EFFECT OF DEFICIT IRRIGATION ON WATER PRODUCTIVITY AND YIELD OF COMMON BEAN (*PHASEOLUS VULGARIS L.*) AT MELKASSA, CENTERAL RIFT VALLEY, ETHIOPIA

MSC THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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EFFECT OF DEFICIT IRRIGATION ON WATER PRODUCTIVITY AND YIELD OF COMMON BEAN *(PHASEOLUS VULGARIS L.)* AT MELKASSA, CENTERAL RIFT VALLEY, ETHIOPIA

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ADVISORS' APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

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This is to certify that the thesis entitled **"Effect of Deficit Irrigation on Water Productivity and Yield of Common Bean (*Phaseolus Vulgaris L.*) at Melkassa, Central Rift Valley, Ethiopia"** submitted in partial fulfillment of the requirement for the degree of maters' with specialization of in **Irrigation and drainage Engineering**, the graduate program of the school of water resources and irrigation Engineering had been carried out by **Abera Tesfaye ID. No PGIDE 001/10** under my supervision. Therefore, I/we recommend that the student had fulfilled the requirement hence here by can submitted to the department.

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We, the undersigned, members of the board of the final open defense by **Abera Tesfaye Tefera** have read and evaluated his/her thesis entitled "**Effect of Deficit Irrigation on Water Productivity and Yield of Common Beans (*Phaseolus vulgaris L.*) at Melkassa, Central Rift Valley, Ethiopia**" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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DEDICATION

I dedicate this thesis to all of my families specially my mother Yeshi Jote and my wife Habtamua Yemane for their love and committed partnerships in the success of my life for nursing me with care, love and moral support.

STATEMENT OF THE AUTHOR

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

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Date of Submission ____________________________

LIST OF ABBREVATIONS AND ACRONYMS

CU	Coefficient of Uniformity
DU	Coefficient of Distribution
Dz	Root Depth
EIAR	Ethiopian Institute of Agricultural Research
ET_C	Crop Evapotranspiration
ET_O	Reference Evapotranspiration
FAO	Food and Agricultural Organization
FAOAQOUSTAT	Food and agricultural organization’s Information System on Water and Agriculture
FAOSTAT	Food and agricultural organization Corporate Statistical Database
FC	Field Capacity
Fn	Net Irrigation Water Requirement
FWUE	Net Irrigation Water Use Efficiency
G	Soil Heat Flux Density
GWR	Gross Water Requirement
HI	Harvested index
IWUE	Irrigation Water Efficiency
Kc	Crop Coefficient
LSD	Least Significant Difference
m a.s.l	Meter above sea level
MARC	Melkassa Agricultural Research Center

MOA	Ministry of Agriculture
MOWR	Ministry of Water Resources
MRR	Marginal Rate Of Return
ND	No Date
P	Moisture Depletion Level
P_b	Bulk Density
PH	Soil Acidity or Basicity Level
PWP	Permanent Wilting Point
RAM	Readily Available Water
SMD	Soil Moisture Deficit
T	Temperature
U_2	Wind speed at 2 meter Height
USDA	Unite State Department of Agriculture
WWAP	United Nations World Water Assessment Programme/UN-Water

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ABSTRACT

The experiment was conducted at Melkassa Agricultural Research Center during off season under semi-arid climatic condition where moisture stress is higher. The study was under taken to evaluate effect of deficit irrigation on water productivity and yield of common bean (Phaseolus vulgaris L.).The experiment was split plot design with three common bean varieties as main plots and four deficit irrigation levels as sub plots all of which replicated three times. Four deficit irrigation levels 100%ETc, 85%ETc, 70%ETc, 55%ETc and three varieties SER-119, Bio fortified small seed-5, Awash-2 were used for treatment combination. The combined result indicates that there was a significant variation among treatments for yield, above ground biomass and water productivity. All common bean varieties were significantly affected under deficit irrigation levels. Consequently, highest yield (3.4 ton/ha) was obtained from irrigating 100%ETc followed by (3.2 ton/ha) with 85%ETc less yield reduction. In contrast the intermediate (2.8 ton/ha) and smallest yield (2.4 ton/ha) was obtained from irrigating 70ETc and 55%ETc.Water productivity was ranged from (0.83 kg/m^3*) at full irrigation to (1.33 kg/m*^{3}*) at higher deficit irrigation. Based on obtained yield and water productivity, under a limited water supply situation where the goal was to gain highest possible yield of common bean and water productivity utilizing application of water from 70%*ET_C* to 85%*ET_C* at each irrigation event offers opportunities for water saving with yield reduction which was compensated by irrigating other area by saved water. The result of economic analysis shown that the highest net benefit obtained from irrigating full 100%ETc of the three common bean varieties. Based on obtained data the MRR was greater than 50% irrigating common bean with deficit irrigation 85%, 70% and 55% is economically feasible depending on accessibility of water.*

