 100%, and the difference is statistically significant ($p < 0.001$). The error bars and individual data points show that this result is consistent across replicates, making it a robust recommendation for maximizing yield in your experiment.

.6. Partial budget Analysis

Based on the dominance analysis, the non-dominated treatments are: Treatment were 5cm*40cm, 15cm *40cm, 15cm*30cm 10cm*40cm, and 15cm intra * 20cm inter row spacing's and the non-dominant treatments were 10cm intra *30cm inter row spacing's and 10cm intra row *20cminter row spacing's (table4.8).

The partial budget analysis indicated that the highest net benefit (NB) (313,547.5ETB ha-^{1}) was recorded at the treatment 10cm x 20cm intra and inter row spacing and followed by (267,285.8 ETB ha-^{1})obtained from 10cm*30cm intra and inter row spacing., while the lowest net benefit (177,075.4ETB ha-^{1}) obtained from 15cm*40cm.

The highest MRR (283.9%) was recorded also par treatment at 10cm x 20cm intra and inter row spacing,

Table 4.8 Sorted Treatments for Economic analysis

Treatments	TVC	GB	NB	Dominated
10cm 30cm	12,580.2	279,866	267,285.8	No
5cm 30cm	19,796.8	280,550	260,753.2	Yes
5cm 40cm	27,092.2	252,864	225,771.8	Yes
15cm 40cm	28,272.6	205,348	177,075.4	Yes
15cm 30cm	29,914.5	234,596	204,681.5	Yes
10cm 40cm	30,184.5	238,986	208,801.5	Yes
15cm 20cm	31,496.9	268,222	236,725.1	Yes
10cm 20cm	37,740.5	351,288	313,547.5	No
5cm 20cm	59,390.5	288,684	229,293.5	Yes

TVC = total variable costs. GB = gross benefit, NB = net benefit

Dominance Analysis

Treatments are compared to eliminate **dominated options** (where another treatment has either: Lower TVC + Higher NB, or Same TVC + Higher NB).

- **Dominated Treatments**:
  5cm* 30cm, 5cm* 40cm, 15cm* 40cm, 15cm *30cm, 10cm *40cm, 15cm*

20cm, and 5cm *20cm
(All have higher TVC and lower NB than 10cm*30cm or 10cm* 20cm).

- **Un-dominated Treatments** (efficiency frontier):
    - 10cm 30cm (Lowest cost, moderate NB)
    - 10cm 20cm (Higher cost, highest NB)

Marginal Rate of Return (MRR)

MRR is calculated between consecutive un-dominated treatments: 10cm 30cm → 10cm 20cm

- **Marginal Cost (Δ Cost)**:
  = TVC_{10cm20cm} - TVC_{10cm30cm}
  = 37,740.5 - 12,580.2 = **25,160.3**
- **Marginal Benefit (Δ Gross Benefit)**:
  = 351,288 - 279,866 = **71,422**
- **MRR**:
  = (Δ Benefit / Δ Cost) × 100
  = (71,422 / 25,160.3) × 100 = **283.9%**

Table4.9 un-dominated tretments on for parital budjeting

Treatment	Total Variable Cost	Marginal Cost	Net Benefit	Marginal Benefit	MRR (%)
10cm 30cm	12,580.2	–	279,866	–	–
10cm 20cm	37,740.5	25,160.3	351,288	71,422	283.9%

Recommendation: Optimal Treatment

- **Recommended Treatment**: 10cm 20cm
    1. Highest Net Benefit (**313,547.5**).
    2. MRR (**283.9%**) exceeds the 50% minimum acceptable rate, justifying the additional investment.

    The Marginal Rate of Return between the two un-dominated treatments is 283.9%, which is well above the commonly accepted minimum threshold of 100% for investment in smallholder agriculture (according to CIMMYT, 1988) standards.

Despite a higher cost than 10cm × 30cm, it offers a significantly higher net benefit. The MRR of 283.9%justifies the additional investment.

3. Un-dominated (no alternative has lower cost and higher net benefit).

- 10cm 20cm maximizes profitability (highest NB) and is economically efficient.
- 10cm 30cm is the second-best option if budget constraints prohibit investing in 10cm 20cm.
- All other treatments are **inefficient** (higher costs yield lower returns).

Sensitivity Note:

- The MRR (**283.9%**) is robust. Even if the acceptable threshold were 100%, 10cm 20cm remains optimal.

