Influence OF PLANT POPULATION AND WEED MANAGMENTON GROWTH AND YIELD OF FABA BEAN (*Vicia faba* L.) IN OMONADA DISTRICT, SOUTHWESTERN ETHIOPIA

M.Sc. THESIS

BY

ASFAW EMBABO MARU

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INFLUENCE OF PLANT POPULATION AND WEED MANAGMENT ON GROWTH AND YIELD OF FABA BEAN (V*icia faba*L.) IN OMONADA DISTRICT, SOUTHWESTERN ETHIOPIA

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Name of student: Asfaw Embabo ID.No. RM1384/09

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I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisors. Hence, I kindly request the department to allow me to present the findings of my work and to summit the thesis.

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We, the thesis advisors have evaluated the contents of this thesis and found it to be satisfactory, executed according to the approved proposal, written according to the standards and formats of the University and is ready to be submitted. Hence, we recommend the thesis to be submitted.

Major Advisor: Gezahegn Barecha(Professor) __________ February 2020___

Name Signature Date

Co-Advisor: Wakuma Bayissa (PhD)___ ________ February2020___

Name Signature Date

Internal Examiner (if depends on the verdict)

Name: ______________________ Signature__________ Date________

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DEDICATION

This Thesis is dedicated to my family for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

First I declare that this thesis is my work and that all sources of the materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Place: Jimma University, Jimma

Date of submission_____________________________________

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ACRONYMS AND ABBREVATIONS

ANOVA	Analysis of Variance
BNF	Biological Nitrogen Fixation
CIMMYT	International Maize and Wheat Improvement Center
CIAT	International Center for Tropical Agriculture
CSA	Central Statistics Agency
DAE	Days AfterEmergence
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agricultural Organization Statistical Division
IPM	Integrated Pest Management
IWM	Integrated Weed Management
JARC	Jimma Agricultural Research Center
LAI	Leaf Area Index
LSD	Least Significance Difference
MARR	Minimum Acceptable Rate of Return
MaslMeters above sea level	
MRR	Marginal Rate of Return
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System

Contents Pages

LIST OF TABLES

LIST OF TABLESIN THE APPENDIX

LIST OF FIGURES IN THE APPENDIX

INFLUENCE OF PLANT POPULATION AND WEEDMANAGMENT ON GROWTH AND YIELD OF FABA BEAN (V*icia faba*L.) **IN OMONADA DISTRICT, SOUTHWESTERN ETHIOPIA**

ABSTRACT

Faba bean (Ficia faba L.) is among the leading legumes in area coverage and production in Ethiopia. However, its productivity is low mainly due to in appropriate plant population and weed management. Studies on the combined use of inter row spacing and weed management for faba bean are lacking at Omo nada area. Therefore, a field experiment was conducted to determine the effect of inter rows spacing and weed management on yield and yield components of faba beanin 2018 main cropping season in Jimma Zone, Omo Nada district, south western Ethiopia. Four inter row spacings ; 30 cm x 10 cm(333,333 plants ha^{-1}),40cmx10cm (250,000 plants ha^{-1}), 50cm x 10cm (200,000 plantsha^{-1}) and 60 cm x 10cm (166,667 plants ha^{-1}) and five weeding regime ; no weeding, one time hand weeding at 20 days after emergence(DAE),two times hand weeding at 20 and 40DAE, three times hand weeding at 20,40 and 60DAE and application of Dual Gold pre-emergence herbicide at a rate of 1.00kgha^{-1}supplemented by hand weeding at 40DAE were laid out in a randomized complete block design with factorial arrangement in three replications. Dataon weed density and dry weight, crop growth, yield and yield components of faba bean variety Tumsa were subjected to ANOVA using SAS version 9.3software. The results revealed that interaction effect of inter rows spacing and weed management significantly ($P<0.05$) affected weed density and dry matter, leaf area, leaf area index, plant height, number of pods per plant ,number of seeds per pod, thousand seed weight, grain yield and above ground biomass of faba bean. However, days to 50% flowering, days to 90% maturity,height to first pod ,Number of productive tillers per plant were not affected by interaction effect of inter rows spacing and weed management . The highest grain yield (3911.7 kg ha^{-1}) and above ground biomass (10589.7 kg ha^{-1}) was obtained from widest inter rows spacing (60cm) and twice hand weeding at20 and 40DAE. Whereas, the lowest grain yield (1984 kg ha^{-1})was recorded for narrowest inter row spacing(30cm) or 166667plants ha^{-1}and unwedded plot and the lowest above ground biomass (5874.6 kg ha^{-1}) was obtained fromcombined application of 50cm inter row spacing or 200000plants ha^{-1} with unwedded. Grain yield was strongly and positivelycorrelated with plant height, leaf area, crop biomass, Number of productive tillers per plant, number of pod per plant, number of seeds per plant and harvest index,however it was strongly and negatively correlated with weed density and weed dry weight. Partial *budget analysis revealed that combined application of 60cm inter row spacing or 166,667plants ha^{-1} with twice hand weeding at 20 and 40DAE resulted in maximum net return (66,817ETBha^{-1}) with marginal rate of return of 3125%.Thus, 60cm inter row spacing or plant density of 166,667 plants ha^{-1}and twice hand weedingwas found to be better both agronomically andeconomically for faba bean variety Tumsa production under rain-fed conditions in the experimental area.*

Keywords: *Grain yield, Hand weeding, Plant density*

1. INTRODUCTION

Globally, faba bean *(Viciafaba*L.*)* is the fourth food legume in terms of production after garden pea, chickpea and lentil (FAOSTAT, 2014). It also generates household income for the farming community. Ethiopia is the fourth largest exporting country of faba bean next to France, Australia and United Kingdom (FAOSTAT, 2014). The contribution of this crop to the country's economy in 2013/2014 crop season in terms of area coverage and production to the total national crop area under faba bean cultivation and production was about 4.34 % (about 538,458.21 hectares) and 3.94% (about 991,700.28 tone), respectively (CSA, 2014).

In 2014/2015 Crop season, about 3.8millon farmers produce on 0.443 million hectare with estimated average productivity level of 1.9 ton/ha(CSA, 2015).Faba bean ranked first among cool season food legumes based on area production and foreign exchange earnings (CSA, 2016). The average national productivity of faba bean 2.1 t ha^{-1}(CSA, 2017) is low as compared to UK the world top producer3$tonha^{-1}$ (Winch .2006)

Faba bean is grown at altitudes ranging from 1300 to 3800 m.a.s.l, but mostly grown from 2000 to 2500 m.a.s.l (Getachew and Chilot, 2009). The crop is well adapted to diverse soil types of Ethiopia where legumes are prominently used as traditional soil fertility maintenance crops in mixed cropping systems. It has also a great contribution for sustainable soil fertility management due to its ability to fix atmospheric N2 (Beck *et al*.1991).

Fababean is used as an effective break crop in cereal rotations since it substantially improves soil fertility through biological nitrogen fixation. Which contribute to agricultural sustainability (Agegnehu, 2006; FAOSTAT, 2014).Moreover, it produces seeds with high protein content frequently exceeding 20-41% and considered as meat and skim-milk substitute (Creponа*et al., 2010*).

The production and productivity of faba bean is constrained by several biotic and abiotic stresses of which lack ofimproved varieties, Optimum plant density and appropriate weed management, shortage of certified seeds, diseases such as rust, powdery mildew and root rot, insect pests such as aphids and low soil fertility, acidity of the soil in high rainfall areas and low existence of effective indigenous rhizobia are the major ones becoming a major challenge to food security (Degife and Kiya, 2016).

Among these planting density affectsthe growth, development and grain productivity per unit area. Plant density has a remarkable capacity to exploit the environment with varying competitive stresses. High plant density or narrower spacing may cause lodging, less light penetration in the crop canopy and reduced photosynthetic efficiency and can reduce the yield drastically; In contrast, low plant density or wider spacing may result in low yield, more weed infestation and poor radiation-use efficiency (Lemerle*et al.,* 2006). It has been reported that among various package of improved production technologies proper plant population with appropriate adjustment of inter and intra row spacing play key role in enhancing faba bean production (Gezahegnet al., 2016).Optimum plant density differs with variety and at different locations, since different locations have different soil type, soil moisture, soil fertility and relative humidity (Elhag*et al.,* 2014).

The other yield limiting factors include, poor weed management in addition to poor soil fertility, untimely sowing, and lack of improved varieties (Ghizaw and Molla, 1994).Faba bean is a very sensitive crop to competition of both broadleaf and grass weed species (Getachew and Rezene, 2006).The extent to which faba bean yield is reduced by weeds depends on weed species, density and on the period for which the crop is exposed to weeds. Therefore, inadequate and untimely weed control operation is one of the crucial factors causing low yields of the crop (Gezahegn*et al.*2016).

Weeds can cause substantial losses to faba bean production when they are not removed during critical period of competition. The critical period of weed competition varies from 3 to 8 weeks after crop emergence. The numerous weeds affecting these crops are rangingfrom broad leaves to both annual and perennial grasses. Major weeds in faba bean crops are managed with hand weeding or by spraying herbicides. Two times hand weeding during 3-4weeks and 6-8weeks after emergence are very essential for faba bean production (EIAR, 2018).

Against annual and broad-leaved weeds, suitable preemergence herbicides are:Terbutryn (Igram 500 FW) at a rate of 2 kg a.i. ha^{-1} and mixture of Terbutryn + Terbutlazine (Topogard

500 FW) at the rate of 2 kg a.i. ha^{-1},Fluazitop-butyl (Fusilade 250 g/l EC) at 0.25 kg a.i. ha^{-1}which are applied as post-emergence treatment to control late emerging annual grass weeds (EIAR, 2018).A field experiment was carried out in 1974 to determine the critical period in faba bean, the critical period of weed competition occurred from the 3rd to the 5th week after 50% crop emergence and when weeds were not controlled seed yield was reduced by 46% (Glasgow et al., 1976).

In Jimma Zone during 2015/2016 and 2016/2017 cropping season, production of faba bean in terms of area tended to increase from 20,194 to 20,704 hectares and also increased in total production and productivity from 368,542 to 414,417 tons and 1.825 to 2 tons per hectare, respectively (CSA, 2016 and 2017).Despite the potential of the zone, productivity of the crop was below the national average productivity(2.1tons ha^{-1})(CSA,2017) and also below thepotential productivity which is estimated to be more than 5tons per hectares (Crop variety registration year book, 2016).

This indicates that productivity of the crop is still far below its potential due to lack of area specific scientific recommendations for optimum plant density and weed management.As a problem, not having optimum plant population and poor weed management practices are the major yield reducing factors in faba bean production by small scale farmers particularly at Omo Nada district.

Those farmers who engaged in faba bean production havepoor access to information and practicesfor adopting proper plant population with appropriate adjustment of inter and intra row spacing and weed management options to boost productivity. Farmers usually control weeds by cultural methods particularly hand weeding .Farmers' access to herbicide to control weed in legumes including faba bean was not common to thestudyarea.Due to such reasons, hand weeding is the common cultural practice to remove weed from pulse crops including faba bean. A few model farmersare hoeing in addition to hand weeding (hand pulling) to reduce weed pressure in faba bean. On the other hand, most farmersdo not control weed timely until pod setting stage due to competitions for labor resources between agriculturalactivities.

Seed size of faba bean varieties determines the amount of seed needed per hectare. Those which have small seed size are sown at a rate of 150-175 kg/ha while those with large size require 200-250 kg/hectare. As well the germination percentage should be above 85% and genetic purity is 95%. Proper seed depth and soil moisture content results good germination and finally gives high yield. As a faba bean package recommendation respect to spacing between row 40cm, distance between plant 10cm and seed depth 5cm to 7 cm depending on seed size and soil types allows adequate space for mechanical cultivation to control weeds(EIAR, 2018).

Lack of area specific research finding and established practical recommendations on optimum plant population and weed management practicesat small scale farmer's level is a major yield limiting problem.

Therefore, to bridge the gap of area specific recommendation, experiment was conducted at*ChalalakaDonga Kebele*on farmer's field during 2018 main croppingseasons with the following objectives.

- To identifythe effect of inter row spacing and weed management on weed density and weed dry biomass.
- To evaluate the effects of different inter row spacing and weeding regimes on growth, yield and yield components of faba bean.
- To identify the economic optimumcombinations of inter row spacingand weedmanagement on growth, yield and yieldcomponents of faba beanin Omonada District, Jimma Zone.

2. LITERATURE REVIEW

2.1. Faba Bean Origin, Taxonomy and World Distribution

Faba bean is assigned to the Central Asian, Mediterranean, and South American centers of diversity and believe to be a native to North Africa and southwest Asia, and extensively cultivated elsewhere (Zohary and Hopf, 2000).

Cubero (1974) postulated a Near Eastern center of origin, with four radi to Europe along the North African coast to Spain, along the Nile to Ethiopia, and from Mesopotamia to India (Hawtin and Hebblethwait, 1983). Secondary centers of diversity are postulated in Afghanistan and Ethiopia. Nowadays, faba bean is widely grown in temperate and subtropical regions and at higher altitudes in the tropics.

In tropical Africa, it is mainly found in East Africa, especially in Sudan and Ethiopia (Musa and Gemechu, 2006).The main producing countries of faba bean in the world are China, Ethiopia, Egypt and Australia in the decreasing order of their production potential (Hawtin and Hebblethwaite, 1983). According to these researchers production is mainly concentrated in the high altitudes of Ethiopia ranging between 1800-3000 m.a.s.l with annual rainfall ranges from 700 to 1100mm and has suitable environmental and soil conditions for highland pulse crops production. Faba bean is one of the oldest food legumes and has been cultivated since antiquity, mainly for human consumption.

Faba bean is cultivated for human consumption, cattle feeding and it is also used as green manure for the poor soils. The Chinese used them for food since 5,000 years ago, and they were cultivated by the Egyptians 3,000 years ago, by the Hebrews in biblical times, and a little later by the Greeks and Romans (Singh and Bhatt, 2012).

The wild progenitor and the exact origin of faba bean remain unknown. Several wild species (*Vicianarbonensis* L*. and V. galilaeaPlitmann and Zohary*) are taxonomically closely related to the cultivated crop, but they contain 2n = 14 chromosomes, whereas cultivated faba bean has 2n =12 chromosomes (Cubero, 1974). Although usually classified in the same genus *vicia*as the vetches, some botanists treat *vicia*ina separate monotypic genus as Faba sativa Moench(ZoharyandHopf, 2000).

Viciafaba is an annual herb with coarse and upright stems, unbranched 0.3 to 2 m tall, with one or hollowed stems from the base. The leaves are alternate, pinnate and consist of 2 to 6 leaflets each up to 8 cm long and unlike most other members of the Genus; it is without tendrils or with rudimentary tendrils. The plant flowers profusely but only a small proportion of the flowers produce pods. Flowers are large, white with dark purple markings, borne onshort pedicels in clusters of 1-5 on each axillary raceme usually between the 5 and 10nodes;1-4 pods develop from each flower cluster, and growth is indeterminate though determinate mutants are available (Hanelt and Mettin, 1989).

About 30% of the plants in a population are cross-fertilized and the main insect pollinators are bumblebees. There is a robust tap root with profusely branched secondary roots. Based on seed size, two subspecies were recognized, paucijuga and faba. *Viciafaba* has a diploid (2n) chromosome number of 12, meaning that each cell in the plant has 12 chromosomes (6 homologous pairs). Five pairs are acrocentricChromosomesand one pair is metacentric (Hanelt and Mettin, 1989; Alghamdi, 2009).

2.2. Faba Bean Production and Importance in Ethiopia

Faba bean is very cold hardy but cannot take excessive heat during flowering. As faba beans mature, the lower leaves darken and drop, pods turn black and dry progressively up the stem (Heknebyy*et al*.2006; Singh *et al*.2013). This annual legume grows best under cool, moist conditions. Hot dry weather is injurious to the crop, so early planting is important. Faba bean tolerates frost. Rainfall of 650 to 1000 mm per annum evenly distributed is ideal for faba bean (Gasim and Link,2007; Abdel, 2008).

Medium textured soils are ideally suited for faba bean production. It prefers types of soil with pH ranging from neutral to alkaline (pH of 6.5 to 8.0) (Rajan*et al.,* 2012). Since the crop requires a good moisture supply for optimum yields,moderate moisture supply is necessary. Faba beans do not tolerate water logging. Moisture requirement is highest about 9 to 12 weeks after establishment(Subash and Priya, 2012).Fababean is more tolerant to acid soil conditions than most legumes (Singh *et al.,* 2010). It also tolerates nearly any soil type; grows best on rich loams. They are considered to be the least drought resistant of legume crops; however, cultivars with high water use efficiency have been developed at ICARDA (Subash and Priya, 2012).

Faba bean is one of the most popular legumes which is tightly coupled with every life of Ethiopians and grown during the main season on both red and black soils primarily in Oromia,
Amhara, Tigray, and SNNP regional states (IFPRI, 2010). It is grown at 1300–3800 meter above sea leavel; but mostly at 2000–2500 m (Musa and Gemechu, 2006).

Rust is the major production constraint below 1800 m, and frost above 3000 m. Faba bean requires an annual rainfall of 700–1000mm, of which more than 60% during the growing period. Faba bean has four main functions in agro-ecosystems: provision of protein rich food and feed; supplying N to agroecosystems by symbiotic N fixation with Rhizobium bacteria to increase soil fertility;Diversifying the crop system to reduce constraints on growth and yield by the other crops in the rotation; and reducing fossil energy consumption for crop production. Besides, faba bean is grown for green manure and can significantly increase the yields of cereal and other crops (Wani et al., 1994).

Faba bean is an excellent crop for cropping systems because its unique ability to fix atmospheric N symbiotically which is heavy depends on the sufficient populations of effective rhizobia (Jensen et al., 2010). It can accumulate N both from soil and the atmosphere (Rajan and Singh, 2012). Due to their indeterminate growth habit, faba beans continue assimilating N for a longer period, reaching about 315 kg N ha-1 after 110 days (Singh and Bhatt, 2012a). The N concentration in the faba bean crop biomass was around 5% a few days before flowering; during the initial stages (30 days) of reproductive growth; the N concentration decline rapidly to c. 2.5–3%, due to the biomass accumulation rate being faster than the N assimilation rate, and the N concentration remained at this level until maturity

(Knaak et al., 1993). Faba bean accumulates N from N fixation at an increasing rate until initiation of the maturation process unless other factors such as water availability restricts the N fixation process earlier in growth (Anetoun and Prevost, 2005).

Faba bean is a common breakfast food in the Middle East, Mediterranean region, China and Ethiopia. The most popular dishes of faba bean are Medamis(stewed beans), Falafel (deep fried cotyledon paste with some vegetables and spices), Bissara (cotyledon paste poured onto Plates) and Nabet soup (boiled germinated beans) (Hawtin and Hebblethpiait, 1983).

Sometimes faba bean was grown for green manure, but more generally for stock feed (Singh and Bhatt, 2012).Large-seeded cultivars are used as vegetable. Roasted seeds are eaten like peanuts in India. Straw from faba bean harvest fetches a premium in Egypt and Sudan and is considered as a cash crop. The straw can also be used for brick making and as a fuel in parts of
Sudan and Ethiopia (Hulse, 1994). Cultivated faba bean is used as human food in developing countries and as animal feed, mainly for pigs, horses, poultry and pigeons in industrialized countries (Singh and Bhatt, 2012a). It can be used as a vegetable, green or dried, fresh or canned (Gasim and Link, 2007).