Key words Deficit irrigation, common bean, evapotranspiration, water productivity, water stress

1. INTRODUCTION

1.1 Background

Water use was increasing worldwide by one percent per year since the 1980s, driven by a combination of population growth, socio-economic development and changing consumption patterns (WWAP, 2019).Global water demand is expected to continue increasing at a similar rate until 2050 accounting for an increase of 20% to 30% above the current level of water, mainly due to rising demand in the industrial and domestic sector (WWAP, 2019). At the beginning of 2019, the world population is approximately 7.7 billion. Swarming of billions of population related to fresh water shortages and food security issues necessities the shifting of fresh water from agriculture to other more pressing uses global fresh water (Wagan and Khoso, 2013). One-third of the world's most cultivated lands faces a shortage of water for agriculture, climate change make this problem more serious (Nouralinezhad et al., 2018). Water is more important resources for all socio-economic development and for protecting healthy ecosystems.

Fereres and Soriano (2007) stated that at present and in the future, irrigated agriculture will take places under scarce water. Irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water used. Farmers and governments forced to change their irrigation practices due to continuous decrease in water resources, increasing water demand for agriculture and other sector like municipal water need (Alomran et al., 2012). Inadequate or expensive available water supply makes it impossible to irrigate the entire irrigable land area. To minimize cost of water and the problem of supply irrigators must decide between fully irrigating a small area for maximum production and reducing the depth of water applied per unit area in order to increase the area put under irrigation.

The Ethiopian economy is mostly based on agriculture, with industry and services slightly increasing recently (FAO, AQOUSTAT, 2016). Agricultural activity is the largest consumer of water in Ethiopia. Ethiopia is endowed with a substantial amount of water resources but it shows very high hydrological variability. Because of high hydrological variability Ethiopia is facing tremendous challenges meeting the food needs of rapidly growing population (Baye, 2011). Although large scale water resources development has been taking place in the Ethiopia, still now vast majority of people do not have potable water for drinking. Insufficient and unreliable supply of water is the major challenge for food production in many part of Ethiopia. Therefore, development of small scale irrigation and efficient utilization of water resources is important for countries like Ethiopia, which has huge water resources: but their population is chronically food insecure.

One important solution for water scarcity is deficit irrigation practice. Deficit irrigation is the application of water below full crop ETc (evapotranspiration) requirements, can be an effective tool to reduce applied water and increase revenue (Chaves et al., 2007; Fereres and Soriano, 2006). Deficit irrigation practices differ from traditional water supplying practices. FAO (2002) states that the main objective of deficit irrigation is to increase the water use efficiency (WUE) of a crop by eliminating irrigations that have little impact on yield. The resulting yield may be small compared with the benefits gained through diverting the saved water to irrigate other crops. Further, yield reductions from disease and pests, losses during harvest and storage, and arising from insufficient application of fertilizer are much greater than reduction in yields expected from deficit irrigation (FAO, 2002)

The practice of deficit irrigation aims at obtaining maximum water use efficiency and stabling yields (Geerts and Raes, 2009). Before implementing a deficit irrigation programme, it is necessary to know crop yield responses to water stress (Kirda and Kanber, 1999). English et al. (1990) stated that the success of deficit irrigation is due to three benefits: improved water use efficiency, lesser irrigation cost and more availability of water for other use. Irrigation level, duration of deficit irrigation and crop grow stages is affected by the magnitude of deficit irrigation. According FAO (2000) in deficit irrigation application, the crop is exposed to a certain level of water stress either during a particular growth period or throughout the whole growing season, without significant reduction of crops yields.

To overcome the scarce water supplies, deficit irrigation is an important tool to achieve the goal of reducing irrigation water use. The important of deficit irrigation is interesting but attention to it is not given. Therefore, deficit irrigation practices are necessary for optimal vegetative and reproductive development in the periods of insufficient precipitation during the growing season of crops.