Practical Implications:

- Farmers should prioritize 10cm 20cm for maximum profit.
- If capital is limited, 10cm 30cm offers a viable low-cost alternative.
- Avoid treatments like 5cm 20cm (high cost, low NB) or 15cm 40cm (low NB despite moderate cost).

Conclusion

- Wider row spacing (10cm rows) generally yielded higher economic returns than narrower ones (5cm).
- While 10cm × 30cm spacing is the **most cost-effective**, the **10cm × 20cm** spacing provides the **best economic return** on investment.
- These findings support promoting **10cm × 20cm** planting configurations in similar agro-ecological conditions.

Chapter5. CONCLUSION AND RECCOMANDATIONS

5.1. Conclusion

In conclusion even though yield related parameters (number of branch per plant, number of pod per plant and hundred seed weight) were higher in wider spacing's, cannot optimize the yield of chick pea, this investigation justifies that too low and high plant population beyond a certain limit often adversely affects the crop yield.

In general the narrowest intra row spacing (5cm) and wider spacing (15cm intra and 40cm inter row spacing's) and later dates are associated with reduced yield of chickpea variety harbu on the study area and similar agro ecology of the region on observation date and spacing's.

5.2. Recommendations

Based on this investigation I would like to recommend early planting and medium intra and narrower inter row spacing (early planting date around 10 August and 10cm intra row spacing and 20 cm inter row) optimize the production of chick pea (variety harbu) and those combination of agronomic practice economical sound, similarly I recommend that 10cm intra * 30cm inter row spacing are the next best alternative combination were resource is limited in the study area and similar agro climatic regions, however the following research gaps were suggested for further research:

(i). since the experiment was conducted for one season and at one location, this research should be repeated over a season and location in order to develop conclusive recommendations.

(ii). May the treatments allocation at narrower range (three planting date, three intra and three inter row spacing) by boosting treatment allocation to develop conclusive recommendation.

(iii). Human labor estimation were difficult to do economic analysis in hectare base, in order to analysis economical treatment well, it is important using row maker, thrashers and other matins to be efficient

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APPENDIXES

Appendix table1. ANOVA for Yield and yield related Parameters

Source variations	Df	SCE	SCH	DF	DM	LG%	NBPP	PH	NPPP	HSW (g)	DBM kg/ha-[1])	SY (kg/ha-[1])	HI	VI
REP	2	Ns	ns	ns	**	Ns	***	**	***	Ns	**	**	**	**
Date	2	*	ns	ns	**	Ns	**	**	ns	**	***	***	**	***
Intra	2	***	***	***	***	***	***	**	***	***	***	***	***	***
Date*Intra	4	Ns	ns	ns	**	Ns	ns	Ns	ns	**	ns	Ns	**	***
Inter	2	***	***	**	ns	Ns	ns	Ns	ns	**	***	***	**	*
Date*Inter	4	Ns	ns	ns	ns	Ns	**	Ns	ns	**	ns	Ns	**	ns
Intra*Inter	4	***	***	ns	ns	Ns	ns	Ns	ns	**	ns	***	***	ns
Date*Intra*Inter	8	Ns	ns	ns	ns	Ns	ns	Ns	ns	**	ns	Ns	**	ns
Grand mean		142.4	126.9	57.5	104.3	2.5	10.0	37.5	56.1	35.6	6986.	1727.7	25.4	30.0
CV (%)		4.5	21.1	6.1	4.1	45.6	35	7.7	38.1	10.1	14.9	13.9	12.7	14.6
Ems		41.1	723.9	12.4	18.5	1.3	12.3	8.2	456.8	12.3	10856.3	57625	10.4	19.2

Appendix table2. (P value table)

REP= replication, df= degree of freedom. CV = coefficient of variation, SCH= stand count at harvest, DF= days of flowering, DM= days of maturity, PH= plant height, L% = logging percentage, NBPP= number of branch per plant, NPPP= number of pods per plant, DBMkg/ha-[1] = dry biomass yelled in kilo gram per hectare , SYkg/ha= seed yield, kilo gram per hectare HI= Harvest Index, VI = vigority index.