2.3. Major Faba Bean Production Constraints in Ethiopia

Production bottlenecks for faba bean in Ethiopia are numerous and can be categorized ascultural, biotic and abiotic factors. Most Ethiopian farmers are of the opinion that pulses do notrequire best land, fertile soil, better seed bed preparation and better weeding practices. Diseases such as chocolate spot (*Hotrytishbae*), black root rot (*Fusariwnsolani*), Rust (*Urotnycesfabae*) and insect pests: African bollworm (*Helicoverpaannigera*) and aphids (*Acyrthosiphonpisum*) and abiotic factors: waterlogging, frost, hail damage, and poor soil fertility are the major faba bean production constraints in Ethiopia (Yohannes, 1997).

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Despite the immense economic and ecologic merits, the productivity of faba bean in Ethiopia is far below the potential due to a number of biotic and abiotic constraints, socioeconomic constraints in smallholder farms and inadequate technological interventions (Basha and Dembi, 2017). Shiferaw*et al*. (2013) also mentioned the productivity of faba bean is far below expected potential due to low input usage, natural disasters like snow storm, depletion of macronutrient from cultivable land and unavailability of essential nutrients such as phosphorus. The productivity of faba bean crop is also constrained by low soil pH associated with low P availability.

Acid soils occur widely in the highlands of Ethiopia where the rainfall intensity is high and the land has been under cultivation for many years. These soils have pH values of less than 5.5, which result in low faba bean yields compared to other faba bean growing areas of the country (Tadele*et al*., 2016).The low yields in such soils could mainly be either due to the deficiency of nutrients, such asP, Ca and Mg (Berry *et al*., 2003; Dodd and Mallarino, 2005), or toxicity of Al,Fe and Mn (Sharma *et al*., 2004). As a result, P deficiency is one of the most widespread soil constraints in these soils. Furthermore, Getachew *et al*. (2005) reported that acid soils could expose faba bean to greater chocolate spot infection thereby reducing yield.

There is a reduction in the cultivated area and productivity of faba bean in many countries. Several adverse biotic and a biotic factors have been reported to this decline of which; failing of practicing optimum population per unit area, weeds and insect pests are the main biotic yield limiting factors in its production (Torres et al., 2006; Pe´rez-de-Luque et al., 2010). Frost is one of a biotic stresses contributing for its low production. For example, in Ethiopian highlands 100% yield losses can be experienced especially with late planting as the plants are exposed to frost damage (Mola, 1996).

Among the biotic factors, the most damaging parasitic weed of faba bean is Orobanchecrenata which germinates in response to chemicals released by faba bean (Joel et al., 2007). It is widespread in Mediterranean basin especially in northern Africa, Asia and southern and eastern Europe, attacking dicotyledonous crops, and losses of 50 to 80% have been reported in faba bean fields (Gressel et al., 2004).

In addition, faba bean is adversely affected by numerous fungal diseases. The major diseases are rust (*Uromycesviciaefabae*), black root rot (*Fusarium spp*.), downy mildew (*Peronosporaviciae)*, ascochyta blight (*AscochytafabaeSpeg*) and chocolate spot (Botrytis fabae) (Hanounik and Robertson, 1989).These diseases resulting up to 90% yield loss in faba bean (Muehlbauerand Tullu, 1997). Chocolate spot (*Botrytis fabae*) is one of the economically important diseases that damage the foliage, limiting photosynthetic activity and reducing faba bean production (Torres et al., 2006).

2.4. Description of the faba bean (*Ficia faba* L).

Faba bean plants are distinctly annual with strong, hollow, erect stems bearing usually one or more basal branches arising from leaf axils. The number of branches per plant in the indeterminate faba bean lines was low during the early vegetative stage and increased, reaching the maximum at flowering stage then declining towards maturity (Silim and Saxena, 1992).

Faba bean is bushy, hardy annual which can grow up to 1.22m tall. It has square stems with leaves divided into leaf lets. Pods are 15.24cm to 20.32cm long and often contains 3 to 6 seeds that can be white, yellow, green, or purple. Fava bean has white flowers with some black or brown spots. In large seeded varieties, 1 or 2 pods grow at each node whereas at small seeded types the number of pods per node can be as high as five. On average there are about 15 pods per stalk on large types and 60 pods on small seeded varieties. When stored under favorable conditions, most faba bean seeds will remain viable for a life expectancy of 3 years.

In optimum growing conditions, germination of faba bean seeds take about 10 to 14 days. Faba bean plants grow at a rate of around 1 node per week. Because stems are strong and upright, the plant can grow from 0.91m to 1.22m, tall depending on the variety. At the 8 to 10 node growth stage, when the plant is around 0.35m high, roughly 25% of the flowers will produce pods which usually contain three to six seeds in each individual pod. Viciafaba shows a high degree of out crossing. Out crossing in faba bean vary widely and is between a minimum of 5% and maximum of 70%. The average reported is about 35% (Bond and Poulsen, 1983).

Faba beans are allogamous, or have a mixed mating system, with both crosspollination and self-pollination, but require insect pollinators to maximize seed set. If low numbers of bees are present, introducing commercial pollinating bees through the crop in a grid of at least 2 hives/ha can increase yield by 30–100%. About 30% of the plants in a population are cross-fertilized and the main insect pollinators are honeybees in Australia. (Patrick and Stoddard, 2010).

2.5. Effects of Plant Population on Growth and Yield of Faba Bean

Several faba bean investigators reported the dense planting resulted in decreases for seeds/pod, seeds/plant, seed weight/plant and seed index (Mokhtar, 2001). While, dense planting had no effect on seeds/pod and on seed index (Zeidan et al., 1990). However, Hassan and Hafiz, 1998 found that seed index was increased in the densest plant population. On the other hand, seed yield was increased by increasing plant density up to 26.7 plant m^{-2} (AbouSalama and Dawood, 1994), up to 31.7plant m^{-2} (Mokhtar, 2001) up to 33plantm^{-2}(Abdel–Aziz and Shalaby, 1999) and up to 44.4 plantm^{-2}(Hassan and Hafiz, 1998). However, Saxena and Stewart (1983) obtained the lowest seed yield from the highest dense planting (33plantm^{-2}). In addition, insignificant yield differences were found between 16.7 and 22.2plant/m2 and between 24 and 67 plant/m^{-2}(Teama, 1994)

Plant density has a remarkable capacity to exploit the environment with varying competitive stresses. High plant density or narrower spacing may cause lodging, less light penetration in the crop canopy, reduced photosynthetic efficiency and can reduce the yield drastically; in contrast, low plant density or wider spacing may result in low yield, more weed infestation and poor radiation-use efficiency (Yucel, 2013). It has been reported that among various package of improved production technology proper plant population with appropriate adjustment of inter and intra row spacing play key role in enhancing faba bean production (Gezahegn et al.,2016).

Optimum plant density differs from each variety and location, since different location has different soil type, soil moisture, soil fertility and relative humidity .Plant density has been recognized as a major factor determining crop yield and is of a particular importance for larger seeded varieties (Matthews et al., 2001). Optimum plant density and suitable plant arrangement per unit area allow crops to exploit resource optimally and produce high yields (Squire, 1993).

However, optimum plant density varies depending on crop species or due to varietal difference in vigor, height and branching, time of sowing, and the nature of the season (Anderson, 2004). The response of crops to plant density tended to be less in the low as compared to the high yielding environments (Matthews et al., 2001). This can also depend on soil type, management practices like seedbed conditions and soil moisture, sowing depth, sowing time, fungicide dressings of seeds, presence of weeds and seasonal rainfall (Matthews et al., 2001).

Since plant density has a direct effect on the cost of seed and final yield, information on this line is highly vital when a new variety is released and growing environments are changed. Optimum plant density of a crop variety at one location may not apply at other locations because of variation in soil type and other environmental conditions; there is a need to develop site-specific recommendations (Gezahegn *et al*.2016).

Shalaby and Mohamed (1978 a) found a significant increase in the number of branches to plant at the distance 25 cmwhen a single crops are planted at 25, 20, 15 and 10 cm between plants. Shalaby and Mohamed (1978b) found there was a significant increase in the total number of seeds when the distance is reduced between plants. The studies on the effect of plant population or plant density on yield and yield components of Faba bean have been carried out by many workers throughout the world. Mekkei (2014) reported that 15 cm between hills significantly produced the highest seed yield, while the 25 cm intra-row spacing gave the lowest.

Comarovschi (1979) from Romania grew the crop at plant densities of 20, 40, 60 and 80 plants per m^2 in row 20, 30, 40, 50, 60 and 70cm apart. The highest grain yield of 2.19 tons/ha was obtained from the 40 plants per m^2 in rows 40 cm apart.

In Tambolo, Itally, Bonari and Macchia (1975) tested the cultivar (minor-portrum) at plant densities of 20, 40, 60, 80 and 100 plants per m^2 in row 25, 50 and 75 cm apart .They found that grain yield increase with increasing plant densities up to 80 plant per m^2 with the best spacing between rows being at 25cm.Day(1979) found no significant difference in grain yield between 18 and 98 plants per meter square working with Faba bean cultivar minor. Keller and Burkhard (1983) in Zurich, Swize-land reported that grain yield of Faba bean increased with increasing plant populations from 10 to 80 plant per m^2, but stalk and seed weight per plant and harvest index were decreased.

Yucel (2013) stated that the highest seed yield of Faba bean was attained between 10 and 12 cm intra-row spacing were found to be optimum under Mediterranean condition. Shalaby and Mohamed (1981) in Egypt found that when Faba bean cultivar (Giza 2) was sown at the spacing of 10, 15 and 25cm between hills, with 1, 2 or 3 plants per hole. The grain yield decreased when spacing was increased and fewer plants per hill were left and he also stated that grain yield decreased with increasing plant population.

In Newzeland, Newton (1983) found that increased plant population from 20 to 65 plant per m^2 reduced the number of pod per node but had little effect on seed number per pod and weight of individual seeds. Bakry*et al.* (2011) and Khalil *et al.* (2010) reported that pod number decreased with increasing plant density. Osman et al. (2010) reported that 15 and 20 cm intra-row spacing gave the highest seed number, however the lowest seed number was obtained by 5cm.

Turk and Tawaha (2002) stated that plant density was negatively related to seed number of Faba bean. Plant population had a significant effect on 100-seed weight. The heaviest seeds were obtained by 15 and 20 cm intra- row spacing (Osman et al., 2010).

Khalil et al., (2011) reported that low plant density produced heavier grains compared with high density. Ageeb (1977a) reported that the variation in row spacing (60, 40 and 20cm), plant spacing (20, 10 and 5cm) and number of plants per hole (1 or 2) had no significant effect on yield of the H72 cultivar grown at Hudeiba Research Station for two consecutive seasons.

Ageeb (1980) found that decreasing the plant spacing from 20 to 10cm and increasing the number of plants per hole from one to two or three, significantly increased the grain yield of Faba bean at Gezira Research Station. Ageeb .,et al (1984), reported that seed yield of Faba bean increased as row spacing was decreased from 60 to 20cm, but the difference between 20 and 40cm spacing was not significant.

Abdalla and Ibrahim (2006) working with Faba bean showed that plant spacing had significant effect on grain yield, number of pods per plant and seed weight. However, plant height was not affected by spacing up to 15cm.

2.6. Losses and Damage Caused by Weeds in Faba Bean

Weeds are a permanent constraint to crop productivity in agriculture and compete for nutrients, space, and light and exert lot of harmful effects by reducing the quality as well as quantity of the crop, if the weed populations are left uncontrolled (Kavalinuskaite and Bobinas, 2006).

Inadequate and untimely weed control operation is one of the crucial factors causing low yields of faba bean. Fessehaie (1994) reported that faba bean suffered significant yield loss of about 24% due to weed competition. The crop is highly sensitive to weed competition from the early establishment to early flowering stage and it requires weed control during this critical period. Weeds play an important role in the proper stand establishment of the growing crop, which ultimately affect the productivity and quality at the end of the growing season.

Some methods to control weeds under low input systems include intercropping and crop rotation, use of competitive crop genotypes, mechanical and hand weeding, use of appropriate sowing date and, often, optimum sowing rates.

Several crops show genotypic differences in their competitive ability mostly related to plant architecture, leaf area, leaf angle, plant stature, seed and seedling vigor. Also different weed species have different competitive abilities with crops .Weeds compete vigorously with legumes for water, nutrients and light due to the low competitive ability of legume crops during the early stages of their growth.

Bahn and Kukula (1987) reported that weeds cause considerable loss in yield of chickpea, although weeding by hand to prevent weed competition during the period before the development of a full canopy cover has invariably bean most effective, but limitations of labor and high labor costs often prevent the adoption of this method. In Sudan result indicated that weed competition reduced seed yield of chickpea 80% (Mohamed et al., 1992). Also studies showed that unrestricted weed growth and delayed weeding accounted for up to 80% loss in lentil grain yield (Mohamed and Nourai, 1994).

According to Fageiry (1987) seed yield of soybean was reduced by 78-100% due to weed infestation and delay in first hand weeding beyond 30 days after sowing adversely affected the soybean yield and three hand-weeding at intervals of 15 days were necessary for adequate weed control and high yield.

Mohamed and Mohamed (1992) reported that unrestricted weed growth reduced grain and straw yield of faba bean by 64% and 70% respectively. When weeds are left uncontrolled they caused serious loss on grain yield of faba bean amounting to 70% (Babiker and Khalid, 1990).

Faba bean is poor competitor to weeds particularly in the seedling stage. This makes integrated weed control essential for successful crop production. The primary tillage should be done several weeks before planting and kill emerged weed with shallow tillagejust ahead of planting consider rotary hoeing the field 7 to 10 days after planting and use spacing cultivator, if holes between 20 or 10cm (Oplinge et al.1989).

Weed growth reduce Faba bean seed yield by 24% (Kavurmaci et al, 2010). He reported that weed had significant effect on Faba bean yield and yield components, he concluded that plots free of weeds gave the tallest plants from which the highest yield was obtained. Ageeb (1977) reported that weed effect on grain yield of Faba bean was not significant. Stagnari and Pisante (2011) stated that with an increased cycle length of weed presence in the farm a decreasing trend in the pod number and bean performance.

Kavurmaci et al., (2010) reported that the increased weed competition had reduced the plant height. The effect of weed elimination on the weight of 100 seeds was highly significant and the highest weight of the 100 seeds was related to the complete weeding and the lowest weight was obtained to the weeding till budding stage. Golipour et al., (2010) investigating weed control in sunflower reported that reduced seed weight was due to the competition with weeds. Van Akar et al.(1993) reported that pod number per plant as one of the most important and most sensitive components of the seed. Ghamari and Ahmadvand (2013) found that the highest seed yield was obtained in the complete weed control and the lowest was gained when weeding prior to budding treatment. The reduction in yield can be related as an unfavorable effect of weeds on the crop via reduction of growth resources which with reduction of yield components lead to final seed reduction.

2.7. The Critical Period of Weed Control in Faba Bean

Crops are most susceptible to weed competition in the first third of their total life span. The "critical period" defines the time up to or after which weeds are tolerated by the crop without apparent losses through competition. The critical period indicates the period in which weeding is really necessary (Braun et al., 1991).

The concept of critical period was introduced by Nieto et al. (1968). It has been used to determine the period when control operations should be carried out to minimize yield losses for many crops. For most crops it is not necessary to control weeds in the first few weeks after crop and weed emergence (Zimdahl, 1988).

A field experiment was carried out in 1974 to determine the critical period in faba bean, the critical period of weed competition occurred from the 3rd to the 5th week after 50% crop emergence and when weeds were not controlled seed yield was reduced by 46% (Glasgow et al., 1976).

Weeds can cause substantial losses to faba bean production when they are not removed during critical period of competition. The critical period of weed competition varies from 3 to 8 weeks after crop emergence. In general, faba bean is more sensitive than field pea to weed competition. The numerous weeds affecting these crops are from broad leaves and both annual and perennial grasses. Major weeds in faba bean crops are managed with hand weeding or by spraying herbicides. Two times hand weeding is very essential for faba bean one 3-4 weeks after emergence and the second 6-8 weeks after emergence.(EIAR, 2018)

2.8. Integrated weed management in Faba bean

Low-input, sustainable agriculture addresses multiple objectives from increasing profits to maintaining the environment, and builds on multiple systems as integrated pest management (IPM), integrated weed management (IWM), and crop rotation. Integrated weed management involves the combination of a number of weed control practices that reduces the dependence on any one type of control method and also lowers the input of herbicides. This approach is important for the control of perennial weeds that are inadequately controlled by any single method (Bridgemohan et al, 1991).

The application of IWM also includes the knowledge of past annual and perennial weed populations in fields and weed seed bank (Bridgemohan and Brathwaite ,1988) competitive crop cultivars, improved crop and soil management practices, and appropriate selection of herbicides (Schweizer, 1988).

Integrated weed management in legumes has been increasing interest in sustainable weed management in low-input farming system. Physical, cultural and agronomic weed control are usually less effective compared with chemical control ,but from an integrated point of view the application of several management practices may represent a practicable way to reduce herbicides rates (Anderson, 2007). In order to control weeds, cultural strategies can largely be put into practice by choosing competitive species and manipulating plant density and plant spacing.

On grain legumes, studies have mostly focused on plant density as an important factor affecting weed competition, and consequently grain yield while less information is available on plant lodging. Spatial arrangement in grain legumes may reduce weed emergence and increase crop competitive ability; indeed, narrow rows generally increase plant height, which is positively correlated with a powerful weed suppression capability (Mohler, 1996). These effects cannot be generalized, since they are dependent up on crop species and location .Plant competition in grain legumes suggests that the ability of crops to suppress weeds at high crop density is often inversely correlated with grain productivity (Benvenuti and Macchia,2000), because of intra-crop competition.

Herbicide use continues to be one of the most important tools in weed management. However, an IWM approach creates an opportunity to reduce herbicide rates and in some instances, just forgo the use of herbicides altogether. Given the high cost of herbicides in the tropics, smallholders sometimes either reduce the herbicide rate or mix with other herbicides with differing modes of action. These practices are not without risk. Oftentimes, smallholders realize that these practices are inconsequential and there is no recourse with pesticide retail outlets regarding poor herbicide performance if label rates have not been followed. Yet, farmers often cut rates as a cost saving strategy.

The effectiveness of a reduced rate usually depends on the type of herbicide, weed species present, weed pressure, environmental conditions and, of course, the competitiveness of the crop stand. If the weed pressure is high or the weeds are under stress, it is probably advisable to use an integrated approach. However, reduced rates of herbicide may lead to some level of herbicide resistance and thus the approach to be taken must be carefully considered.

The extent of herbicide use in the tropics is closely related to the cost and availability of lab ours. Large scale rice and banana production in the tropics receive more than two herbicide applications. However, in the smaller farms, only about 50% of the rice area is treated, particularly where rural available. Herbicides replace hand weeding and enable direct seeding which is less labor demanding, compared to transplanting. Herbicides are also used in the transplanted systems, though to a much lesser extent, and in systems particularly where crop rotation is practiced. There is a need to reduce herbicide input in crop production which can complement cultural practices. With proper timing and selected application methods, good control may be achieved with one-fourth to one-half rates of application (Bridgemohan and Brathwaite ,1988)

Integrated weed management (IWM) systems approaches in the tropics includes any or a combination of the following practices that give a crop a comparative advantage in competing with weeds. (Mashingaidze and Chivinge, 1995). These includes:

Prevention strategies include field sanitation and harvesting methods that do not spread weed seeds and vegetative prop gules at every step of production (such as seed selection, field preparation, planting, fertilization, irrigation, weed control, harvest and transport).