Pathania et al.(2014) stated that common bean (*Phaseolus vulgaris L.*) is one of the most important legume crops grown in all continents of the world excepts Antarctica, because of its high protein, fiber, and complex carbohydrate content. The demand’s for common bean is increasing due to population growth and improvement in economies, especially in developing countries. Common bean is one of the major food and cash crops in Ethiopia and it has considerable national economic implication (Kedir et al., 2014). Demelash (2018) stated that common bean ranks third as an export commodity in Ethiopia, contributing about 9.5% of total export value from agriculture. It is mainly grown in eastern, southern and south western part of Ethiopia. Common bean is also one of the major crops in the middle Rift Valley of

Ethiopia. Common bean production area is increasing in the wet zone and decreasing in the dry zone, but yield is declining in both zones. Ethiopian farmers highly prefer common beans because of its fast maturing characteristics that enables householder to get cash income required to purchase food and other house hold needs when other crops have not yet matured (Legesse et al.,2006).

1.2 Statement of the Problem

Ethiopia is one of the most important beans producing country in the world. But FAO (2008) stated the average beans yield per annum in Ethiopia and other African countries is always lower than that of the world. In order to improve the production of common beans in the country it is important to know and forecast the limiting factor. The principal constraints to increasing bean production are: moisture stress problem, shortage of labor, weeds and biotic factors has been mention as one of the primary sources of lower beans production.

Growing competition for scarce water resources will reduces water availability for irrigation. Increasing proper water management which results in high crop water productivity are important factors which needs higher consideration in agriculture. Irrigation scheduling is governed by evapotranspiration. Central Rift Valley is one of environmentally vulnerable region in Ethiopia, where crop production has expanded rapidly (Janseen, 2007). Like other region in the world climate variability is affect the agriculture with flooding in the wet season and warming or moisture stress in dry season. This warming trend imposes its impact on evaporative demand particularly in the Central Rift Valley for crop production where, results problem of moisture stress in dry season. The sensitivity of common bean crops to moisture stress occurs in this season. In the Central Rift Valley farmer uses rain water and irrigation to produce agricultural products specially cash crops. Especially in off season moisture stress level increases and needs more water for irrigation which ultimately produces irrigation water scarcity. To overcome this problem this research is initiated to determine the effect of deficit irrigation on yield and water productivity under deficit irrigation practice.

1.3 Objectives

1.3.1 General Objectives

The general objective of the study is to determine the effect of deficit irrigation on yield and water productivity of common bean at Melkassa, Central Rift Valley of Ethiopia.

1.3.2 Specific objectives

- To determine the effect of deficit irrigation on yield of common bean varieties.
- To determine the effect of deficit irrigation on water productivity of common bean varieties.
- To identify the level of deficit irrigation that gives high economic return.

1.4 Research Questions

The scarcity of water constraints linking with issues of crop production under irrigation a number of questions can be raised. This study tries to address the following major research questions.

- To what extent deficit irrigation is affect common bean varieties?
- To what extent deficit irrigation is affect water use productivity of common bean varieties?

1.5 Scope and Limitation of the Study

The study is considers consequence of deficit irrigation on three common bean varieties.

Common bean are chosen because of its widely cultivated in Central Rift Valley. Four irrigation level treatments were used as treatment combination. Under this study yield of common bean, water productivity level and seasonal depth of water requirement under full irrigation and deficit irrigation was documented in relation to water shortages. Duration of the experiments was one season. The study uses model such as CROP WAT.8 and SAS version 9 packages for crop water calculation and data analysis respectively. The experiment was limited in determination of nutritional composition of common bean yield under deficit irrigation practices. Understanding groundwater contribution for irrigation in the study is beyond this study.

1.6 Significance of the Study

Agriculture uses 70% of fresh water worldwide (WWAP, 2018). However, most irrigation systems are inefficient. The availability and spatial variation of water differ from place to place and from time to time. Therefore, supplies of water decline, the cost of water increase. These interns increase the competition between water users which also increase conflict of upper stream and downstream water users. The Central Rift Valley is of the semi-arid regions in Ethiopia where water scarcity is serious and it differs from year to year as well as season to season. This scarcity of water is an impact on the production of crop. Therefore deficit irrigation techniques are very vital when it comes to an efficient allocation of scarce resources. Considering the above problem the study generate information on water management such as evapotranspiration of common bean under deficit irrigation condition and also elaborate information on sensitivity of common bean, timing and amount of water applied. The result of the study is helpful for improving common bean production and the food security of the farming community.