Appendix table2 p value table for yield and yield related parameters

Source	DF	SCE	SCH	DF	DM	PH	L%	NBPP	NPPP	HSW (g)	DBY kg/ha	SY kg/ha	HI	VI
REP	**2**	**0.0683**	**0.6391**	**0.5377**	**0.0047**	**0.0048**	**0.9334**	**0.4205**	**<.0001**	**0.7672**	**0.0002**	**0.0138**	**0.0059**	**0.0162**
-Date	**2**	**0.0461**	**0.2009**	**0.132**	**0.0003**	**0.0193**	**0.2946**	**0.0287**	**0.1019**	**0.0165**	**0.0195**	**<.0001**	**0.0173**	**<.0001**
Intra	**2**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**0.0048**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**
Date*Intra	**4**	**0.8537**	**0.5435**	**0.249**	**0.0041**	**0.5161**	**0.9871**	**0.7222**	**0.2493**	**0.0008**	**0.3103**	**0.0798**	**0.0008**	**<.0001**
Inter	**2**	**<.0001**	**<.0001**	**0.0242**	**0.0838**	**0.8721**	**0.6198**	**0.4096**	**0.0915**	**0.0091**	**<.0001**	**<.0001**	**0.0201**	**0.0362**
Date*Inter	**4**	**0.8161**	**0.9114**	**0.874**	**0.4186**	**0.7314**	**0.8119**	**0.0036**	**0.5354**	**0.0103**	**0.0741**	**0.082**	**0.0103**	**0.8195**
Intra*Inter	**4**	**<.0001**	**<.0001**	**0.574**	**0.3706**	**0.3399**	**0.9587**	**0.926**	**0.1237**	**0.005**	**0.3725**	**<.0001**	**<.0001**	**0.1677**
Date*Intra* Inter	**8**	**0.9177**	**0.9416**	**0.6137**	**0.734**	**0.5597**	**0.9578**	**0.4429**	**0.6512**	**0.0004**	**0.5126**	**0.3111**	**0.0169**	**0.0987**

REP= replication, df= degree of freedom. cv = coefficient of variation, SCH= stand count at harvest, DF= days of flowering, DM= days of maturity, PH= plant height, L% = logging percentage, NBPP= number of branch per plant, NPPP= number of pods per plant, DBMkg/ha = dry biomass yelled in kilo gram per hectare , SYkg/ha= seed yield, kilo gram per hectare HI= Harvest Index, VI// = vigority index.

Appendix table3. Means comparison for main effect of planting date, intra and inters row spacing on yield and yield related Parameters of chick pea under moisture deficit area of eastern Amhara.

LSD= list significant difference, cv=coefficient of variation,, Df=degree of freedom, PH=

Treatments	**SCE**	**SCH**	**PH**	**NBPP**	**NPPP**	**HSW (g)**	**DBM(kg/ha)**	**SY(kg/ha-1)**	**HI**	**VI**
planting dates										
August 10	**144.9a**	**132.9a**	38.8a	11.5a	**63.4a**	**36.2a**	**7318a**	**1906.7a**	**26.8a**	**36.7a**
August 17	**140.6ba**	**119.8a**	37.1b	9.3b	**52a**	**33.4b**	**6903ba**	**1673.5ba**	**25.1b**	**26.7b**
August 24	**141.7b**	**128.2a**	36.6b	9.2b	**52.9a**	**34.1b**	**6739b**	**1603b**	**24.3b**	**27.2b**
Sig. level (P < 0.05)	*****	**Ns**	**	**	**Ns**	******	**Ns**	*******	******	*******
Intra-row spacing(cm)										
5 cm	**245.7a**	**206.9a**	38.8a	5.4b	**23.5a**	**29.9c**	**6063a**	**1578b**	**20.4c**	**20.1c**
10cm	**117b**	**112.8b**	37.6b	12a	**72.3a**	**35.1b**	**6903b**	**2072.3a**	**30.1a**	**29.1b**
15cm	**64.4c**	**61.2c**	36.6c	12.6a	**72.4b**	**38.7a**	**7994c**	**1532.9b**	**25.7b**	**40.9a**
Sig. level (P < 0.05)	*******	*******	**	***	*******	*******	*******	*******	*******	*******
Inter-row spacing(cm)										
20 cm	**210.4a**	**178.2a**	37.26a	10.4a	**59a**	**33.1b**	**7778a**	**2033.9a**	**26.9a**	**28.2b**
30 cm	**128.8b**	**119.8b**	37.67a	9.3a	**48.6b**	**36.1a**	**7091b**	**1663.5b**	**24.4b**	**31a**
40 cm	**87.9c**	**82.9c**	37.5a	10.3a	**60.6a**	**34.5ba**	**6090c**	**1485.82c**	**24.96b**	**30.9a**
Sig. level (P < 0.05)	*******	*******	Ns	Ns	**Ns**	******	*******	*******	******	******
CV (%)	**4.5**	**21.1**	7.7	35	**38.1**	**10.1**	**14.9**	**13.9**	**12.7**	**14.6**
EMS	**41.1**	**723.9**	8.2	12.3	**456.8**	**12.3**	**10856.**	**57625**	**10.4**	**19.2**

plant height,, NPPP= number of pods per plant, NBPP= number of branch per plant, , HSW= hundred seed weight, DBM= dry biomass yield, SY= seed yield, HI= harvest index ,VI= vulgarity index, * P< 0.05; ** P< 0.01; NS= non-significant at 5%, Df= degree of freedom, DF= days to 50% flowering, MD=days to maturity , Means with the same letter are not significantlydifferent.