Competitive crops differ in their competitiveness with weeds based on their emergence, leaf-area expansion, light interception, canopy architecture, leaf-angle, shape and competitiveness. Within a crop species, cultivars may vary in their competitiveness. While the improved varieties may be high yielding, the traditional varieties exhibit multiple adaptations, competitive ability against weeds and require less agricultural input. The use of competitive crops to discourage weeds is an important IWM strategy.

Optimum plant population likeRow spacing and seeding rate may influence the ability of the crop to compete with weeds for resources and, therefore, may affect weed management (Donovan et al 2001).

Cover crops have long been used extensively in the tropics for soil and water conservation, to maintain soil structure and enhance soil fertility, especially on steep or difficult terrain. They are often referred to as living mulches. The use of leguminous cover plants to suppress weeds in plantation crops in the tropical world dates back many decades, but the integration of the legumes into arable cropping systems has not been developed to a level acceptable to farmers. Cover crops also contribute to pest management and help to suppress unwanted weeds. Its use has been mainly in plantation crops. The introduction of inexpensive nitrogen fertilizers and herbicides encouraged many farmers to discontinue this practice. Cover crops can be intercropped or interplanted with a crop of economic significance. They work by excluding light and limiting weed emergence. Examples of cover crops in the tropics include: *Desmodiumheterocarpon*varovalifolium .

All crop husbandry practices, particularly precision placement and timing of fertilizer application, enhance maximum stimulation of the crop and minimum stimulation of the weed population. Additionally, the use of clean certified seeds, clean farm implements, effective seedbed preparation and seeding methods that improve crop growth, all reduce weed competition (Bridgemohanand Brathwaite, 1988)

Irrigation practices such as the use of clean water, channels and canals, can reduce the spread of weed seeds to uninfected fields.

Inter-row cultivation and minimum tillage refers to inter-row cultivation is practical in widely spaced row crops, such as maize, vegetables, sugarcane and banana.

Intercropping or relay cropping systems are based on the principle that space should be occupied by crops and not weeds. Relay cropping can be practiced by market gardeners who harvest their crops by hand. These crops should be planted in such a way that the intercrop provides an effective canopy to shade weeds, or that previous crop residue can be used as a mulch to prevent weed growth in succession crops, e.g., pigeon pea (Cajanuscajan) interplanted with maize (Zea mays).

The use of biological agents such as mycoherbicides, insects and pathogens to control weeds in the tropics is not common. However, the potential for its application to control noxious weeds using monophagous/ oligophagous natural enemies must not be overlooked (Labrada,R,2005)

A mix of adoption strategies has been used over the years in an effort to get the right approach to IWM. No silver bullet has been found. It is a work in progress. Given the diverse weed flora, farming experiences and farmer circumstances in the tropical world, scientists, educators and farmers will have to dedicate increased energies towards finding an approach that is economical, culturally acceptable and environment friendly.

2.9. The Use of Herbicides in Faba Bean

The major problem facing the production of faba bean in Northern Sudan is weeds, because of the low competitive ability of faba bean during the early stages of its growth (Mohamed, 1995).Weed control in faba bean in northern Sudan involve late hand weeding to collect fodder for animals, this late removal of weeds does not mitigate the adverse effect of weeds on yield. However, early hand weeding is difficult and expensive, as labor is becoming scarce. Herbicides are, therefore, of great potential importance to eliminate the early competition in faba bean (Mohamed, 1995).

According to Zahran (1983) post-sowing weedicide at 2.5 and 3.0 kg/ha and it was found as effective as hoeing twice and weed free treatments, both from the view point of its effect against weeds and its effect on crop yield. In Sudan removal of weeds was done with pre-emergence herbicides. Trial was carried out at Hudeiba to access the effect of PPOO-9 as post-emergence herbicide on annual grass weeds and its selectivity to faba bean. The herbicide was applied as aqueous spray 5 weeks after planting at 5 rates.

The overall weed control by PPOO-9 was moderate; this was attributed to the domination of broadleaf weeds and Cyperusrotundus which were not controlled by such chemicals. Growth inhibition or phytotoxic symptoms was not observed. The grain yields for treatments were not significantly different.

The application of 1.19 kg a.i. ha^{-1} PPOO 9 brought 40% increase in yield over the weedy check (Badawi, 1983). Unrestricted weed growth in this crop significantly reduced plant stand, plant height and reduced number of pods/plant while there was no effect on seeds/pod or 100 seeds weight.

Mohamed et al., (1998) reported that herbicides goal at (0.2, 0.4, 0.6) L/ha, Ronstar at (0.5, 1, 2.0) L/ha and stomp at (1.5, 2.0, 3.0) L/ha were used to evaluate their efficacy of weed control and to see the tolerance of faba bean. Results showed that the three herbicides at their high rates used gave seed yield which was comparable to the hand weeding control and gave excellent and persistent control of annual grasses but they were less effective on annual broad leaved weeds. Field trials with faba bean showed that application of 2- 4-DB (15 ppm) one month after sowing either alone or in combination with $Fe^{+++}Mn^{++}$ at 1500 ppm increased the yield by greaterthan 20% and pod number by 30% over and above the control.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted on farmer's field in Jimma zone, Omo Nada District, Chalalaka Donga kebel. The site is located at $7^0$35' 17.1" N latitude and $37^0$17' 48.5" E longitude and at an altitude of 2394 meters above sea level.It is situated in the tepid to cool humid-mid highlands of southwestern Ethiopia. ThesoilisclayintextureandmoderatelyacidicwithpHof5.48.Theorganicmatter contentofthesoilwas1.83%andwithmoderate totalnitrogen(0.113%)andavailableP(8.74mgkg^{-1}).Therainfallintheareais characterizedbybimodaldistributionpatternandthemainrainyseason(Meher)isbetweenJuneande ndofSeptemberand the small rain(Belg)isfromlateFebruarytolateMarch/earlyApril.The amount of annual rainfall during the crop season was 1276mm with a maximum and minimum temperature of 26 and 10.60_c, respectively (Appendix 2). The experiment was conducted during 2018 main cropping season under rain fed conditionfrom June to November**.**

3.2.Soil sampling and analysis

Composite soil samples were collected from the experimental plots in a diagonal pattern from the depth of 0-20 cm before planting. Uniform slices and volumes of soil were obtained in each sub sample by the vertical insertion of an auger after which the sub-samples were made in to a composite sample. Then, the composite soil sample was dried, ground using a pestle and a mortar and allowed to pass through a 2-mm sieve and analyzed for the selected soil physicochemical properties mainly organic carbon, total nitrogen, soil pH, available phosphorus, cation exchange capacity, and textural analysis using standard laboratory procedures. Soil sample was analyzed following standard laboratory procedures as outlined by (Sahlemedhin and Taye, 2000).The soil analysis was carried out at Jimma Agricultural Research Center Soil and Plant Tissue Analysis Laboratory.

The textural composition of the experimental soil is 27.8% sand, 27.6% silt and 44.6% clay re (Table 1) andcategorized under a textural class of clay .Soil texture is an important soil physical characteristic as it determines water intake rate (infiltration), water holding capacity in the soil, the ease of tilling, the amount of aeration and also influence soil fertility (Gupta, 2000).It has also been reported that, for best production of the crop, faba bean should be grown on well-structured loam or clay soils with pH of 6.5 to 9.0 (Jensen *et al.,* 2010).

The soil reaction of the experimental site (pH = 5.48) was moderately acidic (Table 1) as per the ratings of Tekalign (1991).Soil pH is an important factor for plant growth, as it affects nutrient availability, nutrient toxicity, and has a direct effect on the protoplasm of plant root cells (Alam et al., 1999).

The organic carbon content of the soils was 1.83% (Table 1) which is rated as moderate (Tekalign, 1991). The lower organic matter (OM) content in cultivated land soil is attributed to anthropogenic factors like reduced crop residues or biomasses return to the soil as a result of removal of plant and animal organic sources and livestock grazing.

The total nitrogen of the experimental soil was 0.133% which is in ranges of moderate (Table 1) as per Tekalign (1991) rating. The available P of the experimental soil was 8.74ppm (Table 1) which is moderate as per the rating of Bray and Kurz (1945). According to Tisdale et al.(2002) plants' demand to available P vary where low demanding crops require concentration of P > 8ppm, moderate-demanding crops > 14ppm and high demanding crops > 21ppm.Acidic soils are naturally deficient in available P and significant portions of applied P are immobilized due to precipitation of P as insoluble Al phosphates. However, the soil acidity correcting agents such as the use of liming materials could reverse this situation and increase soil P to adequate levels. The high reactivity of P with iron, aluminum and calcium, to form insoluble compounds, reduces its mobility in the soil solution (Boudanga et al., 2015).

The cation exchange capacity of the experimental soil was moderate 21.55cmol $^{(+)}$ kg^{-1} (Table 1) according to London (1991) rating. Organic matter particularly plays important role in exchange process because it provides more negatively charged surfaces than clay particles do (Johnson, 2002).

Table 1 Soil physico-chemical properties of the experimental site before planting at Omo Nada in 2018

Soil Parameters	Value	Rating	Reference
P^H (1: 2.5 H_2O)	5.48	Moderately acid	Tekalign (1991)
Av. P (ppm/kg soil)	8.74	Medium	Bray and Kurtz (1945)
CEC (cmol(+) kg^{-1})soil	21.55	Medium	Landon (1991)
Organic Carbon (%)	1.83	Medium/moderate	Tekalign (1991)
Total Nitrogen (%)	0.133	Medium/moderate	Tekalign(1991)and BerhanuDebele (1980)
Sand (%)	27.8		FAO(1990)
Silt (%)	27.6		
Clay (%)	44.6		
Textural Class	Clay		

Where pH= hydrogen power, OC=organic carbon, TN=Total Nitrogen, Av.P=Available phosphorous and CEC=Cation exchange capacity.

3.3. Treatments and Experimental Design

The experiment wasconducted with four levels of inter rows spacing (30cm, 40cm, 50cm and 60cm) and five levels of weeding practices (Unwedded. once hand weeding 20 days after emergency(DAE), twice hand weeding at 20 and 40 DAE, three times hand weeding at 20, 40, 60DAE and Pre-emergence herbicide (Dual Golden 960 EC) application at the recommended rate (1.0kg ha^{-1})which was supplemented with one time hand weeding at 40DAE. The spacing between plants or within rows was the same, i.e.10cm for all the experimental units (Table 2).

Faba bean genotype named Tumsa was used for the study. It was released by Holeta Agricultural Research Centre in 2010. It performs well in agro-ecology of 1800-3000 m.a.s.l with rainfall of 700-1000 mm and well adopted by farmers.Faba bean variety *Tumsa*can produce 2.5-5.0 and 2.1-3.5 t ha^{-1} grain yields under on-station and on-farm conditions, respectively. It was characterized by indeterminate growth habit with 120-130 days to maturity andmoderately resistant to chocolate spot. Thetreatment combinations were arranged in Randomized Complete Block Design (RCBD) in 4 x 5 factorial arrangement with three replications (Table 2).

The gross plot size and net harvest area were 2.5m width x 6 m length (15 m^2) and 1.8m x2.5m (4.5m^2), respectively.Therewere20,15,12 and 10rowsperplotunder30, 40, 50and60 cminter rowspacings,respectively.The harvested number of rows or row length in meter (in parenthesis) were6 of 20 rows (15m), 4.5 of 15rows (11.25m),3.6 of 12 rows (9m)and 3 of 10 rows (7.5m)for inter row spacings of 30,40, 50and60cm ,respectively.

Table 2. Details of treatments Combinations of inter row spacings and weed management

Treatments No.	Inter Row spacing levels*weedmanagement	Treatment description
1	S_0W_o	30cm inter row spacing and un weeded plot
2	S_0W_1	30cm inter row spacing and one time weeding at 20 DAE
3	S_0W_2	30cm inter row spacing and twice hand weeding at 20 and 40 DAE

4	S_0W_3	30cm inter row spacing and three times hand weeding at 20,40 and 60 DAE
5	S_0W_4	30cm inter row spacing and S-metolachlor 1.0 kg ha^{-1}or Dual Golden 960EC pre-emergence herbicide supplemented by one hand weeding at 40DAE
6	S_1W_0	40cm inter row spacing and un weeded plot
7	S_1W_1	40cm inter row spacing and one time weeding at 20 DAE
8	S_1W_2	40cm inter row spacing and twice hand weeding at 20 and 40 DAE (control)
9	S_1W_3	40cm inter row spacing and three times hand weeding at 20,40 and 60 DAE
10	S_1W_4	40cm inter row spacing and S-metolachlor 1.0 kg ha^{-1}or Dual Golden960EC pre-emergence herbicide supplemented by one hand weeding at 40DAE
11	S_2W_o	50cm inter row spacing and un weeded plot
12	S_2W_1	50cm inter row spacing and one time weeding at 20 DAE
13	S_2W_2	50cm inter row spacing and twice hand weeding at 20 and 40 DAE
14	S_2W_3	50cm inter row spacing and three times hand weeding at 20,40 and 60 DAE
15	S_2W_4	50cm inter row spacing and S-metolachlor 1.0 kg ha^{-1}or Dual Golden 960EC pre-emergence herbicide supplemented by one hand weeding at 40DAE
16	S_3W_o	60cm inter row spacing and un weeded plot
17	S_3W_1	60cm inter row spacing and one time weeding at 20 DAE
18	S_3W_2	60cm inter row spacing and twice hand weeding at 20 and 40 DAE
19	S_3W_3	60cm inter row spacing and three times hand weeding at 20,40 and 60 DAE
20	S_3W_4	60cm inter row spacing and S-metolachlor 1.0 kg ha^{-1}or Dual Golden 960EC pre-emergence herbicide supplemented by one hand weeding at 40DAE

Where;S0=30cm,S1=40cm,S2=50cm,S3=60cm and W0:Non Weeding; W1;Hand weeding using hoe onetime at 20DAE; W2;Hand weeding using hoe two times at 20DAE and 40 DAE; W3; Hand weeding using hoe three times at 20, 40 and 60 DAE;W4:Dual Gold herbicide supplemented by hand weeding at 40DAE;DAE=Days after emergency

3.4.Experimental Procedures and Crop Management

The field was well prepared by plowing three times. Faba bean was hand planted on the 14 July 2018 on a plot size of 6mx2.50m (15m^2). Two seeds were placed per hill to ensure the desired stand in each treatment and thinning was practiced after 10 DAE to one plant/hill as of the intended treatments. The planting space was varied between rows at 30cm, 40cm,50cm and 60cm distance but the same 10cm was used within rows ,i.e.30cm*10cm (333,333), 40*10cm (250,000), 50cm*10cm (200,000) and 60cm*10 cm (166,667plants ha^{-1}).In accordance with specifications of the design, each treatment was assigned randomly to the experimental units within a block.

Blended NPS fertilizer (19N–38P2O5-0K-7S grade) was applied at a rate of 100kgha^{-1} in the rows at the time of planting. Pre-emergence herbicideDual Gold 960 EC (trade name), S-metolachlor (Common name), and [2-chloro-6-ethyl N-(2-methoxy-1-methylethyl) acet-o-toluidide (chemical name) was applied to the respective experimental unit before planting as per the recommendation, i.e.1.0 kg ha^{-1}.

Hand weeding practices were doneusing hoe as specifiedfor eachexperimental unit except for the non-weeded plot. Harvesting and threshing were done by hand. All the necessary agronomic practices and crop management activities were undertaken as recommended for faba bean.

3.5. Data Collection

3.5.1. Weed Parameters

Important weeds of the crop were assessed and recorded. The data on Weed species was collected from each unit plot three times at 20, 40 and 60 DAE. A square quadrate of 0.5m x0.5m was placed at three different spots per plot .The infesting species of weeds within the quadrate was identifiedby using colored picture manuals and with the aid of flora books (Stroud and

Parker, 1989; Melaku,2008;Naidu, 2012) and plant net application system.

The population of broadleaved, grass and sedges in a plot size of 0.5m x 0.5m was counted.Summation of individual plants of each weed species in quadrats divided by the number of quadrats multiplied to area of quadratwas used for weed density m^{-2} calculation per experimental unit.The above groundharvestedweedswere tagged andplacedintobagsseparatelyandairdriedbeforedryinginovenata65^{0}Ctemperaturetillconstantweightobtained which means subsequentlythedryweightwasmeasured.Weed data on the following parameters were collected.

3.5.1.1. Weed species

The infesting weed species within the quadrate was identified by using colored picture manuals and with the aid of flora books (Stroud and Parker, 1989; Melaku, 2008;Naidu, 2012) and plant net application system. The category wise (broadleaved, grass and sedges) population count was taken from plot size of 0.5m x 0.5m.

3.5.1.2. Weed drybiomass

While recording weed density, theharvested above ground weed from each quadratewas placed into p bags separately and air dried for 3-4 days. After air dried for 3-4days, the harvested weed were placed in oven at 65°C for 24 hours till constant weight obtained. Subsequently, the dry weight wasmeasured and thenconverted in to g m^{-2}

3.5.1.3. Relative weed density

The relative weed density of each species was calculated using the following formula (Fadayomi and Takim.2009)

$$\text{RWD} = \frac{NIW}{NTW} x100$$

Where: RWD- Relative weed density, NIW- Number of plants of individual weed species in quad rat, NTW- Number of plants of all weed species in quadrat.

3.5.2. Crop data

3.5.2.1. Phenological parameters

3.5.2.1.1. Days to flowering (DF)

Days to flower was determined by counting the number of days from the date of sowing to the period when 50% of the plants produce flower.

3.5.2.1.2. Days to Physiological maturity (DM)

Days to Physiological maturitywas recorded as the number of days from sowing to the time when about 90% of the plants have mature pods in their upper parts with pods in the lower parts of the plants turning dark.

3.5.2.2. Growth parameters

3.5.2.2.1.Leaf area (LA)

Leaf area was calculated by leaf area estimation model as described by Peksen(2007) and three leaves per plant were measured and the mean values was multiplied by the total number of leaves per plant and averaged over ten selected plants at pod initiation.

LA = 0.919 + 0.682LW

WhereLA (cm^2) =leaf area L= leaf length(cm) and W = leaf width (cm)

3.5.2.2.2. Leaf area index (LAI)

Leaf area index at pod initiation wascomputed. It is a measure of leafiness per unit ground area and denotes the extent of photosynthesis (Peksen.2007).It was calculated by the formula

$$\text{LAI} = \frac{(Leaf\ Area * Number\ of\ leaf\ perplant)}{area\ covered\ by\ plant}$$

3.5.2.2.3.Plant height (PH)

Plant height was the average height (measured from base to top bud) and the average value of ten randomly selected plants fromeach plot was taken at physiological maturity.

3.5.2.2.4. First pod setting height (FPH)

First pod setting height was measured by taking average height from base to the first productive pod of ten randomly selected plants for each plot at physiological maturity.

3.5.3. Yield and Yield Components

3.5.3.1. Number of productive tillers per plant(NPTPP)

Number of productive tillers was determined at maturity by counting all tillers /branches producing/setting pods of ten randomly selected plants from each plot and the values was averaged per plant.

3.5.3.2. Number of pods per plant (NPPP)

Number of pods per plant was the average numbers of pods counted from samples of ten randomly selected plants from each plot.

3.5.3.3. Number of seeds per pod (NSPP)

Itwas the total number of seeds per plant divided by the total number of pods on the same plant and averaged over ten plants randomly selected from central rows of each plot.

3.5.3.4. Dry biomass (BM)

All above ground plant part per net harvest area in each plot was harvested at maturity, threshed and measured after well sun dried for uniform weight and converted into kg per hectare.