2. LITRATURE REVIEW

2.1 Water Resources and Irrigation Potential of Ethiopia

Ethiopia is endowed with a substantial amount of water resources (Berhanu et al., 2014). There are 12 basins in the Ethiopia. Those are 8 river basins, 1 lake basin and remaining 3 are dry basins with no insignificant flow out of the drainage system. Ethiopia is considered as water tower of horn of Africa because of all basins originates from highland; high rain fall area and the huge amount of water running into the river basin system (Berhanu et al., 2014). Limiting financial resources, lack of good governance and technical challenges are factors for this potential not fully utilized and translated into developed.

The climate in Ethiopia is geographically quite diverse, due to its equatorial positioning and varied topography (Block, 2008).The economy of the country is highly dependent on the agriculture. In Ethiopia, in spite of the huge potential of fresh water resources, recurrent droughts and rapidly progressing desertification have disrupted food and fiber production systems. Due to this food shortages and starvation is ever increasing. The national economy is either stagnant or declining while population size is rapidly increasing. Although the country's renewable surface and ground freshwater amounts to 123 and 2.6 billion cubic meters per annum, respectively, its distribution in terms of area and season does not give adequate opportunity for sustainable growth to the economy (Birhane, no date). This condition is clearly seen in Central Rift Valley affecting agricultural productivity.

Ethiopia covers a land area of 1.13 million Km^2, of which 99.3% is a land area and the remaining 0.7% is covered with water bodies of lakes MOWR (2002). Hagos et al. (2009) point out that the total irrigated land area account for approximately 5% of the total cultivated land. Awulachew et al. (2010) stated the total potential irrigable land area in Ethiopia is estimated to be around 3.7 million hectares. In 2011 the cultivated agricultural land of Ethiopia under cultivation is about 12 million ha (MoA, 2011a). Moreover, based on many study potential and actual irrigated area is not precisely investigated. But the average estimate of irrigable land in Ethiopia is about 3.5Mha (Gebremedhin et al., 2015). Presently, the MoWR (ministry of water Resources) has identified 560 irrigation potential sites on the major river basins. Both irrigated and rain fed agriculture is important economy. Nevertheless, virtually all food crops (97 percent) in the Ethiopia come from rain agriculture, with the irrigation subsector accounting for only about 3% of food crops (FAO, 2015). But there is significant potential to increase irrigation potential through various surface water schemes, eventually there are many challenges as most of the surface water potential is located in pastoralist areas due to land availability and flow concentration in these low land areas.

2.2 Irrigation Water Demand in Ethiopia

Irrigation in Ethiopia is considered as a basic strategy to alleviate poverty and hence food security (Gebremedhin, 2015). It is useful to transform the rain-fed agricultural system which depends on rainfall into the combined rain-fed and irrigation agricultural system. Agriculture in Ethiopia is small-scale, dominated by limited access to technology and institutional support services. There are about three million smallholder farmers, with an average farm size from 0.5 hectares to 2 hectares, producing 95 percent of the country's food crops (FAO, 2015). According Ulsido and Alemu (2014) undertaking the water management assessment of the existing small scale irrigation schemes is vital to make an appropriate decision between implementing new interventions and improving the existing ones to enhance the performance and contribution to advance food security and cash income of smallholders.

Agricultural production is the major user of the Earth's water resources. The water demand for this is sector is increasing steadily with its root on population growth. River basin master plan studies and related surveys indicate a maximum irrigation potential 5.7 million ha. But about 3.7 million ha is commonly quoted. The irrigation potential of Ethiopia as estimated in 2016 was about 2.7 million ha, considering the availability of water, land resources, technology and finance (FAO, AQOUSTAT, 2016). On other hand agriculture is the main water-withdrawing sector. Also agricultural water withdrawal in 2016 was estimated at around 9000 million m^3 (FAO, AQOUSTAT, 2016).This figure however, seems to be law estimate considering both the large increase in irrigated areas and the changing pattern in irrigated crops.