Appendix table4. mean comparison of treatment combination on yield and yield related parameters

Treatments	SCE	SCH	DF	DM	PH	L%	NBPP	NPPP	HSW (g)	DBM(kg/ha-1)	SY (kg/ha-1)	HI	VI
1	374.5a	373a	52kgih	99.7ihg	3.8ab	4ba	6hgi	18.7g	27.9g	9537ba	1605.4gfh	17m	19.4lmno
2	371b.	224b	53.667kgjfih	105edgcf	37.9ebdac	4.7a	5.3hgi	28.7gf	29.3fe	7870bdec	1624.2gfhe	21.5hklmji	23.5lnkmui
3	150d	150d	57.6egjfih	102ehgf	39.2bdac	4.3a	8hgif	37egf	31.4fcedg	7315gfdec	1538.4jgfhik	22.5hklji	21.5lnkmo
4	179c	179c	55.7egjfih	107ebdacf	40.2a	2dc	12.7ebdacf	87ba	34.8cebd	7963bdec	3087a	39a	33fegd
5	1067e	105e	58.7ebdfc	108.7ebdac	36.9ebdcf	2dc	15bdac	79.7ba	34.8cebd	7410gfdec	1856.9gfde	25hefgdi	33fegd
6	71gh	70gh	58egdfc	110bdac	39.0bdac	2dc	16ba	98a	35.4cbd	6018gih	2000.9cde	33.7bc	39.97cb
7	873f	85f	63bdac	107ebdacf	39.0bdac	1.3d	9.3ehgif	92ba	36.6cb	7778fdec	2183.2cd	28efgd	51.6a
8	64h	62h	61ebdac	109bdac	39.9ba	1.7d	14ebdac	42egdf	57.96a	5859gih	1668.9gfhe	29ecd	55.4a
9	50i	50i	64ba	112.7ba	40.5b	1d	17a	87ba	37.3b	6110gfih	1532.9jgfhik	25.5hefgdi	54.0a
10	365.a	253bc	48k	93.7ij	44a	5.3a	5.3hgi	24g	28.6fg	8704bac	1677.5gfhe	19.5klmg	15.8o
11	215b	213b	53.7kgjih	94ij	35.2ebdcf	4.3a	4.7hi	21g	29.7feg	9815a	1686.8gfhi	17.8lm	16.8o
12	149d	148d	52kgjfih	96ihj	36.8ebdacf	4.7a	4.7hi	18.7g	29.9fedg	6570gheif	1474jghik	22.5hklji	25lhkmgi
13	1767c	175c	58.7ebdfc	109bdac	37.4ebdacf	2.3bdc	14bdac	51egdfc	33.9fcebd	6570gfeih	2266.cb	34.3ba	26lhkgji
14	103e	103e	58egdfch	102hgf	38bdac	2dc	11ehdgicf	47egdfc	34.5cebd	7040gfdech	2004.9cde	28.7efcd	26lhkgji
15	697h	165h	61ebdac	107ebdacf	34bdac	1.7d	8.3ehgif	77bdac	35.7cb	6300gfeih	1536jgfhik	24.7hefgji	35.9cebd
16	80gh	80gh	63bdac	110bdac	39.5bac	1.3d	15bac	98a	36.2cb	592.6gih	1667gfhe	28.9ecd	35.9cebd
17	653i	65h	65a	113a	39b	1d	13ebdacf	61ebdfc	35.9cb	5830gih	1538jgfhik	26.6hefgd	40.2b
18	447i	43i	64bac	112bac	44.3a	1.7d	8hgif	69ebdac	36.5cb	5370ih	1210.6jik	23.hkgji	35.5fcebd
19	371a	369a	51k	90j	39.5bac	4ba	5hi	22.7g	28.7fg	8330bdac	1561jgfhi	19klm	21.8lnkmo
20	215b	215b	53.7kji	92j	35.2ebdacf	3.7bac	4i	22.8g	31.9fcebdg	7500gfdec	1544jgfhik	21.2klmji	27hkgji
21	188d	176d	53kgjfih	63j	35.2e	4.7a	5.5hgi	18.3g	32.1fcebdg	6270gfeih	1428jhik	22.7hklgji	16o
22	177c	176c	52.7kgjih	104edgf	38.3bdac	2dc	11ebdgcf	68ebdac	35.5cbd	8610bac	2611b	30.3bcd	22.9lnkmjo
23	106e	105e	61ebdac	106ebdagcf	36.2ebdacf	1d	7.7hgif	64ebdac	35.5cebd	6670gfdeih	1884cfde	28.6efcd	27hkgji
24	69h	65h	57.7egdfih	101hgf	37.4ebdacf	1.7d	13ebdacf	78bac	35.7cb	5555.6ih	1403jhik	26.3hefgdi	29.3fhegji
25	857f	84h	59.7ebdac	106ebdgcf	36.6ebdacf	1d	14.7bdac	69ebdac	35.9cb	6570gfeih	1646gfhe	25.6hefgdi	28.5fhegji
26	62h	62h	47.6k	110.6bdac	36.6ebdacf	1d	10ehdgcf	71ebdac	36.3cb	5834gih	1163.4k	21.3klmji	36.7cbd
27	437i	42h	60.6ebdac	112.7ba	40a	1d	12ebdacf	62ebdfc	36.2cb	52778i	1185.8jk	23.5hkfgji	36.7cbd
TRT.mean	29302.7	17401.	62	150.0	11.8	6.6	51.9	8120.3	3.3	469866	541006.0	80.6	85.7
REP. mean	116.	327.0	8	110.0	48.7	0.08	9.0	2216.5	91.3	1122070.	268307	59.0	361.0
GM	142	127	57	104	37.5	2.5	10.0	56.0	34.6	6987	1727.7	25.0	30.0
Sig. level (P < 0.05)	***	***	***	***	Ns	***	***	***	***	***	***	***	***
CV	4.5	21.2	6.1	4.1	7.7	45.5	35.0	38.1	10.1	14.9	13.9	12.7	14.6
SE±	41.1	723	12.4	18.5	8.2	1.3	12.3	456.8	12.3	10856.	57625	10.4	19.2