3.5.3.5. Harvest index (HI)

Manfred (1993) and Rkmhay (1995) defined harvest index as the ratio of grain yield to above ground biomass of net plot. Hence, it was calculated as

$$\mathrm{HI}(\%) = \frac{YD}{BM} * 100$$

Where HI=harvest Index, YD=Grain Yield and BM=above ground biomass

3.5.3.6. Grain yield (YD)

The weight of seeds obtained fromnet harvested area of each plot was measuredusing electronical sensitive balance after adjusting to 11.5% moisture content and computed for its mean values, then converted to yield in kg per hectare.

3.5.3.7. Thousand Seed weight (TSW)

Thousand seeds wererandomly taken from bulk of threshed seedsin each plot and after adjusting to 11.5% moisture content, their weight was measured for mean values per plot.

3.6. Partial Budget Analysis

To investigate the economic feasibility of the treatments partial budget analysis was conducted. The average yield was adjusted downwards by 10% to reflect the difference between the experimental yield and the expected yield of farmers from the same treatment. This is done because experimental yields, even from on-farm experiments under representative conditions, are often higher than the yields that farmers could expect using the same treatments (CIMMYT, 1988).

The amount of seed required was varied with inter row spacing and also the number of labours required was varied with weeding regime and so do herbicide used. However, other input costs like fertilizer used considered to be constant for all treatments.

A dominance analysis was carried out by first listing the treatments in order of increasing costs that vary. Any treatment with net benefits less than or equal to those of treatments with lower costs is dominated and not used for further MRR analyses.

The process of calculating the marginal rates of return (MRR) of alternative treatments, proceeding in steps from the least costly, and deciding if they are acceptable to farmers, is called marginal analysis. According to CIMMYT (1988), the tentative recommendations was computed based on the comparisons of the rates of return between treatments and the minimum rate of return acceptable to farmers i.e. 100%. Consequently, any treatment with MRR of greater than 100% is considered as a profitable treatment and recommended to be used by farmers. Economic analysis was done using the prevailing market prices for inputs at planting and for outputs at the time of harvest. All costs and benefits were calculatedin Ethiopia Birr (ETB) per hectare.

Partial budget analysis was conducted based on the following concepts: These includes mean grain yield is the average yield (kg ha^{-1}) of each treatment.The field price of faba bean grain is its point of sale at retail price minus the costs of harvesting, bagging and transporting .The gross field benefit (GFB) ha^{-1} is the product of field price of faba bean grain and the mean yield for each treatment. The field price of seed kg^{-1} is the seed retail cost kg^{-1} plus the cost of transport from the point of sale to the farm .The field cost ha^{-1} seed is the product of the quantity required by each treatment per hectare and the field price of seed. The field cost of Dual Gold 960 EC herbicide is the chemical retail cost $Liter^{-1}$ plus the cost of transport from the point of sale to the farm.The cost of Labor for weeding is the product of man-days used in weeding and wage rate. The total variable costs (TVC) is the sum of field cost of seed and Laborfor weeding and herbicide cost. The net benefit (NB) ha^{-1} for each treatment is the difference between the GFB and the TVC.

Therefore, to select potentially profitable treatments from the range was tested. A percentage of marginal rate of return (MRR) was calculated.

MRR (*between* treatments, a andb) $= \frac{\textbf{change in NB} \ (NBb - NBa)}{\textbf{change in TCV} \ (TVCb - TVCa)} \boldsymbol{x100}$

Where,NBb=net benefit from treatment b;

NBa=Net benefit from treatment a

TVCb=Total variable cost of treatment b;

TVCa= Total variable cost of treatment a

3.7. Data Analysis

The data were subjected to Analysis of variance (ANOVA) using SAS software version 9.3. Least significant difference (LSD) at 5% level of significance was used to separate treatment means.Weed density data was transformed by using a square root transformation to harmonize the data set.Correlationanalysis were performed to determine the association among variables.

The analytical Model for the experiment was:

$$Yijk = \mu + \alpha i + \beta j + rk + (\alpha\beta)ij + eijk$$

Where:

- μ = the overall mean effects

- α_i = the effect of i^{th}level of inter row spacing level i=1-4
- β_j= the effect of j^{th} level of weeding level j=1-5
- r_k=the effect of k^{th} replication
- $(\alpha\beta)_{ij}$=the interaction effect of inter row spacing and weeding level
- e_{ijk}=the random error compared for the whole factor
- k=number of replications

4.RESULTS AND DISCUSSIONS

4.1. Effects of Inter Row Spacing and Weed Management on Weed Parameters

4.1.1 Weed Species composition

Nine families and fifteen weed species comprising eleven broadleaved, three grasses and one sedge were identified in weedy plots at 60DAE.Thespecies identified includes:*Galinsoga parviflora Cav.Polygonumnepalense*,*Guizotiascabra (Vis.) Chiov*,*Bidenspachyloma*,*Bidenspilosa*,*Medicagopolymorpha*, *Galiumaparine*,*Amaranthusspinosus*, *Rumexcrispus*, *Datura stamonium*, *Portulacaoleracea*

L, Setariaviridis(L) *Beauv, Cynodonnlemfuensis,Snowdenia polystachya andCyperusrotundus* L.Among these species*Galinsoga parvifloraCav*.wasobserved with the highest relative weed density followed *Polygonumnepalense*.*Cyperusrotundus* L was lowest in relative weed density. Weed infestation relative density by Broad leaves, Grass and sedge were 73.63%, 21.70% and 4.67% respectively(Table 3).

Theresult wasin agreement with the findings of Rezene*et al.* (1992) and Kasa*et al.* (2002) who reported that among the annual weeds*Cyperusrotundusof the family Cyperaceaeare is* disastrous and*Galinsoga parvifloraCav*,*Guizotiascabra*,and other broadleaf and grass weeds are important in southwestern parts ofthe country.

The possible reason for more weed species occurrence in the field could be relatedto high weed seed in soil bank and favorable environmental factors such as soil type,altitude, and previous crop grown in the site and more rainfall at early stage of the crop growth. In line with this result, Tamado and Milberg (2000) reported that altitude, rainfall, month of planting, number of weeding and soil type were the major environmental and cropmanagement factors that influenced the number of weed species.

Table 3Weeds species composition and mean relative density of non-weeded plots in 2018.

Botanical name	Family	Relative density (%)
Broad leaf		73.63
Galinsoga parviflora Cav	Astraceae	11.45
Polygonumnepalense	Polygonaceae	10.38
Guizotiascabra (Vis.) Chiov	Asteraceae	10.17
Bidens pachyloma	Astraceae	10.10
Medicagopolymorpha	Fabaceae	8.89
Galiumaparine	Rubiaceae	5.78
Rumexcrispus	Polygonaceae	4.04
Bidenspilosa	Asteraceae	3.77
Amaranthusspinosus	Amaranthecea	3.36
*Datura stamonium*L	Solanaceae	3.32

*Portulacaoleracea*L	Portulacaceae	2.37
Grass		21.70
Snowdonia polystachya	Poaceae	10.20
Cynodonnlemfuensis	Poaceae	5.42
Setariaviridis(L)*Beauv*	Poaceae	6.08
Sedge		4.67
Cyperusrotundus L	Cyperaceae	4.67
		100.00

4.1.2. Weed density and dry weight

4.1.2.1 .Weed density

Weed density was significantly (P<0.05) influenced by interaction effects of inter row spacing and weeding treatment(Appendix Table 1).At any growth stage of the crop, weed density was highest with widest inter row spacing (60cm) and non-weeding . Significantly (P<0.05)the highest mean total weed densities was obtainedfor60 cm inter row spacing with unwedded plots at 20,40 and 60DAE with mean values of 57.53,52.65,and55.46weed m^{-2}, respectively.Whereas, the lowest (0.5weed m^{-2})weed density at 60DAE was observed for combination of three times hand weeding and 60cm inter rows spacing which wasstatistically at par with combination of all inter rows pacing and three times hand weeding (Table 4).

The higher weed densities were observed for the combination of 40cm inter row spacing and unwedded plotsat 20, 40 and 60DAE with mean values of 58.57, 58.573 and 48.94 weed m^{-2} and those values were statistically at par with 50 and 60cm inter row spacing with unwedded combination.

For the first 20DAE, all inter row spacings with herbicide treatments before emergence supplemented with hand weeding at 40DAEgave the lowest weed density (0.5m^{-2}) but the highest weed density at the same day observed for widest or 60cm inter row spacing plus with unwedded plot.Hence, as weeding levels increase from unwedded to one time, twice and thrice hand weeding, weed density decrease as compared to the mean weed density values of the unwedded treatments with the same spacing over time.

The reason for highest weed density for the combination of widest inter-row spacing (60cm) and unwedded conditions could be lack of weed interruptions which might have provided adequate and more space for weeds to occupy than did the other narrower inter row spacing. Less number of weed density (0.5m^{-2}) were found from all inter row plant spacing combined with three times hand weeding at 60DAE.

Furthermore, interaction of narrowest inter row (30cm) plant spacing combinedwith unwedded gave the lowest weeddensities as compared to the wider (50 and 60cm) inter row spacings with unwedded treatments. This could be attributed to competitive advantage of the crop; as the later emerging weeds were more suppressed by taller crop plants under closer spacing, thereby, resulting in reduced total weed density.

In line with this,Holmes and Sprague (2013) reported weed suppression was maximized in narrower (38 cm) than wider (76 cm) row spacing in common bean. In agreement with the current finding, Yohannes (1997) has also reported that faba bean required at least two early weeding (20 and 40 days after emergence) for efficient weed management, which led to significantly higher crop yields. The uninterrupted growth of weeds might have offered severe competition to the crop, thereby, interfering in the utilization of various growth factors.

Table 4 Interaction effects of inter row spacing and weed management on weed density and dry weight during 2018 main cropping at Omonada

Treatments	weed density m^{-2}			weed dry matter (gm^{-2})		
	20DAE	40DAE	60DAE	20DAE	40DAE	60DAE
S0W0	47.28bc	41.98b	35.44d	19.527c	37.66c	52.34c
S0W1	40.12de	23.02cd	14.57f	15.8d	16.63de	19.42d
S0W2	32.17fg	21.24cde	7.46h	14.567	10.703f	2.48g
S0W3	8.50h	0.5f	0.5i	3.473g	0.33g	0.23g

S0W4	0.5i	15.91de	14.57f	0.23i	11.35def	14.58ef
S1W0	58.57a	58.57a	48.94b	24.267b	53.07b	60.97b
S1W1	0.5i	19.46cde	14.57f	18.85a	15.44def	18.83de
S1W2	28.50g	12.94e	10.42gh	12.163e	11ef	4.523g
S1W3	5.81h	0.5f	0.5i	1.123i	0.33g	0.23g
S1W4	40.48cde	18.87cde	18.13e	0.23i	15.443def	4.647g
S2W0	52.49ab	52.65a	40.06c	22.35b	47.74b	55.64c
S2W1	34.14efg	17.68cde	13.98f	15.06d	16.92d	19.29d
S2W2	28.50g	25.98c	13.98f	9.76f	11.59def	4.463g
S2W3	8.05h	0.5f	0.5i	2.02gh	0.33g	0.23g
S2W4	0.5i	17.69cde	7.463h	0.23i	16.92d	1.8g
S3W0	57.53a	52.65a	55.46a	29.56a	59.59a	78.89a
S3W1	41.89dc	12.35e	11.61fg	19.40c	14.85def	18.24de
S3W2	36.04def	15.31de	9.24gh	16.523d	11ef	3.22g
S3W3	8.38h	0.5f	0.5i	3.1gh	0.33g	0.23g
S3W4	0.5i	18.28cde	9.24gh	0.23i	16.03def	10.33f
Mean	26.52	34.13	16.36	11.42	18.36	18.53
LSD (5%)	3.2632	4.32	1.57	0.9968	2.56	2.02
CV	16.64408	26.3	13.0176	11.8052	18.87	14.76

LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

4.1.2.2 Weed dry biomass (gm^{-2})

The interaction of inter row planting space and weeding regime significantly ($P<0.05$)affects weed dry biomass (Appendix Table 1).The highest dry weight was recorded for 60cm inter row spacing with unwedded treatment at20, 40 and 60DAE with mean values of were 29.56, 59.59 and 78.89 gm^{-2},respectively (Table 4). The highest weed dry weight in non-weeded (78.89gm^{-2}) plot at widest inter row spacing(60cm) might be due to higher weed density(55.46 m^{-2}) that provided an opportunity to the weeds to compete vigorously for nutrients, light and water. As the number of days after crop emergence increased from 20 to 60DAE, dry weight accumulation by the weeds also increased in unweddedplots(Table 4).

The highest weed dry weight (78.89 g m^{-2}) was recorded in unwedded treatment with 60cm inter row spacing at 60DAE, which was significantly higher than the values for all inter row spacings and weed managementpractices.

Unwedded plots under the widest(60cm)inter row spacings gave the highest dry matter due to high number of weed density and high accumulation of dry matter. High dry matter accumulation under wider space gave advantage to weeds to use resources like sun light, nutrients, air, moisture and space in more efficient way.

This observation was in agreement with the findings of Naem et al (2000) who reported significant decrease in weed dry weight in all weed management practices showed as compared to weedy check ingarden cress *(Lepidiumsativum*L*)crop.*

4.2. Effectsof Inter Row Spacing and Weed management On Phenological parameters

4.2.1. Days to 50 % flowering

The number of days required for 50% flowering was significantly ($P < 0.05$) affected byinter row spacing(Appendix Table 1).But, it was not significantly affected by weeding regimes nor by the interaction of weeding and spacing. The lowest values (56 days) was recorded fornarrow inter row spacings (30cm and 40cm) .Whereas, the longest days to reach 50% flowering (58 days) was recorded from the wider inter row spacings of 50cm and 60cm (Table 5).This finding was in line with that of Shad K. *et al* (2011) who reported on faba beanthin plant density or wider spacing (150,000ha^{-1}) of faba bean took more days to flowering (60.5) compared with thick plant density (600,000ha^{-1}).

The result of this study was also in agreement with the findings of Alessi*et al* (1977) who reported significantly delayed flowering of sunflower planted at wider spacing than the denser planting. Similarly, Ahmad *et al*(2002) also reported that sesame row spacing had significant effect on number of days to flower and maximum days (56) was taken to flower at 60 cm row spacing, while crop sown at 30 cm rows took minimum days (52) to flowering and this might be attributed to more nutritional area available in wider spacing, which caused more vegetative growth.

Turk *et al* (2003) have also reported that high plant density promotes phenological development; with flowering occurring 14 days earlier in the high plant density of lentil.Furthermore, Al-Rifaee*et al*(2004) have found that plants from lower densities flowered significantly later than those from higher densities.

4.2.2. Days to 90% maturity

The number of days required for 90% maturity was significantly ($P < 0.05$) influenced by inter row spacing(Table 5).But, weeding treatments or weeding by spacing interaction had no significant effect on number of days to physiological maturity. Thenarrow inter row spacings(30cm and 40cm)with different combinations of hand weeding resulted in minimum days to physiological maturity (135days).Whereas, the maximum value (142.00 days) was recorded for the wider inter row spacing of 60cmand 50cm. Physiological maturity of the crop was later by 7 days at wider inter row spacings (60cm and 50cm) than narrower inter row spacing (40cm and 30cm).

This result was in agreement with that of Langham (2007) who noted that plant spacing affects the phenotype and length of time of the phases and stages as plants compete for light at high population densities and tend tomature earlier and faster than low population density. These results were also in agreement with the findings of Lopez et al. (2005) and Oad et al. (2000) who reported that closer row spacing increased number of days to maturity.

Table 5.Main effects of inter rows spacing on faba bean DF and DM during 2018 main cropping season

Inter rows Spacing	DF (50%)	DM (90%)
30cm	56b	135b
40cm	56b	135b
50cm	58a	142a
60cm	58a	142a
Mean	*57*	*138.5*
LSD(5%)	*1.13*	*1.15*
CV	*1.40*	*1.74*

LSD = Least Significant Difference; CV = Coefficient of Variation; DF=Days to flowering; DM=Days to physiological maturity. Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.

4.3. Effects of Inter Row Spacing and Weed management on Growth

4.3.1. Leaf area index (LAI)

Leaf area index was highly significantly ($P < 0.05$) affected by the interaction of inter row spacing and weeding frequency (Appendix Table 1).Combination of the narrowest inter row spacing (30cm) and three times hand weeding gave higher LAI (2.57). The lowest LAI (0.887) was obtained from the widest inter row spacing (60cm)in non-weeded plots (Table 6).

LAI was significantly affected and inversely related to inter row spacing. Hence, the highest LAI was obtained from the narrowest inter-row spacing while the lowest was from the widest

(60cm)inter rows spacing (Table 6). This was probably due to decrease in the ground area when inter row spacing increased. This result was in agreement with López-Bellido et al. (2005) who reported that the leaf area index of faba bean was positively associatedwith relatively higher plant density.

Worku and Demisie (2012) have also reported that a high LAI at high plant density may attribute to improved light interception thus, ensuring high biomass and yield than at low plant density.

4.3.2. Plantheight (cm)

Inter row spacing and weed management practices as well as their interactions significantly ($P<0.05$) influenced plant height (Appendix Table 1) .The Tallest plant (176.86 cm) was obtained from narrower inter row spacing of 40 cm with one hand weeding, followed by 50cm inter row spacing (173.26 cm) .The shortest plant (152.13cm) was observed forone hand weedingat 40DAEplus application of pre-emergency herbicide (Dual Gold) and the widest(60cm) inter row pacing (Table 7).

Plant height is one of the important growth parameters of any crop plant as it determines or modifies the yield contributing characters and finally shapes the grain yield. For instance, characteristics associated with high yielding modern varieties, such as short stature and erect leaves, are considered to be unfavorable for weed suppression (Johnson et al, 1998).In the current study ,it was observed that plant height at physiological maturity increase from the widest inter row spacing with one hand weeding plus application of dual Gold treatment combination (152.13cm) to narrower(40cm) spacing with one time hand weeding(176.86 cm) (Table 7).

The narrowest inter row spacing gave significantly taller plants than the rest of the spacing treatments. Under narrow inter-row spacing, there is comparatively low solar radiation interception through crop canopy compared to wider inter-row spacing where there is a better light interception.

Therefore, high and low interplant competition for light in the narrow and wide spacing respectively could have resulted in such variation in plant height. These results were in agreement with the findings of Gezahegn et al. (2016) who noted taller plants in a narrow spacing because of competition for light compared to the case in wider spacing where light distribution was normal.

Dean and Mendham (2006) have also reported that plant height increased significantly with increased plant density particularly at the end of flowering. Moreover, plants grown at higher plant densities were taller than those at lower densities (Pilbeam, *et al.*1990).

Table 6.Interaction of spacing and weedmanagement on growth parameters

Treatments	PH(cm)	FPH(cm)	LA(cm^2)	LAI
S_0W_o	156.33de	93.13ab	17.75h	1.76def
S_0W_1	169abcd	96.07a	24.63defg	2.42a
S_0W_2	170.93ab	82.8abcd	24efg	2.3ab
S_0W_3	157.13cde	90.13abc	26.42bcdefg	2.57a
S_0W_4	168.8abcd	81.73abcd	24.89bcdefg	2.39ab
S_1W_0	168.6abcd	83.33abcd	23.39efgh	1.65efg
S_1W_1	176.87a	82.13abcd	27.76bcde	2.01cd

S_1W_2	171.87ab	85.4abcd	23.58efgh	1.68efg
S_1W_3	166.33abcd	78.867abcd	30.33bcd	2.13bc
S_1W_4	162.27bcde	78.4abcd	26.43bcdefg	1.89cde
S_2W_o	163.6abcde	83.6abcd	28.42bcde	1.51fg
S_2W_1	165.8abcde	81.07abcd	28.88bcde	1.51fg
S_2W_2	173.27ab	73.47cd	26.9bcdefg	1.43fg
S_2W_3	172.67ab	85.67abcd	32.36b	1.7efg
S_2W_4	162.87abcde	73.53cd	21.56gh	1.1367ij
S_3W_o	159.2bcde	77.6bcd	22.03fgh	0.89j
S_3W_1	164.67abcde	68.93d	28.26bcde	1.15ij
S_3W_2	164.07abcde	71.87d	39.58a	1.54fg
S_3W_3	166.8abcd	71.87d	40.00a	1.57fg
S_3W_4	152.13e	69.87d	30.79bc	1.21hi
Mean	165.66	80.47	27.39	1.72
LSD (5%)	14.33	18.21	5.99	9.64
CV	5.24	13.71	13.27	0.27

Where-PH,FPH,LA and LAI designated for plant height, First pod height, Leafarea and leaf area index ,respectively.CV-Coefficient of variation;LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within a column are not significantly different at 0.05 probability level.