2.3 Deficit irrigation

2.3.1 Concept of Deficit Irrigation

The limited and/or expensive available water supply makes it impractical to irrigate land area. So suitable water utilization in agriculture is critical and has to be practiced. To overcome these irrigators must decide between fully irrigating a small area for maximum production and reducing the depth of water applied per unit area in order to increase the area put under irrigation. Deficit irrigation is an optimization strategy that allows to some extent of water stress during a certain cropping stages or the whole season without a significant reduction in a yield (Dejene et al., 2017). Merit of deficit irrigation in crop production is an approach to save in areas of water shortage and longer drought during production period so as to maximize water productivity. According to FAO (2000) in deficit irrigation application, the crop is exposed to certain level of water stress either during a particular growth period or throughout the whole growing season, without significant reductions in yields. Ali et al. (2007) stated that the expectation in yield reduction (especially in water-limiting situations) will be compensated by increased production from the additional irrigated area with the water saved as result of deficit irrigation. By limiting water application to during whole season, this practice aims to maximize water productivity than maximize yields.

Deficit irrigation requires precise knowledge of crop response to drought stress, as drought tolerance varies considerably by genotype and phonological stage. When correctly done deficit irrigation benefits include substantial savings in irrigation water and limiting unnecessary shoot growth.

As practicing deficit irrigation agronomic practices such as plant population, application of fertilizer, planting date may require modification that means decrease plant population, less fertilizer, implementing flexible planting date and select shorter-season varieties. The appropriate application of water, regulated irrigation or deficit irrigation practices can produces significant saving in irrigation water allocation (FAO, 2002). Regulated irrigation can lead, in principle to increased profits where water supplies are limited.

2.3.2 Effect of deficit irrigation on common bean

As much as 60% of common bean production in the developing world occurs under condition s of significant drought stress. This is probably the reason why the average global yield of beans remains low. Beans are rapidly growing plants and very sensitive to soil water conditions and quality, so yield can suffer greatly from even brief periods of water shortage.

Common beans have shallow rooting system and it requires frequent irrigation. So it was respond strongly to deficit irrigation. Deficit irrigation can affect growth, development and physiological process of common bean crops which can reduces grain yield and above ground biomass. The amount of irrigation applied at the developmental (vegetative and reproductive) stages, affect bean production in plant growth and yield are reduced by water stress. Bean yield loss due to drought stress depends on severity and duration of stress and genetic variations of genotypes. Irrigation not only reduces the risk of crop failure but also increases the productivity of beans with larger harvests (Carvalho et al., 2018).Common bean has high nitrogen requirement for expressing their genetic potential. Water stress is a very common problem during the growing period often aggravated by the declining soil fertility, diseases, and limited access to improved seeds and suboptimal agronomic practices.

2.3.3 Management of deficit irrigation

Management of deficit irrigation differs from traditional water applying practices. Before implementing a deficit irrigation program it is necessary to know crop yield responses to water stress during grows stage or whole season. Deficit irrigation requires precise knowledge of crop response to drought stress, as drought tolerance varies considerably by genotype and phonological stage. When water deficit occurs during a specific crop development period, the yield response can vary depending on crop sensitivity at that growth stage. Crops that are most suitable for deficit irrigation are those with a short growing season and are tolerant of drought. Both the timing and level of water stress are critical to the success of deficit irrigation. Under deficit irrigation practices, agronomic practices may requires modification, for instance decrease plant population, apply less fertilizer, adopt flexible planting dates and select shorter – season varieties (Kirda, 2002). On other hand understanding of plant water relations and soil water management is essential to use irrigation successfully to produce consistent yields of high-quality. One strategy for managing deficit irrigation consists of trying to mitigate the impact of water stress on crop growth and grain yield by withholding irrigation at growth stages that are less sensitive to water deficit as compared to others. It was practiced when water allocation was limited (Rudnick et al, 2019). If peak ETc demands cannot be met, such as insufficient pumping capacity, a reduced percentage of full irrigation requirements of full irrigation may be a more appropriate strategy, which is limited irrigation water. This strategy of crops a crops potential ETc, and therefore, it moderates crops water stress by targeted allocation of the available water through available water throughout the growing season.