Appendix Table.5. Mean comparison on the interaction effects of Intra and Inter row spacing's on yield and yield related parameters

Intra *inter	SCE	SCH	DF	DM	PH	L%	NBPP	TPPP	HSW	DBY	SY	HI	VI
5cm 20cm	370.2a	281.3a	50.44e	94.6d	34.77b	4.444a	5.44b	21.78cd	28.38c	885.8e	1615d	18.55e	19.03d
5cm 30cm	218ab	198ba	52.78de	96d	36.98ab	4.222a	4.67b	24.11cd	30.28c	839.5de	1618d	20.16c	22.51d
5cm 40cm	148.9b	141.4bcd	54.11de	98.1d	36.98ab	4.556a	6b	24.67cd	31.14c	672.8bc	1647d	22.59c	18.75d
10cm 20cm	177.1bc	173bc	55.67bc	106.8b	38.62ab	2.111b	12.67a	68.78ba	34.73b	771.6cd	2655a	34.55a	26.93bc
10cm 30cm	104.6b	100.6b	55.67bc	105.7b	37.08ab	1.667b	10.78a	63.67bc	34.79b	703.7c	1915bc	27.5bc	28.43b
10cm 40cm	69.4c	64.7cd	55.67bc	106.3b	37.08ab	1.667b	12.67a	84.44a	35.67b	595.7ab	1647d	28.24ab	31.88b
15cm 20cm	84bcd	80.2bcd	61.78 b	107.7b	38.4a	1.222b	13.11a	86.44d	36.16b	675.9bc	1832bc	27.47bc	38.65a
15cm 30cm	63.9c	60.8cd	61.67ab	111.1bc	38.96a	1b	12.33a	58.11b	43.34a	584.2a	1618cd	25.63cd	42.06a
15cm 40cm	42.4e	40.7e	61.67a	112.6a	38.92a	1.222b	12.33a	72.78ba	36.64b	558.6a	1310e	24.05d	42.09a
Significant level(p<0.05)	***	***	ns	Ns	ns	Ns	Ns	ns	**	Ns	***	***	ns
CV (%)	4.5	21.2	6.1	4.1	7.65	45.6	35.0	38.1	10.1	14.9	13.9	12.7	14.6
Error	41.1	723.93	12.4	18.5	8.2	1.3	12.3	21.4	12.2	108.56	576.25	10.4	19.2
R-Square	0.99	0.92	0.72	0.81	0.49	0.72	0.68	0.76	0.79	0.72	0.83	0.80	0.91
Grand mean	142.4	126.98	57.5	104.3	37.48	2.5	10	56.1	34.6	69.8	172.7.	25.4	30.0