4.3.3.Height to first pod (cm)

Plant height to the first pod reflects the ability of the cultivars to be mechanically harvested. Height to first pod was significantly ($P<0.05$) affected by interactions of inter rows spacing and weeding regimes (Appendix Table 1). Highest mean values (96.07 cm) was obtained from the highest plant density or 30cm inter row spacing while the lowest first pod height (68.87 cm)was obtained forthe interaction of wider inter-row spacing (60 cm) and herbicide treatment supported by one time hand weeding at 40DAE.Hence, the widest inter rows spacing with different weeding regimes resulted in the shortest height to first pod.

The highest value for heightto the first pod might be due to increase in inter node length at thehighest plantdensity, as the crops compete for sun light .This result was in agreement withthe findings of

Sharifi (2014) from Iran who reported that plant height to the first pod was significantlyaffected by faba bean genotypes and plant density.

4.4.Effects of Inter Row Spacing and Weed management on Yield and Yield Components

4.4.1 Number of productive tillers per plant

There was a significant (($P<0.05$) difference between inter row spacings for number of tillersbut weeding regimes andthe interaction between spacing ad weeding had no significant effect (Appendix table 1). The highest number of tillers per plant (0.64) was obtained from the wider inter row spacing (60cm and 50cm).whereas, the lowest value (0.29) was obtained from the narrowest inter row spacing(30cm)(Table 7).

The production of more productive tillers/branches at the wider spacing might be attributed to the more efficient use of available nutrients, water, and light energy which, could favor more photosynthesis and allocation of carbohydrate for all growth points compared to the closest spacing. In contrast, plants spaced closer gave less number of productive tillers/ branches per plant; the decrease in branch/tiller number was parallel with the increase in inter row spacing.

The potential of tiller production is genetically controlled behavior ,but, when combined with wider inter row spacing may lead to a more reduction in competition between faba bean plant and thereby leading to high productive tillers as compared to narrow inter row spacing . Theresult is in agreement with Al-Suhaibani*et al.* (2013) who reported a maximum number of productive tillers per plantfor faba bean under low plant population.

Table 7.Effect of inter rows spacing on Number of productive tillers per plant(NPTPP)

Inter rows spacing	NPTPP
30cm	0.29b
40 cm	0.45ab
50 cm	0.57a
60 cm	0.64a
Mean	0.49
LSD (5%)	0.24
CV	66.47

Where; LSD-Least significant differences; CV = Coefficient of Variation; Means values followed by the same letter(s) within a column are not significantly different at 0.05 probability level.

4.4.2Number of pods per plant

There was a significant (P<0.05) difference in the number of pods per plant as affected by interaction of inter row spacing and weed management (Table 8). The highest number of pods per plant(12.73) was recorded for the widest inter row spacing (60cm) and twice hand weeding,whereas the lowest value(7.87) was obtained fromthe narrowest spacing(30cm) with non-weeding .

This finding was in agreement with Hawtin and Webb (1982)who reported that number of pods per plant increased significantly under low planting density, as low planting densities result in high tillering, high number of pods and high seed yield per plant. Similar results have been reported by Fucinman, (1984) and Gah El Rasoul (1986) whonoted that low plant density increased the number of pods /plant. This could be due to low competition between plants and between the different parts of individual plant which favour the development of higher number of pods per plant under relatively thin plant density.

An increase in the competition for light and nutrients in high population may lead to a decrease in photosynthesis and so more abscission and development of lower pods per plant. The result of the present study was in line with the findings of Abdel (2008) and Shad et al. (2010) who reported a decrease in the number of pods per plant in faba bean relativelyat higher plant densities.

4.4.3Number of seeds per plant:

Number of seeds per plantwas significantly(P<0.05) affected byinteraction of inter row spacing and weeding management(Appendix table 1). The highest number of seeds per plant(33.73) was recorded for interactionof wider inter row spacing(50cm)and twice hand weeding followed by 60cm inter row spacing and twice hand weeding (30.13).whereas, the lowest value(19.47) was obtained from combined application of 40cm inter row spacing and herbicide supplemented by one times hand weeding ,which, was statistically at par with the mean values for the combination of 30cm inter row spacing withunweddedand three times hand weeding (Table 8).

Contrast to this result,Fucinman(1984)reported that the number of seeds per plant of faba bean was insignificantly affected by planting density suggesting, that this character is genetically controlled.

4.4.4. Number of seeds per pod:

Number of seeds per podwas a significantly ($P<0.05$) affected by interaction effect of inter row spacing and weeding management (Appendix table 1). The highest number of seeds per pod (2.84) was found from the interaction of the wider inter row spacing (60cm)and twice hand weeding whereas the lowest number of seeds per pod (2.25) obtained from combined application of 30 inter row spacing and herbicide supplemented by one times hand weeding (Table 8).

The result was similar Hawtin and Webb (1982) indicated that plant population may have effect in reducing the number of seeds per pod under high planting density.Kubure *etal*. (2016)reported number of seedsper pod didnotvarysignificantlyamongthegenotypes, whileittendedtovarywithplantdensityand manualweed management.

4.4.5. Thousand Seedweight

Thousand grain weight of faba bean was significantly ($P<0.05$) influenced by the interaction of inter row planting space and weed management. The mean comparison of the effect of different levels of inter row spacing and weedmanagementon weight of 1000-grains showed that the highest weight (789gm) resulted from the density of17 and 20 plants/m^2 or 60cm and 50cm inter row spacing, while,the lowestvalue (761gm) was from density of 33plants/m^2or 30cm inter row spacing withonetime hand weeding at (Table 8).

Biswas *et al* (2012) reported that in low density of plant, more pods and heavier grains were obtained compared to high density because of better utilization of nutrition and light. The decrease in 1000-grainsweight with increase plant population might be due to non-uniform distribution of light and decrease in leaf area which leads to decrease in rate of photosynthesis and or decrease of reservoir and assimilates mobilization to the reservoirs. The study was in agreement with the findings of El Obied (1997) who reported that low plant density slightly increased the mean 1000seed weight in faba bean under effective weed management.

4.4.6.Above ground dry biomass (kg ha $^{-1}$)

The maximum aboveground dry biomass yield (10,589.7kg ha^{-1}) was obtained from the treatment combination of widest inter row spacing(60cm) and twice hand weeding(Appendix Table 1). The non-weeded combination with wider inter rowspacing (50cm) resulted in the lowest aboveground dry biomass yield (5874.6 kg ha^{-1}), which was significantly ($P<0.05$) lower than all other treatments with different weeding regimes. The highest aboveground dry biomass yield at the interaction of two hand weeding and widest inter row spacing(60cm) might be due to better condition for the crop toeffectively utilize resources as compared to the combined application of 30cm inter spacing and unwedded treatment (Table 8).

This finding was in agreement with that of Shrestha et al. (2010) who reported that the removal of weeds from crop at earlier time with optimum population could boost the yield components and yield. On the other hand, the lowest total dry biomass, which wasrecorded for weedy check with 30cm row spacing, could be due to unavailability of more space for better light interception and competition for nutrients and moisture.It also could be due to high infestation of weed population, which was not controlled during crop growth period. This finding was in line with the study of Naveed et al. (2008) who reported that weeds are naturally strong competitors and compete with crops for space, nutrient, moisture, light and carbon dioxides and thus could reduce dry matter accumulation in crop straw and grains.

4.4.7.Harvest index (%)

Interaction of row spacing and weeding management significantly ($P<0.05$) affected harvest index(Appendix Table 1). The wider inter row spacing (50cm) combined with twice hand weeding gave higher harvest index (40.03%).The lowest harvest index (30.52) was observed for narrowest spacing (30cm) under non-weeded condition (Table 8). Contrary to this result Khamooshi*et al.* (2012) reported non-significant effect of plant density on harvest index of faba bean. On the other hand weber (1996) reported that lower plant population tended to increase harvest index in soybean.

4.4.8.Grain yield (kg ha^{-1})

The interaction row spacing and weed management was significant ($P<0.05$) for grain yield (Table 8). The lowest grain yield (1,974 kg ha^{-1}) was recorded for 30 cm inter row spacing with non-weeded plot. The highest grain yield (3911.7kg ha^{-1}) was recorded for 60 cm row spacing with twice hand weeding. Reduced crop weed competition due to effective weed control by twice hand weeding resulted in better growth and development of the crop. Therefore, Wider inter row spacing combined with twice hand weeding significantly gave higher number of pods plant$^{-1,}$, higher Number of seeds pod^{-1}, and maximum 1000 seed weightwhich contributed to the production of higher grain yieldcompared to all other treatments(Table 8).

Narrowest inter spacing (30 cm) combined with non-weeded plots gave lowest yield probably due to high weedcompetitionwith faba bean and with each other for resources required for plant growth and development. Thehighest yield advantagewas obtained from combined application of60cm inter row spacing and twice hand weeding,which was 553.7kgha^{-1}or 16.49% as compared to the control.

On the other hand, higher yields of faba beanobtained at lower density may be due to larger number of pods per plant and higher seed weight. The high yielding performance of the variety used in the present study has also been reported e by Teame et al. (2017).

These results were in agreement with the findings of Al-Rifaeeet al(2004) andThalji(2006) who reported that low plant density produced a higher yield in faba bean. However, these results are in contrast with those of Khalil *et al.* (2010) and Dahmardeh*et al* (2010), who reported high yields of faba beans at higher planting density.

In agreement with the results of the present study, Al-Suhaibani et al. (2013) reported that when the planting density is too low each individual plant may perform at its maximum capacity by producing productive tillers/branches. Dahmardeh et al. (2010) have also found high seed yield of faba bean in sandy loam soil at lower plant density (20 plants m^{-2}). However, Gezahegn et al. (2016) found highest seed yield of faba bean at Vertisol in 30 cm inter and 8 cm intra row spacing compare to 40 cm inter and 10 cm intra row spacing.

Table 8.Interaction effects of Spacing and weed management on Yield and Yield components

Treatments	YD($kgha^{-1}$)	BM($kgha^{-1}$)	HI (%)	TSW(g)	NPPP	NSPP	NSPPo
S_0W_o	1974h	6484.6ij	30.52g	761d	7.87c	19.67d	2.67abc
S_0W_1	2921.3ef	9140.4cd	32.597fg	761d	8.53bc	20.73cd	2.58abcd
S_0W_2	3365c	10097.6ab	33.36ef	765.3d	8.87bc	22.47bcd	2.55abcd
S_0W_3	2581.3g	7987.8efg	32.33fg	779ab	8.33bc	19.6d	2.37cd

S_0W_4	3152.3cd	9140.4cd	34.49def	774c	8.87bc	19.47d	2.25d
S_1W_0	2895f	7861.9fg	36.86bcd	774c	8.4bc	20.73cd	2.49abcd
S_1W_1	3124de	8010.5efg	39.05ab	784ab	9.93abc	25.53abcd	2.62abcd
S_1W_2	3358c	8666.7cdef	38.75ab	774c	9.4abc	24.73abcd	2.6abcd
S_1W_3	3291.3cd	8852.4cde	37.21bc	774c	8.47bc	23.13bcd	2.83ab
S_1W_4	2912.7ef	7849.5fg	37.1bc	774c	11.53ab	28.87abc	2.49abcd
S_2W_o	1977h	5874.6j	33.66ef	789a	10.87abc	26.8abcd	2.50abcd
S_2W_1	2642.3g	7451.9gh	35.47bcd	789a	11.67ab	31.47ab	2.66abc
S_2W_2	2906.7ef	7259.8ghi	40.03a	789a	12.67a	33.73a	2.70abc
S_2W_3	2906.3ef	7750.2fgh	37.51bc	789a	9.13bc	22.6bcd	2.47bcd
S_2W_4	2596.7g	6819.9hij	38.06ab	789a	11.53ab	28.87abc	2.50abcd
S_3W_o	2745.7fg	7428.3ghi	36.98bc	774c	9.47abc	25.53abcd	2.69abc
S_3W_1	3195cd	8008efg	39.92a	789a	10.13abc	28.4abcd	2.39cd
S_3W_2	3911.7a	10589.7a	36.98bc	789a	12.73a	30.13ab	2.84a
S_3W_3	3669b	9612.3bc	38.20ab	789a	11.13abc	28.4abcd	2.69abc
S_3W_4	3194.7cd	8540.5def	37.4bc	789a	11.4ab	29.67abc	2.66abc
Mean	*2966*	*8171.35*	*36.32*	*779.77*	10.05	25.53	2.58
LSD(5%)	*218.52*	*957.12*	*2.4075*	*5.30*	3.49	9.18	0.37
CV	*4.46*	*7.10*	*4.02*	*0.41*	21.09	21.79	8.69

Where: TSW,YD ,BM HI,NPPP,NSPP,NSPPo-Designated for thousand seed weight, Yield, Dry biomass , harvest index, Number of pod per plant, number of seed per plant,Number of seed per pod respectively; CV-coefficient of Variation, LSD-least significant difference, values with the same letter/s within columnstatistical not vary at P<0.05

4.5.CorrelationAnalysis among Traits

The relationships among quantitative traits of faba bean plants and weed parameters at different stages are presented in (Appendix Table 3).Seed yield was significantly and positively correlated with plant height (0.25**), number productive tillers per plant(r=0.21**), dry biomass(r=0.87**) and harvest index (r=42**) but it was significantly and negatively correlated with first pod bearing height (r=0.26**) Weed density at 40DAE(r=52**),Weed dry Weight at 40DAE(r=52**).Weed density at 60DAE(r=49**) and Weed dry Weight at 60DAE(r=53**).These results gave a clear indication that the yield components were very closely associatedwith each other but negatively associated with weed density andweed dry weights (Appendix Table 3).

This result was in close agreement with previous findings by several authors (Taddesse*et al*., 2011; Yassin, 1973), where grain yield was reported to have been strongly associated with the major yield components. Similarly, the findings of Vandana and Dubeyin(1993) indicated positive association of seed yield per plot with plant height, pods/plant, productive tillers per plant and number of seeds/plant.

Similarly, it has been reported that seed yield of a faba bean crop is the product of number of plants per unit area and four plant components: number of pod-bearing nodes/plant, number of pods/pod bearing node, number of seeds/pod and average seed weight (Sjodin, 1976; Thompson and Taylor, 1977).

The most stable of these plant components in relation to environment is the number of ovules per pod, and average seed weight is next most stable. It is well known that compensation for reduction in one component of yield may occur through any one or several others. For the same yield, there were large differences in the magnitude of the various components (Sjodin, 1976; Thompson and Taylor, 1977). In line with this study, it has been reported that primary components of seed yield in legumes are number of pods/plant, number of seed /pod and seed weight (Graff and Rowland, 1987).

4.6. Partial Budget Analysis

In order to evaluate the economic benefits of the different management practices, partial budget analysis was done.Ineconomicanalysis,farmersrequireaminimalrateofreturnof 100%,representinganincreaseinnetreturnofatleastone birrforeveryone birrinvested,toadopt new agriculturaltechnology (CIMMYT, 1988). Thus,todraw recommendations for farmersfrom Marginalanalysisinthisstudy,100%returntotheinvestmentisreasonable a n d minimum acceptablerateofreturnsincefarmers'inthestudyareausuallywell-defined optimum plant density with optimum weeding management with or without agrochemical to manage weeds in order to maximize yields and economic return.

The total costs for seed and weed management vary between the treatments but all other costs were assumed constant all over the treatments. According to the partial budget analysis, the maximum total variable cost wasincurred from 30 cm inter row spacing or 33plants m^{-2} and three times hand weeding at 20,40 and 60DAE.The highest total costs that vary in 30cm inter row spacing under three times hand weeding was due to the highest cost incurred for the three times manual weeding and seed costas compared to the other treatments(Table 9).

The highest (66,817ETBha^{-1}) net benefit was obtained from widest (60 cm) inter row spacing or 17plants m^{-2} under twice handweeding at 20 and 40DAE. In contrast, the lowest (29,925 ETB ha^{-1}) net benefit was recorded for 30cm inter-row spacing or 33plants m^{-2} and unwedded combination of treatment (Table 9).

Dominance analysis showed that all inter row spacing combined with all different weed management except 60 inter row spacing combined with one and two times hand weeding was dominated as their net benefits were less than those of treatments with lower variable costs.Hence,all dominated treatments were eliminated from further consideration for marginal rate of return analysis.

All undominated treatments gave marginal rate of return (MRR) which was greater than the minimum acceptable rate of return (100%). The highest MRR (3125%) was obtained from 60 cm inter row spacing and twice hand weeding, followed by 60 cm inter row spacing and one times hand weeding.

Therefore, 60cm inter-row spacing (17 plants m^{-2}) and twice hand weeding gave the highest net benefit (66,817ETBha-1) and percent of MRR (3125%) which was higher than the minimum rate of return (100%). The result was in agreement with that of Al-Suhaibani*et al*. (2013) who found a higher profit of faba bean from lower seed rate.

Table9.Partial budget analysis for the combined effects of inter row spacing and weed management on faba bean grain yield in Omo Nada in 2018.

Treatments	AGY(kgha-1)	GFB(ETB)	NB(ETB)	MRR (%)
S0W0	1776.67h	35532h	29925j	D
S0W1	2629.33ef	52584ef	46577fg	D
S0W2	3028.67c	60570c	54163cd	D
S0W3	2323.33g	46464g	39657i	D
S0W4	2837.33cd	56742cd	50285def	D
S1W0	2605.67f	52110f	47910ef	D
S1W1	2811.67de	56232de	51632cde	D
S1W2	3022c	60444c	55444c	D
S1W3	2962cd	59244cd	53844cd	D
S1W4	2621.33ef	52428ef	47378fg	D
S2W0	1779.33h	35586h	32226j	D
S2W1	2378.33g	47562g	43802gh	D
S2W2	2616ef	52320ef	48160ef	D
S2W3	2615.67ef	52314ef	47754ef	D
S2W4	2337g	46740g	42530hi	D
S3W0	2471fg	49422fg	46629fg	D
S3W1	2875.33cd	57510cd	54317c	1922
S3W2	3520.33a	70410a	66817a	3125
S3W3	3302.33b	66042b	62049b	D
S3W4	2875.33cd	57504cd	53861cd	D
mean	2669.43	53388.00	48748.00	
LSD (5%)	92.43	1849.10	1849.10	
CV	4.46	4.46	4.89	

AGY=Adjusted Grain yield; GFB = Gross field benefit; NB = Net benefit; D=Dominated treatment; ETB = Ethiopian Birr; Price of Seed= 21birr kg^{-1}; Price of Dual Gold herbicide = 450birr kg^{-1}, Wage rate = 50 Birr $man\text{-}day^{-1}$; Retail price of grain = 20 birr kg^{-1}; 1USD = 27.80 ETB.