2.3.4 Advantages and Constraints of Deficit Irrigation

The main advantages of deficit irrigation are it maximizes the productivity of water. In arid and semi-areas where water is the limiting factor for crop production, maximizing water productivity by deficit irrigation is often economically more profitable for the farmer than maximizing yield. Deficit irrigation creates a less humid environment around crop than full irrigation, so it can decrease the risk of fungal diseases. Reducing irrigation applications over the crops cycle will also reduce nutrient loss through leaching from the root zone, resulting in improved ground water quality and lower fertilizer needs on the field. Deficit irrigation reduces nutrient loss by leaching of the root zone, which results in better groundwater quality (Unlu et al., 2006). It also lower fertilizer needs as for cultivation under full irrigation (Pandey et al., 2000). Deficit irrigation problems are not immediately seen. If it is applied more efficiently the risk for soil salinization is higher under deficit irrigation as compared to full irrigation (Geerts et al., 2008). To use deficit irrigation the following condition are met which is considered as a limitation: Crop response to drought stress should be studied carefully. Irrigators should have unrestricted access to irrigation water during sensitive growth stages. A minimum quantity of irrigation water should always be available for application.

2.3.5 Deficit irrigation and water productivity

According Molden (2003) crop water productivity (WP) or water use efficiency (WUE) is a key term in the evaluation of deficit irrigation strategies. Water productivity is the ratio of the mass of marketable yield (Ya) to the volume of water consumed by the crop (ETa):

$$WP = \frac{Ya}{ETa} \quad (1)$$

Where, CWP is expressed in kg/m^3 on a unit water volume basis, Y is grain yield (Kg/ha) and ETa (m^3/ha) is actual crop evapotranspiration.

As stated by Allen et al. (1998) ETa refers to water lost either by soil evaporation or by crop transpiration during the crop cycle. Since there is no easy way of distinguishing between these two processes in field experiments, they are generally combined under the term of evapotranspiration (ETc). Crop water productivity is typically used to identify the environments or management strategies by which the yield per unit water can be maximized (Mubarak and Hamdan, 2017). Increasing productivity of water in agriculture can be achieved by producing more agriculture output with the same amount of water resources to crops. Many irrigation experiments involving different irrigation levels showed that deficit irrigation usually has higher crop water productivity than full irrigation. There are several methods for improving the crop productivity (yields) of water including replacing high water consuming crops with lower-consuming ones and adopting management and systems improvements to increase productivity per unit of water consumed. Deficit irrigation requires more control over the amount and timing of water application than full irrigation practice. Information on when and how much to irrigate is needed in order to reduce unwanted effect of water stress on water production. The estimation of water productivity suggests that the amount of seed produced is equal to the water used during growth multiplied by water productivity, which thus implies that the amount of seed increases with increasing water productivity for constant water use.

2.4. Scarcity of water for crop production

In Ethiopia, water scarcity is majorly associates with climate and economic considerations. In spite of, abundance in some parts the country is highly water scarcity due to lack of water control infrastructure (Seleshi et al., 2007).Water scarcity has various origins; natural and man-made desertification (Pereira et al., 2002a). The natural one was natural aridity and drought. Man-made desertification and water shortages are aggravating the natural scarcity while population is growing and the demand for water faces an increased competition among water user sectors. In order to cope with future estimates water shortages, some measures aimed at streaming and optimizing the efficiency of water competition in the agricultural sector are critical in the view of large volumes of water required for the production of crops (Mancosu, 2014).

Agriculture is both a cause and a victim of water scarcity (FAO, 2016).Water scarcity has a huge impact on food production. As the global population heads for more than 9 billion people by 2050, demand for food is expected to surge by more than 50% (FAO, 2016).To provide food fast growing population people do not have means for watering their crops without water. Struggle for increasingly scarce land, water and energy resources is intensifying, further aggravated by the existential threat of climate change. As a consequence of increasing water scarcity and drought, resulting from climate change, considerable water use for irrigation is expected to occur in the context of tough competition between agribusiness and other sectors of the economy (Mancosu et al., 2015). The excessive use and degradation of water resources is threatening the sustainability livelihoods dependent on water and agriculture.

2.5. Advantages of Furrow Irrigation over Other Surface Irrigation Methods

Furrow irrigation is considered as one of the main types of surface irrigation. Most of the cultivated crops are grown under such types of watering (Mohamed, 2014).The wide usage of farrow irrigation methods might be due to its no special technical experience regarding operation, maintenance needed, no specific equipment are required and the long practical background among local farmers regarding usage of such system. Furrow irrigation is especially recommended for growing row crops on medium to heavy textured soils. It is also preferred over other surface irrigation methods due to its simplicity and low capital cost (Crevoisier, 2008).