Appendix table6. Mean value of the interaction between planting date and Intra row spacing's

Planting Date	Intra row	SCE	SCH	DF	DM	PH	L%	NBPP	TPPP	HSW	BMT	SY kg/ha-1	HI	VI
Augest10	10cm	118.1	114.6	57.6	108.7	38.7	1.9	14.7	88.3	35.0	712.9	2314.9	32.7	34.9
Augest10	15cm	67.1	64.2	62.7	109.7	39.8	1.1	13.4	73.8	43.9	658.3	1794.9	27.5	53.7
Augest10	5cm	249.4	220	53.9	102.3	37.7	4.3	6.4	28.1	29.5	824.0	1610.1	20.4	21.5
Augest17	10cm	115.9	111	59.1	106.2	36.7	2	10.8	58.6	34.7	663.6	1935.6	29.2	25.84
Augest17	15cm	63	58.9	63.7	111.9	39.4	1.3	12.1	76.2	36.2	570.9	1472.1	26.2	37.2
Augest17	5cm	242.9	189.4	51.3	94.6	35.1	4.8	4.9	21.2	29.4	836.4	1612.6	19.9	17.0
Augest24	10cm	117.1	112.8	57	103.9	37.3	1.6	10.7	70	35.5	694.4	1966.0	28.4	26.5
Augest24	15cm	63.2	60.6	59.9	109.8	37.0	1	12.2	67.3	36.0	589.5	1331.7	23.5	31.9
Augest24	5cm	244.8	211.3	52.1	91.8	35.4	4.1	4.8	21.2	30.9	737.7	1511.3	20.9	21.8

Appendix table8. Mean value of the interaction between Planting date and Inter row spacing's

planting date	Inter	SCE	SCH	DF	DM	PH	L%	NBPP	TPPP	HSW	BMT	SY kg/ha-1	HI	VI
Augest10	20cm	213.7	187.9	57	104.6	38.4	2.4	9.3	66	33.1	842.6	2291.9	28.0	34.6
Augest10	30cm	130.8	124.8	57.7	106.7	38.3	2.6	11.4	50.2	40.7	704.6	1716.6	25.2	36.9
Augest10	40cm	90.2	86.1	59.4	109.4	39.6	2.3	13.8	74	34.7	648.2	1711.6	27.3	38.5
Augest17	20cm	206.9	166.2	56.4	104.3	36.7	3	11.7	57.8	32.9	706.8	1870.3	27.6	25.7
Augest17	30cm	127.8	112.3	58.4	103.1	37.8	2.4	9.1	43.1	33.4	756.2	1743.3	24.4	27.7
Augest17	40cm	87	80.8	59.2	105.2	36.8	2.7	7	55.1	34.0	608.0	1406.8	23.5	26.7
Augest24	20cm	210.8	180.4	54.4	100.1	36.7	2.3	10.2	53.2	33.3	783.9	1939.5	24.9	24.41
Augest24	30cm	127.8	122.3	57.4	103	36.9	1.9	7.2	52.6	34.3	666.7	1530.5	23.7	28.3
Augest24	40cm	86.6	81.9	57.1	102.3	36.1	2.4	10.2	52.8	34.7	570.9	1339.0	24.2	27.5

Appendix table 9. Mean value of interaction of planting date, Intra and inter row spacing's on yield and yield related parameters