5. SUMMARY AND CONCLUSION

Faba bean is the least expensive source of protein for the people in Ethiopia. It is widely cultivated in the farming communities of Jimma zone. However, lack of optimum plant population with appropriate weed management practices is the major challenge for the farmers in Omonada area. Thus, the study was done to determine economic optimum interactions of inter row spacing and weeding regimesfor faba bean production in the study area.

Based on the result, variation of inter row spacing and weeding regimes had significant effects on growth, yield and yield components of faba bean in clay soil. The highest seed yield was recorded in 60 cm inter row spacing and twice hand weeding at 20 and40 DAE. Therefore, 60 cm inter row spacing and twice hand weeding can be recommended for obtaining high yield of faba bean inclay soil of study area.

Weed pressure is the main factor that influences production and productivity of faba bean in the area. Integrated weed management approaches is the best option for effective and sustainable weed control ,of which, cultural practice is one of the best strategy for the controlof weed, particularly in areas where access to post or pre-emergence herbicide is very limited.

The result of this experiment, which focused ondifferent weed control practices, revealed that hand weeding twice at 20 and 40 DAE with wider(60cm) inter row spacing or low plant density (166,667 plantsha-^{1}) of faba bean resulted in highest yield advantage equals to 553.7kgha^{-1}or 16.49% as compared to control and hence recommended for the experiment area.

From economic point of view, 60cm inter row spacing or (166,667 plants ha^{-1}).and twice hand weeding at 20 and 40DAE gave highest net benefit with acceptable MRR (%).Thus, twice hand weeding and a plant density of 166,667 plants ha^{-1} (60cm x 10cm) were found to be better both agronomically and economically for faba bean producing farmers in the study area.

However, as this study was conducted for one season and at one location, further study need to be done over seasons and locations to determine optimum plant populations and weed management options for better recommendation to increase faba bean production and further ascertain their effects on growth, yield and yield components of faba bean.

6. REFERENCES

Abdalla, A., A. Ibrahim. 2006. Effect of plant spacing, plant number per hill and their interaction on growth and yield of broad bean in Desert region of South Iraq.

Abd-Aziz El El-Set A and Shala.1999. Physiological studies on response of new released faba bean varieties to different plant populations. Zagazig J. Agric. Res.***26 (5)****: 1229-1244.*

Abdel, L. 2008. Effect of seed size and plant spacing on yield and yield components of faba bean *(Vicia faba L.).Research Journal of Agriculture Biology Science,* ***4****:146148.*

AbouSalama, A.M .and R.A. Dawood .1994. Yield response of faba bean *(Vicia faba, L.*) to planting density and phosphorus fertilization. *Assiut J. Agric. Sci.* ***25 (2):*** *83-91.*

Ahmad, R., Mahmood,T.,Saleem,M.F. and Ahmad,S.2002.Comparative performance of two sesame (Sesamumindicum L.) varieties under different row spacing. Asian Journal of Plant Sciences, **1(5),** 546-547.

Ahmed M.ElNaim, Mona A. Eldouma, Elshiekh A. Ibrahim, Moayad and M.B. Zaied, 2011. Influence of Plant Spacing and Weeds on Growth and Yield of Peanut *(Arachishypogaea L)* in Rain-fed of Sudan.*Journal of Advances in Life Sciences,* ***1(2):*** *45-48.*

Ageeb, O.A.A.1977. Effect of plant and row spacings on the grain yield of Faba bean. Hudeiba Research Station. Annual report 1976-1977, El-Damer Sudan.

Ageeb, O.A.A. 1980. Effect of time of harvest on the grain yield and percentage of hard seed of broad bean. FABIS New letter 2: 38-39. Ageeb, O.A.A., M.B. Ghorashi, A. M.Dawelbeit and Ali. 1984. Report on Raba bean agronomy. Paper presented at ICARDject/IFAD Nile Vally Project, Fifth annual Coordination Meeting 9-13 September, 1984 Cairo Egypt.

Ageeb, O.A.A.1982. Faba bean improvement G. Hawtin and C. webb (eds.) 1982 ICARDA ISBN 9024725933 Printed in the Netherlands.

Agegnehu, G., R .Fessehaie.2006. Response of faba bean to phosphate fertilizer and weed control on nit sols of Ethiopian highland*s. Italian Journal of Agronomy* ***2****:281-290*

Alam, S.M.,Naqvi, S.S.M. and Ansari, R. 1999. Impact of soil pH on nutrient uptake by crop plants. pp. 51-60. In: Pessarakli, M. (eds.), Handbook of Plant and Crop Stress. New York: Marcel Dekker.

Alem B, Beniwal SPS, Amare G, Asfaw T, Hailu B, 1990. On farm evaluation of four management factors for faba bean production in the Holeta Zone of Shewa. Ethiopa*J AgricSci**12**: 17-28.*

Alghamdi, S.S. 2009. Heterosis and combining ability in a diallel cross of 8 faba bean (Vicia faba L.) genotypes. *Asian Journal of Crop Science,* ***1(2)****:66-76.*

Al-Rifaee, M. O. H. D., Turk, M. A., and Tawaha, A. R. M. 2004. Effect of seed size and plant population density on yield and yield components of local faba bean (Vicia faba L.major). *International Journal of Agriculture and Biology,* ***6****, 294–299.*

Al-Suhaibani, N., El-Hendawy, S., and Schmidhalter, U. 2013. Influence of varied plant density on growth, yield and economic return of drip irrigated Faba bean (*Vicia faba L.*). *Turkish Journal of Field Crops,* ***18****, 185–197.*

Amare G. 1990. Evaluation of faba bean *(Vicia faba L.)* production packages on farmers' fields in ArsiAdministrative Region. Alemaya University of Agriculture, Ethiopia.

Amare Ghiza and Adamu Molla. 1994. Faba bean and field pea Agronomy Research, pp 199-229. In: Asfaw T.,Geletu B,, M.C.Saxenaa,dM.B.Solh (eds.).Cool-Season Food Legumes of Ethiopia. Proceedings of the First National Cool-season Food Legumes Review Conference, 16-20 December 1993. Addis Ababa, Ethiopia. ICARDA/Institute of Agricultural Research.

Anderson, W. K. Sharma, D. Shackley, B. J., and Antuono, M. F. 2004. Rainfall, sowing time, soil type, and cultivar influence optimum plant population for wheat in Western Australia. Australian *Journal of Agricultural Research,* ***55****,921–930.*

Anetoun, H. and Prevost, D. 2005. Ecology of plant growth promoting rhizobacteria. pp. 1-38. In: Siddiqui, Z. A. (Eds.), PGPR: Bio- control and fertilization. Springer, Dordrecht.

Anil, K.S., Bharati1, R. C., Naresh, C. M. and Anitha, P. 2013. An assessment of faba bean (*Vicia faba L.*) current status and future prospect. African Journal of Agricultural Research, **8(50)**: 6634-6641.

Ashby.1990. Evaluating technology with farmers: A handbook. CIAT Publication no. 187. Obtain from CIAT, ApartadoAereo 6713, Cali, and Columbia. pp95.

Asfaw T, Geletu B, Alem B.1994.Role of cool season food legumes and their production constraints in Ethiopian agriculture. Cool-season Legumes of Ethiopia. ICARDA, Addis Ababa, Ethiopia.

Awol M, Seyum A, Eyeberu A, Niguse S.2016.Participatory evaluations of faba bean (Vicia faba l.) varieties in Wollo, Ethiopia. *Journal of Agricultural Economics, Extension and Rural Development.* ***4(7):*** *488-495.*

Babiker, A.G.T. and Khalid, M.E. 1990.Chemical weed control in faba bean at Wad Hamid .Annual Report, *Hudieba* Research Station *.Agric. Res. Corp. ARC, Sudan, 183-185.*

Badawi, T.E.1983. Studies on weed control Sudan ICARDA/IFAD Nile Valley Project on faba beans Report of the annual meeting pp 44-45. Aleppo, Syria January 1983.

Bahn, V.M. and Kukula, S.1967. Problems and potential of chickpea production in the nineties. Proceedings of the second International Workshop on Chickpea Improvement 1989, ICRSAT Centre, India pp 13-25.

Bakry, B. A., T. A. Elewa, M. R. Elkaramany, M. S. Zeidan and M. M. Tawfik. 2011. Effect of row spacing on yield and its components of some Faba bean varieties under newly reclaimed sandy soil condition .*World Journal Agricultural Sciences* ***7(1)*** *68-72.*

Bakry, B., Elewa, T., Zeidan, M.2013. Effect of Row Spacing on Yield and its Components of Some Faba Bean condition. *World Journal of Agricultural Sciences.* ***7(1):*** *68-72.*

Ball RA, Purcel LC, Vories ED.2000.Short season soybean yield compensation in response to population and water regime. *Crop Science* ***40****: 1070-1078.*

Bauer,A.and Black Al.1994. Quantification of the effect of soil organic matter content on soil productivity. *Soil Science Society of America Journal,* ***58****, 185–193.*

Beck, D.P., Wery, J., Saxena, M.C. and Ayadi, A. 1991. Dinitrogen fixation and balance in cool-season food legumes. *Agronomy Journal,* 83: 334-341.

Berhanu Debele. 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Biswas, D., Haque, M., and Rahman, M. 2012. Influence of plant population density on growthand yield of two blackgram varieties. *Pakistan J ournal Agronomy.* **1**(2-3): 83-85.

Bond, D.A. M.H. Poulsen. 1983. Pollination. pp. 77-101.In: P.D. Hebblelhwaite (ed.). The Faba bean (*Vicia faba*).

Bonari, E. and M. Macchia. 1975. Effect of plant density on yield and yield components of (Vicia faba L.) Peterm, Beck. Rivista di Agronomia, 9: 416-23.

Boroomandan, P., Khoramivafa, M., Haghi, Y., and Ebrahimi, A. (2009). The effects of nitrogen starter fertilizer and plant density on yield, yield components and oil and protein content of soybean (Glycine max L. Merr). *Pakistan Journal of Biological Sciences**, 12,**378–382.*

Boudanga, L., Farissi, M., Bouizgaren, A., Ghoulam, C. 2015. Growth and nodulation in faba bean-rhizobia symbiosis under different soil phosphorus levels: acid phosphatase and phosphorus deficiency tolerance. *Journal of Materials Environmental Science,* ***6 (4)*** *997-1003.*

Bouyoucos, G. J.1951. A recalibration of the hydrometer method for making mechanical analysis of soils. *Agronomy Journal,* ***43,*** *434–438.*

Brady, N. C. and Weil, R. R. 2002. The Nature and Properties of Soils (13th ed.), Pearson education Ltd., USA. pp. 156-198. Brady, N.C. 1990. The Nature and Properties of Soils (10th Edition). Macmillan, New York. 621pp. Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available form of phosphorus is soils. *Soil Science,* ***59:*** *39-45.*

Braun, M.; Burgstaller, H.; Hamdoun and Walter,H. 1991. Weed problems in Central Sudan in common weeds of Central Sudan, pp. 7-14.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available form of phosphorus is soils. *Soil Science,* ***59****: 39-45.*

Bremner, J. M. and Mulvaney, C. S. 1982. "Total nitrogen", In: A. L. Page, R. H. Miller and D. R. Keeny, (Eds.), Methods of Soil Analysis, American Society of Agronomy and Soil Science Society of America, Madison, pp. 1119-1123.

Bridgemohan, P, and Brathwaite, R. A. I. 1988.Weed management strategies for the control of *Rottboelliacochinchinensis* in maize in Trinidad. *Weed Research.* ***29,*** *433-440.*

Bruin, JLD, Pederson, P. 2013. Effect of row spacing and seeding rate on soybean yield. *Agronomy Journal.* 100**(5):**704-710.

Burkharo, .J. Keller.E.R.1983. Influence of plant density, gibberellic acid and site on the yield and yieldcomponents of different faba bean growing types. *Fabis Newsletter No.7: 37-39.*

Burn ER. 1971. Method of estimation of tannin in grain sorghum. *Agron. J., **63**: 511.*

CSA. 2013. Report on area and production of crops. Central Statistics Agency agricultural sample survey for 2013 / 2014, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency).2016. Agricultural sample survey 2015/2016. Vol. I. Report on area and production for major crops (private peasant holdings, meher season). Statistical Bulletin 532, Central Statistical Agency. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2017. Agricultural Sample Survey, 2016 / 2017 (2009 E.C.). Report on Area and Production of Major Crops in the Meher season. Statistical Bulletin. 584. Volume I, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2017. Agricultural Sample Survey, 2016 / 2018 (2009 E.C.). Report on Area and Production of Major Crops in the Meher season. Statistical Bulletin. 588. Volume I, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

Chafi, M.H. and Bensoltane, A. 2009. Faba bean *(Viciafaba L.).* A source of organic and biological manure for the Algerian Arid Regions. *World Journal of Agricultural Sciences, **5 (6)**: 698-706.*

Chapman, H.1965.Cation exchange capacity. Methods of soil analysis. Part 2. Chemical and microbiological properties.(pp.891–901).Madison, WI: Alliance of crop, soil and environmental science society.

Chapman, H.D. and R. F .Pratt, 1978.Methods analysis for soil, plant and water. University of California. *Div.Agric.Sci.pp:16-38.*

Comarovschi, G. 1979. Effect of sowing method on yield of Faba bean. Field Crop Abstracts 32: P. 123.

Crepona, K., Marget, P., Peyronnet, C., Carrouea, B., Arese, P., Duc, G., 2010. Nutritional value of Faba bean *(Vicia faba L.)* seeds for feed and food: *Field Crop Research, **115**, 329-339.*

CIMMYT (International Center of Wheat and Maize Improvement). 1988. From Agronomic data to Farmer Recommendations: An Economic work Book. Mexico, D.F. 89pp.

Cottenie, A. 1980. Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations, Rome.

Crop Variety Registration year book, 2016. Addis Ababa, Ethiopia, ***18(6***)

Cubero, J.I. 1974. On the evolution of Vicia faba. *Theory Applied Genetics, **45**:47-51*.

Dahmardeh, M., Ramroodi, M. 2010. Effect of plant density and cultivars on growth, yield and yield components of faba bean (Viciafaba L.).*African Journal of Biotechnology. **9(50):** 8643-8647.*

Dawood, D.A. 1989.Effect of crop weed competition on faba bean production in Selaim basin (North Sudan) Annual report Hudeiba Research Station, Agric. Re. Corp. (ARC), Sudan, 120-124.

Day, J. M. 1979. The effect of planting density on yield of Vicia faba. Journal of Agricultural Science, Cambridge 93:629-633.

Dean, G. and Mendham. N. 2006 .Optimum plant densities forfaba bean sown on raised bedsTasmanian Institute of Agricultural Research.Aleppo;ICARDA

De Boef WS, Thijssen MH.2007. Participatory tools working with crops, varieties and seeds. A guide for professionals applying participatory approaches in agro biodiversity management, crop improvement and seed sector development. Wageningen, Wageningen International, 83p.

Degife Asfaw and KiyaAbera. 2016. Evaluation of faba bean (Viciafaba L.) varieties for yield at Gircha Research Center, GamoGofa Zone, Southern Ethiopia. *Scholarly Journal of Agricultural Science, **6(6):** 169-176.*

Donovan, O, Harker, J. T, Clayton, K. N, Newman, G. W, Robinson, J. C, and Hall, D. L.M.2001. Barley seeding rate influence the effects of variable herbicide rates on wild oat. *Weed. Science, **49**, 746-754.*

Ethiopian Institute of Agricultural Research (EIAR). 2018, Faba bean Production Guideline Using Rhizobial Bio-fertilizer Technology. Addis Ababa, Ethiopia

Edwards, J. T., and Purcell, L. C. 2005. Soybean yield and biomass responses to increasing plant population among diverse maturity groups. *Crop Science*, ***45***, *1770–1777.*

El Obied,A. M. 1997. Interactive Effects of WateringIntervals and Plant Density on Growth and Reproductive Development of Faba Bean *(ViciafabaL.)* .M.Sc. thesis, Univ. of Khartoum.

Emmanuel, A. 1995. The effects of plant density and planting date on the growth yield. Storability and viability of two soybean varieties. Retrieved July15, 2019, from http:// hdl.handle.net/123456789/623.

Ethiopian Institute of Agricultural Research.2011. Faba bean producing manual. Holetta Agricultural Research Center. Addis Ababa, Ethiopia.

Fadayomi, O. and Takim, F.O. 2009. Residual effects of legume cover plants on soil weed seed bank and weed growth in a subsequent maize crop. *Nigerian Journal of Weed Science***22:** 15-22.

Fageiry,K .A. 1987. Weed control in soybean (*Glycine max*) on vertisols of Sudan. *Tropical pest Management, 33(3): 220-223.*Fuciman, L. 1984. *The effect of different population densities on Faba bean seed yield. **30 (5)** 471 - 477.*

Fuciman, L. 1984. The effect of different population densities on Faba bean seed yield.*Journal of Central European Agriculture,***30 (5**) *471 - 477.*

FAO STAT. 2014. Data base. Available at:*http://faostat3.fao.org/faostat-gateway*

FAO (Food and Agriculture Organization). 2000. Fertilizers and their use 4th eds.International fertilizer industry association, FAO, Rome, Italy; *FAO Soil Bulletin10,Rome, 160pp.*

FAO (Food and Agriculture Organization). 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO*, Fertilizer and Plant Nutrition Bulletin* ***16,*** Rome.

Fessehaie R.1994. Weed research in cool season food legumes. In:Cool season food legumes of Ethiopia. Proceedings of the 1st National Cool-season Food. Legumes Review Conference, Addis Ababa, Ethiopia, Aleppo, Syria.

Food and Agriculture Organization of the United Nations.2008.FAO fertilizer and plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis, FAO, Rome, Italy. 203p.

Gah El Rasoul, A. E. 1986. Response of Faba beans *(Vicia faba L.)* to Sowing date, Interplant Spacing and Phosphorus Fertilization M.Sc. thesis, Fac. Univ. of Khartoum.

Gasim, S. and Link, W. 2007. Agronomic performance and the effect of soil fertilization on German winter faba bean (Vicia faba L.). Journal of Central European Agriculture, 8:121-127.

Gemechu, K., J. Mussa, and W. Tezera. 2006. Faba bean *(Vicia faba L.)* Genetics and Breeding Research in EThiopia: A Review. In: A. Kemal et al., editors, Food and Forage legumes of Ethiopia: Progress and Prospects. Proceedings of the Workshop on Food and Forage Legumes, 22-26 September 2003, Addis Ababa, Ethiopia.Sponsors:EIAR and ICARDA. ICARDA, Aleppo, Syria. p. 43-66.

Getachew, A., Asnake, F., and Ayalew, T. 2006. Cropping systems, soil fertility, and crop management research on cool season food legumes in the central highlands of Ethiopia: A review. In K. Ali (Ed.), Food and Forage Legumes of Ethiopia: Progress and Prospects (pp. 135145). Aleppo: ICARDA.

Getachew Agegnehu and ChilotYirga. 2009. Integrated Nutrient Management in Faba Bean and Wheat on Nitisols of central Ethiopian Highlands. Research Report No. 72.

Getachew Agegnehu, Taye Bekele and Agajie Tesfaye.2005. Phosphorus fertilizer and FYM effect on the growth and yield of faba bean and some chemical properties in acidic nitisols of central high land of Ethiopia. *Ethiopian Journal of Natural Resources*, **7**:23-39.

Getachew Agegnehu and ChilotYirga. 2009. Integrated Nutrient Management in Faba Bean and Wheat on Nitisols of central Ethiopian Highlands. *Research Report No.**72.*** Ethiopian Institute of Agricultural Research (EIAR). Addis Ababa, Ethiopia, 24pp.