Date	Intra	Inter	SCE	SCH	DF	DM	PH	L%	NBPP	TPPP	HSW	DB Mkg/ha	SY kg/ha	HI	VI
Augest10	**10cm**	**20cm**	179	175.3	55.7	107	40.2	2	12.7	87.3	34.8	796.3	3087	39.	32.95
Augest10	**10cm**	**30cm**	104.7	100.3	58.7	108.7	36.9	2	15	79.7	34.8	740.7	1856.9	25.2	31.9
Augest10	**10cm**	**40cm**	70.7	68	58.3	110.3	39.0	1.7	16.3	98	35.4	601.9	2000.9	33.7	39.9
Augest10	**15cm**	**20cm**	87.3	85.3	63	107	39.0	1.3	9.3	92	36.6	777.78	2183.2	27.9	51.6
Augest10	**15cm**	**30cm**	64	58.3	60.7	109.3	39.9	1	14	42.3	57.9	585.9	1668.9	28.9	55.4
Augest10	**15cm**	**40cm**	50	49	64.3	112.7	40.5	1	17	87	37.2	611.1	1532.9	25.5	54.
Augest10	**5cm**	**20cm**	374.7	303	52.3	99.7	36.0	4	6	18.7	27.9	953.7	1605.4	17.1	19.4
Augest10	**5cm**	**30cm**	223.7	215.7	53.7	102	37.9	4.7	5.3	28.7	29.3	787.0	1624.2	21.5	23.5
Augest10	**5cm**	**40cm**	150	141.3	55.7	105.3	39.2	4.33	8	37	31.4	731.5	1600.9	22.5	21.5
Augest17	**10cm**	**20cm**	175.7	172.3	58.7	109.3	37.4	2.3	14.3	51	33.9	657.4	2266.2	34.3	24.9
Augest17	**10cm**	**30cm**	103.3	98.7	58	102	38.	2	9.7	47.3	34.5	703.7	2004.9	28.7	26.2
Augest17	**10cm**	**40cm**	68.7	62	60.7	107.3	34.8	1.7	8.3	77.3	35.7	629.6	1536.2	24.7	26.4
Augest17	**15cm**	**20cm**	80	73.3	62.7	110	39.5	1.33	15.3	98.3	36.2	592.6	1667.1	28.9	35.9
Augest17	**15cm**	**30cm**	65.3	64.7	64.7	113.3	40.0	1	13	61	35.9	583.3	1538.4	26.6	40.2
Augest17	**15cm**	**40cm**	43.7	38.7	63.7	112.3	38.7	1.7	8	69.3	36.5	537.0	1210.6	23.2	35.5
Augest17	**5cm**	**20cm**	365	253	48	93.7	33.2	5.3	5.3	24	28.6	870.4	1677.5	19.5	15.8
Augest17	**5cm**	**30cm**	215	173.7	52.7	94	35.2	4.3	4.7	21	29.7	981.5	1686.8	17.8	16.8

Augest17	**5cm**	**40cm**	148.7	141.7	53.3	96	36.9	4.7	4.7	18.7	29.9	657.4	1473.6	22.5	18.4
Augest24	**10cm**	**20cm**	176.7	171.3	52.7	104	38.3	2	11	68	35.5	861.1	2611.1	30.3	22.9
Augest24	**10cm**	**30cm**	105.7	103	60.7	106.3	36.2	1	7.7	64	35	666.7	1883.8	28.6	27.2
Augest24	**10cm**	**40cm**	69	64	57.7	101.3	37.4	1.7	13.3	78	35.9	555.6	1403.2	26.3	29.3
Augest24	**15cm**	**20cm**	84.7	82	59.7	106	36.6	1	14.7	69	35.7	657.41	1645.8	25.7	28.5
Augest24	**15cm**	**30cm**	62.3	59.3	59.7	110.8	36.9	1	10	71	36.2	583.3	1163.4	21.3	30.5
Augest24	**15cm**	**40cm**	42.7	40.3	60.3	112.7	37.6	1	12	62	36.2	527.8	1185.8	23.5	36.7
Augest24	**5cm**	**20cm**	371	288	51	90.3	35.0	4	5	22.7	28.7	833.0	1561.5	19.0	21.8
Augest24	**5cm**	**30cm**	215.3	204.7	52	92	37.8	3.7	4	22.7	31.9	750	1544.2	21.2	27.2
Augest24	**5cm**	**40cm**	148	141.3	53.3	93	33.4	4.7	5.3	18.3	32.1	629.7	1428.2	22.7	16.3

Appendix table10. available information during field layout and planting

Plot no.	**Planting dates**	**Intra and inter row, left to right**	**Number of row/plot**	**Number of plant/row**	**Number of plant/plot**	**Number of harvestable row**	**Number of Harvestable plant/row**	**Number of harvestable plant**
1	August 10	5cmx20cm	12	40	480	10	36	380
2	August 10	5cmx30cm	8	40	320	6	36	228
3	August 10	5cmx40cm	6	40	240	4	36	152
4	August 10	10cmx20cm	12	20	240	10	18	180
5	August 10	10cmx30cm	8	20	160	6	18	108
6	August 10	10cmx40cm	6	20	120	4	18	72
7	August 10	15cmx20cm	12	13	156	8	12	88
8	August 10	15cmx30cm	8	13	104	6	12	66
9	August 10	15cmx40cm	6	13	78	4	12	44
10	August 17	5cmx20cm	12	40	480	10	36	380
11	August 17	5cmx30cm	8	40	320	6	36	228
12	August 17	5cmx40cm	6	40	240	4	36	152
13	August 17	10cmx20cm	12	20	240	10	18	180
14	August 17	10cmx30cm	8	20	160	6	18	108
15	August 17	10cmx40cm	6	20	120	4	18	72
16	August 17	15cmx20cm	12	13	156	8	12	88