Getachew Mekonnen, J., J. Sharma, LisaneworkNegatu and Tamado Tana, 2017. Effect of Planting Pattern and Weeding Frequency on Weed Infestation, Yield Components and Yield of Cowpea [Vignaunguiculata L.) WALP.] inWollo, Northern Ethiopia. Journal of Agriculture, Forestry and Fisheries. *Science Publishing Group. **6(4):** 111-122.*

Getachew, M.,Sharma, J.J., Lisanework, N., Tamado, T., 2017. Effect of planting pattern and weeding frequency on weed infestation, yield components and yield of Cowpea (*Vignaunguiculata L*. WALP in Wollo, Northern Ethiopia. *J. Agr. Forest. Fish. Sci. Pub. Group, **6(4),** 111-122.*

Getachew, A.,andRezene, F., 2006. Response of Faba bean to phosphate fertilizer and weed control on Nitisols of Ethiopian Highlands. *Italy J. Agron. Riv. Agron*., **2,** 281-290.

Gezahegn , A. M., Tesfaye, K., Sharma, J. and M. D. Belel.2016. Determination of optimum plant density for faba bean *(Vicia faba L.)* on vertisols at Haramaya, Eastern Ethiopia. *Cogent Food and Agriculture. 2(1), pp. 122-448.*

Ghamari, H. and G. Ahmadvand .2013. The effect of different interference cycles and weed control on the height, performance components of the red bean. Production and processing of the Garden and Arable products Magazine, Third year, Ninth Number.

Ghizaw, A., and Molla, A., 1994. Faba bean and field pea agronomy research.In: Telaye, A., Bejiga, G., Saxena, M.C., Solh, M.B. (eds.): Cool-season food legumes of Ethiopia.

Gholipoor, H. B. Mirshekari, Z. Hossein, A. H. Moghbeli and Shanifiyan. 2010. Critical period of wheat control in sunflowers field. Journal of new Agriculture, 31, 83-90. Proceedings of the 1st National Cool-season Food Legumes Review Conference, 16-20 December, 1993, Addis Ababa, Ethiopia. ICARDA / IAR. ICARDA: Aleppo, Syria, 199-229.

Gomez, K. A., and Gomez, A. A.1984. Statistical procedures for agricultural research (2nd Ed.). New York, NY: John Wily and Sons.

Graf, R. J. and Rowland .G. G. 1987. Effect of plant density on Yield and components of yield of faba bean. *Canadian Journal of plant science **67(1)** 1-10 (En Fr, 22 ref) Crop development Cent.*

Gressel, J., A. Hanafi, G. Head, W. Marasas, A.B. Obilana, J. and Ochanda .2004. Biotic constraints to African food security that may be amenable to novel biotechnological solutions. *Crop Protection **23**: 661–689.*

Gupta, P.K. 2000. Hand book of soil fertilizer and manure. Anis offset press, Paryapuni, New Delhi, India. 431pp.

Hanelt, P. and Mettin, D. 1989. Biosystematics of the genus *Vicia L*.(Leguminosae). Annuals Revised. Ecology System, 20:199–223.

Hassan AA and Hafiz SI.1998.Agronomic characteristics yield and its components of some field bean cultivars as affected by planting methods and plant spacing. Proc. 8th Conf. Agron., Suez Canal Univ., Ismalia, Egypt, 28- 29 Nov., pp. 317-325.

Hawtin, G. and Webb. C, 1982. Faba Bean improvement Flower and Pod Drop (ICRD) Printed in Netherlands.

Hawtin, G.C. and Hebblethpiaite, P.D. 1983. Background and history of faba bean production. Pages 3-22 in The Faba Bean *(Vicia faba L.)* (Hebblethwaite, P.D.,ed.). Buttenvorths, London, U.K.

Hekneby, M., Antolin, M.C. and Chez-Diaz, S.M. 2006. Frost resistance and biochemical changes during cold acclimation in different annual legumes. Environmental Experimental Botany, 55:305–314.

Hulse, J.H. 1994. Nature, composition and utilization of food legumes. pp: 77-97. In: Muehlbauer, F.J. and Kaiser, W.J. (Eds.), Expanding the Production and Use of Cool Season Food Legumes. Kluwer Academic Publishers, Dordrecht, the Netherlands.

IBPGR, ICRISAT and ICARDA..1993. Descriptor for Chickpea (*Cicer arietinum L*.). IBPGR, Rome Italy/ ICRISAT, Patancheru, India/ICARDA, Aleppo, Syria.

IFPRI (International Food Policy Research Institute). 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system, (IFPRI). Working paper, Washington, USA.

Ishag, H. M. 1973. Physiology of seed yield in field beans *(Vicia faba L).* Yield and yield components Journal of *Agricultural Science Cambridge.* ***80****:181-189.*

Jackson, M. L.1958. Soil chemical analysis. New Jersy, NJ: Prentice Hall. Retrieved from *http://www.archive.org/ details/soilchemicalanal030843mbp.*

Jackson, M.L. 1967. Soil Chemical Analysis. Constable and Co L.etd.London

Jensen, E. S., Peoples, M. B. and Nilsen, H. H. 2010. Faba bean in cropping systems. Field Crops Research, **115(3**): 203-216.

Jettner, R., Loss. S. P, Siddique. K. H. M. and Martin. L. D.1996. Responses of faba bean *(Vicia faba L.)* tosowing rate in south-western Australia II Canopy development, radiation absorption and dry matterpartitioning. *Australian Journal of AgriculturalResearch* ***49(6):*** *999- 1008.*

Joel, D.M., J. Hershenhorn, H. Eizenberg, R. Aly, G. Ejeta, P.J. Rich et al. 2007. Biology and management of weedy root parasites. *Horticulture Review* ***33*** *267–349.*

Johnson, C.E. 2002. Cation exchange properties of acid forest soils of the northeastern USA. *European Journal of Soil Science****,*** ***53****: 271-282.*

John, R. and Abdul, R. 2005. Phosphorus. *ResearchGate.*

Johnson, C.E. 2002. Cation exchange properties of acid forest soils of the northeastern USA. *European Journal of Soil Science,* ***53:*** *271-282.*

Kaant, G.andKonig .K.Hijazi. 1988. Effect of plant density, sowing date technique and topping on yieldand yield components of field beans. *Journal of agronomy and crop science* ***160 (2)****:*83-88.

Kambal, A. E. 1969. Components of yield in field beans. Journal of Agricultural Science Cambridge. **72:**59-363.

Kakiuchi J. and Kobata T .2004. Shading and thinning effects on seed and shoot dry matter increase in determinate soybean during the seed filling period. *Agron. J.**96**: 398-40*5.

Kavalinuskaite, D.andBobinas, C. 2006. Determination of weed composition critical period in red bat. *Agronomic Research, **4**: 217-220.*

Kavurmaci, Z. U. K. Karadavut.Okokten and A.Bakoglu.2010. Determining critical period of weed crop competition in Faba bean (*Vicia faba* L). International Journal of Agriculture and Biology, **12**, 318-320.
Kebede D.2000.Weed control methods used in Ethiopia. Head, Agricultural Implements and Equipment's, Rural Technology Promotion Department Ministry of Agriculture, Addis Ababa, Ethiopia.

Keller, E. R. and J. Burkhard. 1983. Relationship between plant density and structure of yield in different growth types of Vicia faba. Faba bean Abstracts No. 3.

Khalil, N. A., W. A. Al-Murshidy, A. M. Eman and R. A. Badawy. 2015. Effect of plant density and calcium nutrition on growth and yield of some faba bean varieties under saline conditions. *Agriculture and Food. **3,** pp. 440-450.*

Khalil, S.A, Dissouky RF, Amer MI, El-Hady MM, and Hassan .1993. Performance of yield and yield components of two faba bean *(Vicia faba L.)* cultivars as affected by two plant densities and foliar disease control in the new reclaimed land. *J. Agric. Sci. Mansoura Univ. **18(5)**: 1306-1314.*

Khamooshi, H., Mohammadian, N., Saamdaliri, M., &Foroughi, Z. 2012. Study on effect of plant density and nitrogen on yield and yield components of Faba bean (*Vicia faba L.).Journal of Ornamental and Horticultural Plants, **2**, 161–167.*

KissiWakweya D. and RetaDargie, 2017.The effect of pre emergency herbicide (Dual Gold) and Hand Weeding Frequencies on Faba Bean *(Vicia fabaL.)* Growth, Yield and Yield Components in Bale Highlands, Southeastern Ethiopia. *Scientific Journal of Pure and Applied Sceinces**, 6(7)**: 589-596.*

Knaak, C., Roskothen, P. and Robbelen, G. 1993. Symbiotic efficiency of Vicia faba genotypes after field inoculation with different strains of Rhizobium leguminosarum preselected in greenhouse tests. *Journal of Plant Physiology, **141**:49–5.*

Kubure TekleEdossa, Raghavaiah, C.V. and Hamza Ibrahim. 2016. Production potential of faba bean (Vicia faba L.) genotypes in relation to plant densities and phosphorus nutritiononVertisolsofCentralHighlandsofWestShowaZone,Ethiopia,East Africa. *Advanced Crop ScienceTechnology, **4**: 214. doi:10.4172/23298863.1000214*

Labrada, R. 2005.Weed management: A basic component of modern crop production. In Sustainable weed management. Singh, H.P., Batish, D.R., Kumar Kohli, R. (eds). (2005). Food Products Press, and imprint of the Haworth Press Inc., NY.

Langham, D. R. 2007. Phenology of sesame. In A. Janick& J. Whipkey (Eds.), Issues in new crops and new uses (pp. 144–182). Alexandria, VA: ASHS Press.

Landon, J.R., 1991. Booker Tropical Soil Manual: A hand book for soil survey and agricultural land evaluation in the tropics and subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York.

Lemerle, D., B. Verbeek and S. Diffey.2006. Influences of field pea *(Pisumsativum)* density on grain yield and competitiveness with annual ryegrass *(Loliumrigidum)* in south-eastern Australia. *Animal Production Science,* ***46(11),*** *pp. 1465-1472.*

Lindeman, W.C. and Glover. 2003. Nitrogen fixation by legumes. In: Cooperative Extension Service Guide A-129, editor New Mexico State University and the USDA.

López-Bellido, F. J., López-Bellido, L.and López-Bellido, R. J. 2005.Competition, growth and yield of faba bean *(Vicia faba L.).European Journal of Agronomy,* ***23(4),*** *359-378.*

Magyarosi,T. and J. Sjodin.1976. Investigation of yield and yield components in field bean *(Viciafaba L.)* varieties with different ripening time. Zpfucht. **77**: 133- 144.

Mashingaidze, A. B,andChivinge, 1995 .Weed control using reduced herbicide dosages: a Theoretical Framework, Transactions of Zimbabwe Scientific Association (1995). , **63,** 12-19.

Manfred Huehn.1993.Harvest index versus grain/straw ratio: Theoretical comments and experimental results on the comparison of variation. *Euphytica,* ***68:*** *27-32*.

Matthews, P., Carpenter, D., Smith,A. and Fettell, N.2001. Faba bean seeding rates for central and southern New South Wales. In Proceedings of the 10th Australian Agronomy Conference. Hobart: Australian Society of Agronomy.

Melaku W. 2008. A Preliminary Guide to Plant Collection, Identification and Herbarium Techniques. The National Herbarium Addis Ababa University, Ethiopia.

Mekkei, M. E. 2014. Effect of intra-row spacing and seed size on yield and seed quality of Faba bean (Vicia faba L.). International Journal of Agriculture and Crop Sciences. Vol.(10):665-670.

Mihailovic, V.,Mikic,A., Cupina, B. and Eric, P. 2005. Field pea and vetches in Serbia and Montenegro.*Grain Legumes,* ***44****:25-26.*

Milthorpe, F. L. and J.Moorby .1975. An introduction to crop physiology. Published, Reprinted in Great Britain at the University of Cambridge.

Ministry of Agriculture and Rural Development (MOA).2008. *Crop Variety Register (Issue **No.11**).* Addis Ababa: Crop Development Department.

Ministry of Agriculture. 2011. Animal and Plant Health Regulation Directorate. *Crop Variety Register*. *Issue No.* ***14.*** Addis Ababa, Ethiopia. pp. 71-73.

Mohamed, El.;Babiker, A, Mohamed G. and Khalid, M.E.1992.Chemical weed control in faba bean, experiment. Annual Report, Hudeiba and Dongla Research Substation. Agricultural Re. Corp ARC. Sudan. 75-77.

Mohamed, El. S.1995. Weed control in legumes in production and improvement of cool season food legumes. In the Sudan. pp 185-201.

Mokhtar, A.2001. Response of yield and yield components of faba bean *(Vicia faba L.)* to increasing level of nitrogen and phosphorus under two levels of plant stand density. *Agric. Sci., Ain Shams Univ**., 46 (1);** 143-154.*

Mola, A. 1996. Effect of sowing date, weeding frequency and seed rate on yield of faba bean grown on pellicvertisols at Sheno. Proceedings of the Conference of the Agronomy and crop physiology society of Ethiopia (ACPSE). Addis Abeba, Ethiopia.

Muehlbauer, F and A.Tullu. 1997. *Vicia faba L.* New crop factsheet Purdue University, US.

Murphy, B. and Hazelton, P. 2007. Interpreting soil test results: What do all the numbers mean, 2ndEdition? CSIRO Publishing. 20pp.

Musa Jarso and GemechuKeneni.2006. *Viciafaba L*. http://database.prota.org /search.>. Accessed on March 15, 2018.

Naeem, M.,Saeed, A.andHakoomat, A. 2000. Efficacy of faluazifop butyl (Fusillade 25 EC) and fenoxaprop-P- ethyl (Pumas 69 EW) for weed control in mung bean. *Pakistan Journal Agricultural Science, **37**:1-2.*

Naeem Sarwar, Muhammad Shehzad, Asif Tanveer1, Muhammad Ayub, Khuram Mubeen, Muhammad Ibrahim and Imran Qadir. 2011. Effect of weed-crop competition on growth and yield of garden cress *(Lepidiumsativum* L*.)*Journal of Medicinal Plants Research,***5(26)****:* 6169-6172.

Naidu, V.S.G.R. 2012. Hand Book on Weed Identification. Directorate of Weed Science Research, Jabalpur, India.

Nair, K.M. and Chamuah, G.S. 1993. Exchangeable aluminum in soils of Meghlaya and management of Al3+ related productive constraints. Journal of Indian Society Soil Science, **4(1/2):** 331-334.

Nieto, J.H..Brando, M.A. and Gonzales, J.T.1968.Critical period of the growth cycle for competition form weeds. *Pest Adtic. News Summ.* ***14****: 159.*

Nurlaeny, N., Marschner, H.and George, E.1996. Effects of liming and mycorrhizal colonization on soil phosphate depletion and phosphate uptake by maize (*Zea Mays L.)* and soybean (Glycine max L.) grown in two tropical acid soils. *Plant Soil, 275-285.*

Oad, C., Samo, M. A.,Qayyum,S.M,and Oad, N. L. 2002. Inter and intra row spacing effect on the growth, seed yield and oil content of safflower *carthamus tinctorius L.F. Asian Journal of Plant Sciences,****1(1),****18– 19.*

Osman, A. A. M., S. O.Yagoub and O. A. Tut. 2010. Performance of Faba bean (Vicia faba L.) cultivars grown in new agro-ecological regions of Sudan(South Sudan) Australian. *Journal of Basic and Applied Sciences,* ***4(11):*** *5516-5521.*

Olsen, S. R., Cole, F. and Dean, L.1954. Estimation of Available Phosphorus in soils by extraction with sodium bicarbonate (Circular No. 939). Washington, DC: USDA.

Oplinger, E. S., D. H. Putnam, J. D. Doll, and S. M. Combs. 1989. Field crops manual. Depts of Agronomy and Soil Science, Cooperative Extension Service and College of Agricultural and Life Sciences University of Wisconsin-Madison, WI 53706.

Patrick and Stoddard.2010. Physiology of flowering and grain filling in faba bean. *Field Crops Research* ***115(3),*** *234–242.*

Pandey, R.K. 1982. Time of sowing a major factor for higher seed yields of faba bean in Northern India. *FABIS Newsletter 1981.* ***3****:43-44.*

Peksen, E.2007. Non-destructive leaf area estimation model for faba bean *(Vicia faba L.).Scientia Horticulturae,* ***113(4):*** *322-328.*

Pilbeam, C.J. and P.D. Hebbethwaite .1990. Effect of plantPopulation density on spring – Sown field (*Vicia faba*L.) with different growth habits. *J. of agric. Sci., canb.****114****:19 - 33.*

Putman, A.R.1988.Allelopathy; problems and opportunities in weed management in the agro ecosystems: Ecological Approaches, CRC Press, Boca Roton, Florida.

Rajan, K. and Singh, A.K. 2012. Faba bean (Vicia faba L.) carbon sequestration and its role in soil quality. pp. 285-291. In: Singh, A.K. and Bhatt, B.P. (Eds.), Bean (Vicia faba L.): A potential leguminous crop of India, ICAR, RC for ER, Patna.

Rezene F. 1985.Review of weed science research activities in wheat and barley. A Review of Crop Protection Research in Ethiopia. Tsedeke Abate, Addis Ababa, Ethiopia.

Rezene Fessehaiyo.1994. Weed Research in cool season food legumes, pp. 252-275. In; Asfaw T.,Geletu B,M.C. Saxena and M.B. Solh (eds.).Cool-Season Food Legume's of Ethiopia. Proceedings of the First National Cool-season Food Legumes Review Conference, 16-20 December 1993. Addis Ababa, Ethiopia. ICARDA/institute of Agricultural Research.

Rezene Fessehaie and Getachew Agegnehu .2006. Response of faba bean to phosphate fertilizer and weed control on Nitisols of Ethiopian Highlands. *Ital. J. Agron. Riv. Agron.,* ***2****: 281-290.*

Rkmhay.1995.Harvest index: A review of its use in plant breeding and crop physiology. Annals of Applied Biology, **126:** 197-216.

Sahlemedhin and Taye.2000.procedures for soil and plant analysis. National soil Research center. Ethiopia Agriculture Research organization. Addis Abeba.Ethiopia.

Sarah, A.E., A.B. Hassan, and E.E. Babiker. 2009. Nutritional Evaluation of cooked Faba bean *(Vicia faba L.)* and white bean *(Phaseolus vulgaris L.)* cultivars.*Australian Journal of Basic and Applied Sciences* ***3:****2484-2490.*

Saxena, M.C. and R.A. Stewart.1983.Faba bean in the Nile valley. Report on the first phase of the I CARDA/IFAD Nile valley project, P. 70-74. MartinusNijhoff Publishers, The hague / Boston / London.

Schweizer, E. E.1988. New technological developments to reduce groundwater contamination by herbicides. *Weed Technology* ***2,*** *223-227.*

Shad, K., Khalil, A., Wahab, A., Rehman, F. M., Wahab, S., Khan, A., Amin, R. (2010). Density and planting date influence Phenological development assimilate partitioning and dry matter production of faba bean. *Pakistan Journal of Botany,* ***42,*** *3831–3838.*

Shalaby, Y. Y, and L. K. Mohamed. 1978 a. Variations in growth analysis of field beans due to plant density and phosphate fertilization at different planting date. *Egypt Journal of Agronomy* ***3(1)*** *1-11.*

Shalaby, Y. Y. and L.K.Mohamed. 1978b. Differences in yield of field bean due to planting date plant density and phosphate fertilization. *Egypt Journal of Agronomy. **3 (1):** 13-23.*

Shalaby, Y. Y. and L.K.Mohamed. 1981. Differences in yield of field bean due to planting date plant density and phosphate fertilization. Field Crop Abstracts No. 34.P. 72.

Sharifi P .2014. Correlation and path coefficient analysis of yield and yield component in some of broad bean (Vicia faba L.) genotypes. *Genetika**46(3)**:905-914*.

Singh, A.K., Chandra, N., Bharati, R.C., Dimree, S.K. 2010. Effect of seed size and seeding depth on Fava bean (Vicia fava L.) productivity. *Environmental Ecology, **28(3A):**1722-1527.*

Silim, S.N., and M.C.Saxena.1992. Comparative performance of some faba bean *(Vicia faba L.)* Cultivars of contrasting plant types. Growth and development in relation to yield, *Journal of Agricultural Science Cambridge, **118**: 333-342.*

Singh, A.K. and Bhatt, B.P. 2012. Faba Bean (Vicia faba L.): A potential leguminous crop of India. ICAR, RC for ER, Patna, 518p.

Singh, A. K., B. P. Bhatt, P. K. Sundaram, A. K. 2013.Gupta and Deepak Singh. Planting geometry to optimize growth and productivity in faba bean (*Vicia faba L.)* and soil fertility. *Journal of Environmental Biology. **34(1),** pp. 117.*

Sjodin, J. 1982: Protein quantity and quality in Vicia faba. Pages 319-331 in Faba Bean Improvement (Hawtin, G. and Webb, C., Eds.).MartinusNijhoff Publishers, The Hague, the Netherland.

Squire, G. R.1993. The physiology of tropical crops. *Tropical Agricultural Science, **3,** 120–280.*

Stagnari, F. and M. Pisante.2011. The critical period for weed competition in French bean (Phaseolus vulgaris L.). In Mediterranean areas. *Crop Protection **30**, 179-184*

Stroud.A, 1989.Weed Management in Ethiopia.An Extension and Training Manual. FAO.Rome.

Sustainable land Management Programme (SLMP).2010. Causes, consequences and solution of land degradation in Omo Nadda district: Annual report by SLMP woreda level. Nadda, Ethiopia.

Statistical Analysis system (SAS).2008. SAS /STAT. 9.2 user's guide, Cary, NC. SAS Institute Inc. United States of America Schmidtke, K., and R. Rauber.*Grain legumes and nitrogen cycling in organic crop systems. Grain legumes **30**:16 -17.*

Stroud A, Parker C. 1989. A weed identification guide for Ethiopia. Food and Agriculture Organization of the United Nations, Rome, Italy, 213 p.

Subash, N., Priya, N. 2012. Climatic requirements for optimizing faba bean *(Vicia faba L.)* production In: Faba Bean *(Vicia faba L.)* A Potential Legume for India. (Eds.), Singh and Bhatt. ICAR, RC for ER, Patna, pp. 197-204.

Tafere M, Tadesse D and Yigzaw D., 2012. Participatory varietal selection of faba bean *(Vicia faba L.)* for yield and yield components in Dabat district, Ethiopia. *Wudpecker Journal of Agricultural Research, **1**: 270 – 274.*

Tadesse T, Fikere M, Legesse T, Parven A .2011. Correlation and path coefficient analysis of yield and its component in faba bean (Vicia faba L.) germplasm. *Int Journal of BiodiversConserv 3:**16.** 376-382.*

Taj, F. H., Akber, H., Basir, A., &Ullah, N. 2002. Effect of Row spacing on Agronomic traits and Yield of Mung bean (Vignaradiata L. Wilczek). *Asian Journal of Plant Sciences, **1,** 328–329.*

TalalThalji and GhalibShalaldeh. 2006. Effect of planting Date on Faba Bean *(Vicia faba L.*) Nodulation and Performance under Semiarid conditions.

TamadoT,MilbergP.2000.Weedflorainarablefieldsof easternEthiopiawithemphasisontheoccurrenceof*Partheniumhysterophorus.Weed Research, **40**: 507-521.*

Tawaha, ARM., Turk, MA, Lee, KD. 2005. Adaptation of chickpea to cultural practices in Mediterranean type environment. *Journal of Agriculture and Biological Science**.** **1(2):**152-157.*

Teama, E.A., 1994. Effect of skip irrigation and plant density on yield and quality of faba bean. *Assiut Agric. Sci.* ***25(5)*** *19-27.*

Teame, G., Ephrem, S., Lemma, D., 2017. Participatory evaluations of faba bean (Vicia faba L.) Varieties in EndaMekoni District, Northern Ethiopia. Afr. J. Agric. **4(2),** 263-268.

Tebeest, D.O. and Templeton, G.E.1985. Mychoherbicides: progress in the biological control of weeds .*Plant Diseases, **69**: 6-10.*

Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Tepe I., Erman, M., Yergin, R. and Bukun, B. 2011. Critical period of weed control in chickpea under non-irrigated conditions. *Turk Journal of Agriculture and Forestry, **35**: 525-534.*

Thangwana, N. M., and Ogola, J. B. O. 2012. Yield and yield components of chickpea (Cicer arietinum): Response to genotype and planting density in summer and winter sowings. *Journal of Food, Agriculture & Environment, **10,** 710–715.*

Thompson, R. and H. Taylor. 1 977. Yield components and cultivar sowing date and density in field beans *(Vicia faba L.).Ann. Appl. Biol. **86**: 313-320.*

Tisdale Samuel, Nelson, W.L., Beaton, J.D. and Havlin, J.L. 2002. Soil fertility and fertilizers. (5th Eds.), Prentic-Hall of India, Netherlands, Wageningen. 371pp.

Thulin Mats. 1983. Leguminosae of Ethiopia. Opera Bot. **8:** l-223. Copenhagen.

Torres, A.M., M.T. Moreno, and J.I. Cubero. 1993a. Genetics of six components of auto fertility in Vicia faba. *Plant Breeding **110**:220-228.*

Turk, K. J., Hall, A. E., &Asbell, C. W. 1980. Drought adaptation of cowpea. Influence of drought on seed yield. Agronomy Journal, **72**, 413–420.

Turk, M. A. and A. M. Tawaha. 2002. Impact of seedind date and method of phosphorus application in Faba bean (*Vicia faba* L. minor) in the absence of moisture stress. Biotechnology Argon, Soc. Enveriom., **6(3):**171-178.

Turk, M. A., Tawaha, A. and El-Shatnawi, M. K. J. 2003. Response of lentil (*Lens culinarisMedik)* to plant density, sowing date, phosphorus fertilization and ethephon application in the absence of moisture stress. *Journal of Agronomy and Crop Science, **189(1**), 1–6.*

Turpin, J. E., Robertson. M. J., Hillcoat. N. S. and Herridge.D. F. 1991. Faba bean *(Viciafaba L.)* in Australia's northern grains belt: canopy development, biomass, and nitrogen accumulation and partitioning *.Australian Journal of Agricultural Research **53(2):**227-237.*

Van Aker, RC. C. J. Swanton and S. F. Weise. 2013. The critical period of weed control in soybean (Glycine max L.). *Weed Science **41,** 194-200.*

Vandana K, Dubey DK (1993) Path analysis in faba bean. *FABIS **32**: 23-24.*

Walkley, A. and Black, I. A. 1934. Method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science, **37,** 29–38.*

Wani, S.P., McGill, W.B., Haugenkozyra, K.L. Robertson, J.A. and Thurston, J.J. 1994. Improved soil quality and barley yields with faba beans, manure, forages and crop rotation on a gray luvisol. *Canadian Journal of Soil Science,* ***74****: 75-84.*

Winch, T. 2006. Growing Food. A Guide to Food Production. Springer. 58:86-93.

Worku W. and Demisie, W. 2012. Growth, light interception and radiation use efficiency response of pigeon pea (CajanusCajan) to planting density in Southern Ethiopia. Journal of Agronomy, **11,** 85–93.

Yassin TE .1973. Genotypic and phenotypic variances and correlations in field beans (Vicia faba L.). *J AgricSci****81****: 445-448.*

Yohannes Degago.1997. Faba Bean (Vicia faba L.) in Ethiopia. Inistitute of Biodiversity Conservation and Research (IBDCR), Addis Abeba, Ethiopia.

Yucel, D. O.2013. Optimal intra-row spacing for production of local faba bean *(Vicia Faba L. Major*) cultivars in the Mediterranean conditions. *Pak. J. Bot.* ***45(6),*** *pp. 1933-1938. 2013.*

Zahran, M.K.1983. Studies on Orobanche and weed control Egypt ICARDA/IFAD Nile Valley Project on faba beans, Report of the 3rd annual meeting. pp. 44-45. Aleppo, Syria January 1983.

Zeidan, E.M.;E. Nagger, and M. I. I.Makhloof.1990.The influence of planting methods, plant densities and weed control treatments on seed yield and its quality of faba bean. *Zagazig J. Agric. Res****. 17(4A):*** *1079 – 1092.*

Zohary, D. and Hopf, M. 2000. Domestication of plants in the old world: The origin and spread of cultivated plants in West Africa, Europe and the Nile valley. Oxford University Press, New York, USA, 316pp.

7. APPENDICES

APPENDIX TABLE 1. MEAN SQUARES OF ANALYSIS OF VARIANCE FOR WEED AND FABA BEAN PARAMETERS AS AFFECTED BY INTER ROW SPACING AND WEED MANAGMENT AND THEIR INTERACTION IN OMONADA DURING 2018 CROPPING SEASON.

SN	Parameters	Source of variation				CV (%)
		Spacing (3)	Weeding frequency(4)	Spacing ×weeding frequency(12)	Error(38)	
1	weed densitym^{-2}					
	20DAE	47.0362ns	5903.87257*	28.18372**	19.48789	16.64
	40DAE	29.68808ns	4114.22418*	70.41702**	34.1344	26.3
	60DAE	50.69588*	3391.91933*	72.63621**	4.5336	13.01
2	weed dry weight(g $m^{-2)}$					
	20DAE	41.745202ns	1200.325986*	13.82122**	1.818473	11.81
	40DAE	68.77871*	4098.95386*	52.64902**	12.01626	18.87
	60DAE	97.00979*	7669.26837*	106.42429**	7.48298	14.76
3	TSW	1375.93*	122.39*	89.73**	10.12	0.41
4	YD	1612698.8*	1559701.71*	174035.56**	15450.21	4.19
5	BM	9531018.5*	8102578.44*	1583751.13**	326757.98	7
6	HI	92.25*	13.81*	6.12**	2.21	4.09
7	PH	53.83*	181.11*	486.07**	78.26	4.43
8	FPH	712.90*	134.45*	47.52*	127.24	14.02
9	NPTPP	0.35*	0.37ns	0.23ns	0.11	66.48
10	NPPP	23.95**	7.59*	2.58*	4.07	21.09
11	NSPP	228.58*	49.88ns	15.69ns	26.82	21.79
12	NSPPo	0.08*	0.06*	0.07**	0.05	8.87

13	DF	20*	0.01^{ns}	299.69^{ns}	0.17	1.4
14	DM	245*	0.02^{ns}	38.68^{ns}	0.12	1.74
15	LA	192.79^{*}	142.52*	46.54**	11.46	12.36
16	LAI	5.54*	2.92*	2.56**	0.11	8.97
17	AGY	1305805.8*	1263144.558*	141052.092**	12508.59	4.19
18	GFB	522514411*	505343354*	56387523**	5005867	4.46
19	NB	628369405*	452715704*	56387523**	5005867	4.89

ns, * and ** are non-significant, significantly different at 5% P level and significantly different at 1% P level, respectively; Figures in parentheses are the degree of freedom. DAE=Days after emergency; TSW=Thousand seed weight; YD=Grain yield; BM=total dry biomass ;HI=harvest index ;PH=plant height; FPH=first pod setting height; NPTPP=Number of productive tillers per plant ;NPPP=Number of pods per plant; NSPP=Number of seeds per plant; NSPPo=Number of seed per pod; DF=Days to flowering; DM=days to physiological maturity; LA=leaf area; LAI=Leaf area Index;AGY=Adjusted Grain yield; GFB=Gross field benefitting=Net benefit

Appendix table 2.Monthly average air temperature and rainfall at Omo nada during the crop growing season of 2018

Month	Rainfall (mm)	Min. Temp. (^{o}C)	Max. Temp. (^{o}C)	Mean Temp. (^{o}C)
January	66.2	11.5	26.4	18.95
February	71.3	10.1	26	18.05
March	82.2	10.3	24.1	17.2
April	77.6	10.4	25.6	18
May	114.2	10.4	25.6	18
June	188.4	10.2	26.1	18.15
July	190.3	10.7	24.6	17.65
August	179.1	11.5	28	19.75
September	101	11.2	26.8	19
October	124	10.8	26.6	18.7
November	55	10.6	28.3	19.45
December	27	9.5	28.2	18.85
Mean	1276.3	10.6	26.36	18.48

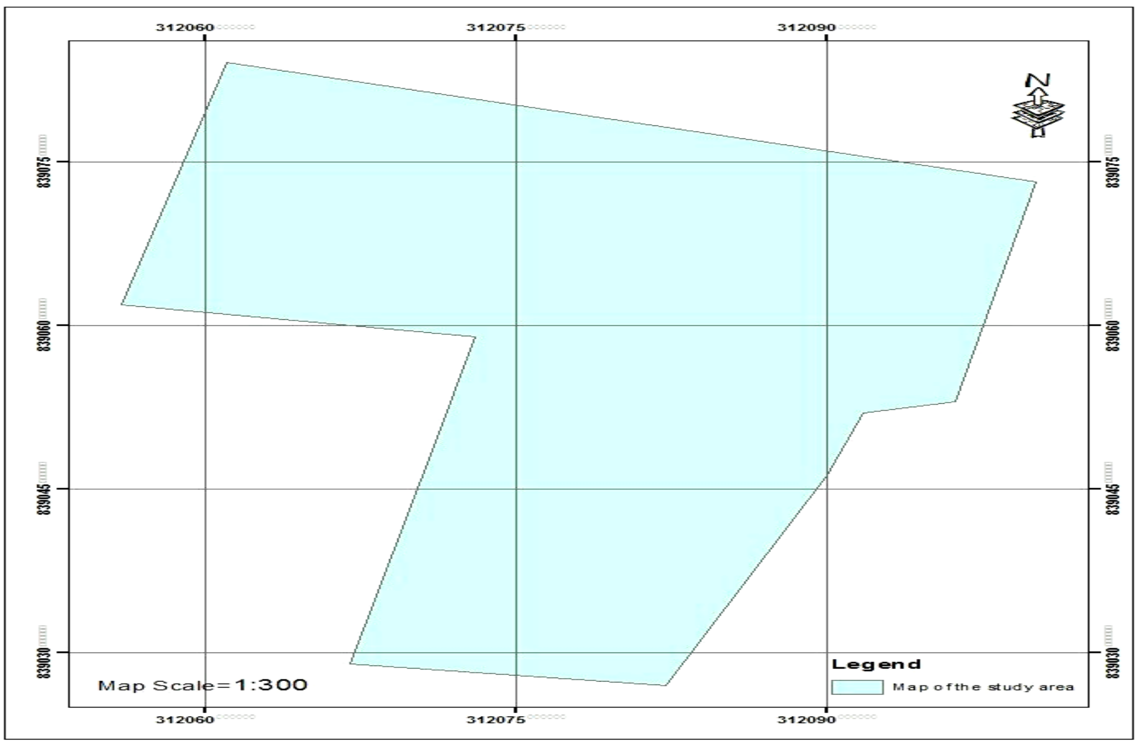
Source: Western Oromia meteorology Service Center Jimma, 2018.

Appendix Table 3. Pearson correlation coefficients among different growth, yield, and yield components and weeds parameters of faba bean in 2018

	20DAE(NW)	20DAE(WD)	40DAE(NW)	40DAE(WD)	60DAE(NW)	60DAE(WD)	TSW	YD	BM	HI	PH	FPH	NPTPP	NPPP	NSPP	NSPPo	DF	DM	LA	LAI
20DAE(NW)	1	0.98**	0.57**	0.58**	0.58**	0.68**	-0.13ns	0.18ns	-0.15ns	-0.10ns	0.09ns	0.15ns	-0.16ns	-0.16ns	-0.10ns	0.16ns	0.08 ns	0.08ns	-0.01ns	-0.15ns
20DAE(WD)		1	0.53**	0.56**	0.55**	0.66**	-0.11ns	-0.14ns	-0.13ns	-0.07ns	0.08ns	0.11ns	-0.13ns	-0.15ns	-0.09ns	0.18ns	0.10 ns	0.10ns	0.03ns	-0.17ns
40DAE(NW)			1	0.94**	0.91**	0.87**	-0.27**	-0.52**	-0.46**	-0.21ns	-0.09ns	0.10ns	-0.35*	-0.01ns	0.01ns	0.06ns	-0.01 ns	-0.00ns	-0.40**	-0.27*
40DAE(WD)				1	0.96**	0.95**	-0.21*	-0.52**	-0.47ns	-0.19*	-0.17*	0.07ns	-0.29*	-0.04ns	-0.04ns	0.01ns	0.06 ns	0.06ns	-0.40**	-0.39**
60DAE(NW)					1	0.96**	-0.27	-0.49**	-0.45ns	-0.17ns	-0.15ns	0.09ns	-0.34**	-0.09ns	-0.08ns	0.01ns	-0.01 ns	-0.00ns	-0.42**	-0.336
60DAE(WD)						1	-0.25**	-0.53**	-0.46**	-0.25**	-0.19*	0.14ns	-0.32**	-0.15ms	-0.15ns	0.01ns	0.03 ns	0.03ns	-0.39**	-0.318
TSW							1	0.14ns	-0.14ns	0.54**	0.03ns	-0.39**	0.34**	0.41**	0.41**	-0.01ns	0.76**	0.76**	0.52**	-0.50**
YD								1	0.87**	0.42**	0.25*	-0.26*	0.31**	0.38**	0.27*	0.15ns	0.01ns	0.02ns	0.53**	0.07ns
BM									1	-0.06ns	0.27*	-0.1ns	0.06ns	-0.03ns	-0.01ns	0.05ns	-0.19*	-0.19*	0.42**	0.35**
HI										1	0.22*	-0.35*	0.38**	0.32**	0.39**	0.19*	0.38**	0.38**	0.25*	-0.50**
PH											1	0.19ns	0.04ns	0.02ns	0.07ns	0.09ns	-0.12*	-0.12*	-0.01ns	0.13*
FPH												1	-0.37**	-0.5**	-0.5**	-0.11ns	-0.41**	-0.40*	-0.29*	0.39**
NPTPP													1	0.14ns	0.13ns	0.05ns	0.29*	0.3**	0.25*	-0.21ns
NPPP														1	0.94**	-0.01ns	0.45**	0.44**	0.13ns	-0.43**
NSPP															1	0.31**	0.49**	0.499**	0.18*	-0.48**
NSPPo																1	0.13ns	0.13ns	0.19ns	-0.17ns
DF																	1	0.99**	0.40**	-0.75**
DM																		1	0.41**	-0.75**
LA				-															1	0.1*
LAI																				1

* = Significant at P < 0.05; ** = Significant at P < 0.01; ns=non-significant; DAE=Days after emergency; NW=weed density per m^{-2} ;WD=weed dry weight(gm^{-2});TSW; thousand seed weight=seed yield: HI=Harvest index; PH=Plant height; FPH=first pod height: NPTPP=Number of productive tillers per plant; NPPP=Number of pods per plants; NSPP=Number of seed per plant; NSPPo=Number of seed per pod; DF=Days to flowering; DM=Days to physiological maturity; LA=Leaf area; LAI=Leaf area index.

Appendix Figure 1: Research Site Map



Appendix Figure 2: Different Pictures during Research periods