17	August 17	15cmx30cm	8	13	104	6	12	66
18	August 17	15cmx40cm	6	13	78	4	12	44
19	August 24	5cmx20cm	12	40	480	10	36	380
20	August 24	5cmx30cm	8	40	320	6	36	228
21	August 24	5cmx40cm	6	40	240	4	36	152
22	August 24	10cmx20cm	12	20	240	10	18	180
23	August 24	10cmx30cm	8	20	160	6	18	108
24	August 24	10cmx40cm	6	20	120	4	18	72
25	August 24	15cmx20cm	12	13	156	8	12	88
26	August 24	15cmx30cm	8	13	104	6	12	66
27	August 24	15cmx40cm	6	13	78	4	12	44

Appendix table.11. Experimental site whether data information

whether type	January	February	March	April	May	June	July	August	September	October	November	December	Total	average
Rain fall	17.9	00	10.8	75.4	13.3	52.5	157.4	205.	66.7	18	63.5	4.0	683.3	56.94
maximum temperature	25	26.1	26.3	25.5	27.2	27.5	26.4	26.0	24.2	22.1	21.4	23.5	30.1.2	25.1
Minimum temperature	10	12	11.4	11.5	12.	14	11.2	10.1	10.0	9.5	9.3	10.1	131.1	10.9
Relative humidity	41	42	47.1	49	44	42	50	54	51	47	48	44	424.1	35.3

Appendix table.12.Treatment description and Randomization.

Treatment code	Planting date,Intra and inter row Respectively	Rep.I Plot number	Rep.II Plot number	Rep.III Plot number
1	August 10 * 5cm *20cm	1	30	66
2	August 10 *5cm *30cm	2	52	70
3	August 10 *5cm*40cm	3	39	73
4	August 10*10cmx20cm	4	50	71
5	August 10*10cm*30cm	5	48	55
6	August 10*10cm*40cm	6	46	62
7	August 10*15cm*20cm	7	32	72
8	August 10*15cm*30cm	8	44	74
9	August 10*15cm*40cm	9	37	67
10	August 17*5cm*20cm	10	54	61
11	August 17*5cm*30cm	11	35	65
12	August 17*5cm*40cm	12	40	80
13	August 17*10cm*20cm	13	47	77
14	August 17*10cm*30cm	14	41	75
15	August 17*10cm*40cm	15	38	68
16	August 17*15cm*20cm	16	49	76
17	August 17*15cm*30cm	17	34	64
18	August 17*15cm*40cm	18	31	81
19	August 24*5cm*20cm	19	29	58
20	August 24*5cm*30cm	20	36	63
21	August 17*5cm*20cm	21	43	79
22	August 24*10cm*20cm	22	45	69
23	August 24*10cm*30cm	23	33	59
24	August 24*10cm*40cm	24	28	78
25	August 24*15cm*20cm	25	42	57
26	August 24*15cm*30cm	26	51	56
27	August 24*15cm*40cm	27	53	60

Apendix.Figure1. Pictures taken thorough site preparation to harvesting of chickpea evaluation under factorial arraignment

BIBLOGRAPHY

The author, Sisay Bisetegn, was born on May 5, 1985, in the Amhara National Regional State, North Wollo Administrative Zone, in Gidan district Muja, town. He attended his primary school education at Muja mariyam elementary school, and in the subsequent years, he enrolled at Kulmesk secondary school, where he sat for the Ethiopian Schools Leaving Certificate Examination in 2002. After passing the examination, he joined Mersa College of Agriculture and completed a diploma in Plant science in 2005.Right after graduation, Sisay was employed by the ministry of agriculture and served for more than 6 months as a development agent, head of the district agriculture office, In May 2006, he joined Sirinka Agricultural research center and after six years later he joined woldiya university to pursue his undergraduate program in the College of Agriculture, , Department of Plant Sciences. In 2015, he obtained his B.Sc. degree in Plant Sciences with great distinction. After graduation, he joined Woldiya University and served as assistance researcher for six years up to 2022. In 2023, the author joined Bahir Dar University to pursue his postgraduate study in Agronomy.