The size and shape of the furrow depends on the crop grown, equipment used and spacing between crops rows. Water is applied by running small streams in furrows between the crops rows. The length of time water is flow in the furrows depends on the amount of water required ridge of furrows to replenish the soil moisture in the root zone, the infiltration rate of the soil and the rate of lateral spread of water in the soil (Singh, no date).

According to Michael (2008) furrows are particularly well adapted to irrigating crops, which are susceptible to fungal root since water ponding and contact with plant parts can be avoided. Furrow irrigation is advantageous when the available irrigation streams are small, and for land of uneven topography. Hansen et al. (1980) forwarded that furrow irrigation is adaptable to a great variation in the slope.

2.6 Irrigation Scheduling and Crop Water Requirement

According to Allen et al. (1998) crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The term crop water requirement is the amount of water required to compensate the evapotranspiration loss from the cropped field. For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ET_O) and the effect of crop characteristics (Kc) are important (Doorenbos and Pruitt, 1977).

The growth and yield of any crop is related to the amount of water used. Hillel (2004) stated that the variable amount of water contained in a soil and its energy state are important factors affecting growth of plants. Nuha and Hnery (2000) mentioned that the accuracy of determination of crop water requirements will be largely dependent on the type of the climatic data available and the accuracy of the method chosen to estimate the evapotranspiration.

Based on the comparative studies of the reference evapotranspiration methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the Penman Monteith equation has been adopted as the globally best performing method of estimating evapotranspiration (Smith et al., 1991).The calculation can be done using CROPWAT model. Reference evapotranspiration (ET_O) is calculated based on the FAO Penman-Monteith method (Allen et al., 1998) as:

$$\mathrm{ETo} = \frac{0.40\Delta(\mathrm{Rn} - \mathrm{G}) + \gamma \frac{900}{\mathrm{T} + 273} \mathrm{U2}(\mathrm{es} - \mathrm{ea})}{\Delta + \gamma(1 + 0.34\mathrm{u2})} \tag{7}$$

where, ETo is reference evapotranspiration (mm/day), Rn is net radiation at the crop surface (MJ/m2/day), G is soil heat flux density (MJ/m2/day), T is mean daily air temperature at 2 m height (°C), U2 is wind speed at 2 m height (m/s), es is saturation vapor pressure (kPa), ea is actual vapor pressure (kPa), es - ea is saturation vapor pressure deficit (kPa), Δ is slope of vapor pressure curve (kPa/°C), ϒ is psychrometric constant (kPa/ °C).

The equation uses standard climatological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water. The updated values of crop coefficients are determined from (Allen et al., 1998).

$$ET_C = ET_O X\, K_C \tag{8}$$

Where: ETc is crop evapotranspiration, Kc is crop coefficient, ETO is reference evapotranspiration

A procedure for calculation of crop evapotranspiration for well-watered conditions using the reference crop approach is recommended by (Allen et al., 1998).

Reference evapotranspiration (ET_O) can be estimated using the Penman-Monteith equation. Various crop growth stages and their respective lengths are identified for the locations of interest, and then Kc for the various stages of the crop is determined. Kc values are then adjusted for frequency of wetting condition for rain or irrigation. Then crop coefficient curves are developed to determine Kc values for periods of any length, e.g. monthly or daily periods.

2.7 Cultural Practice of Common Bean Production

Common bean (Phaseolus vulgaris L.) is the world’s most important food legume which is used for direct human consumption (Demelesh, 2018). According to the FAO, in 2010 the total world production of all the cultivated common bean species was about 23 million tons. It is one of the major food and cash crops in Ethiopia and it has considerable national economic significance and also traditionally ensures food security in Ethiopia. It is an important and fast expanding legume that provides an essential part of the daily diet of most Ethiopians. High in nutrients and commercial potential, common bean holds large guarantee for combating hunger, increasing income and improving soil fertility in sub Saharan Africa (Teame et al., 2016).

According to Legesse et al. (2006) Common bean is very favored by Ethiopian farmers because of its fast maturing uniqueness that enables households to get cash returns essential to pay for food and other household needs when other crops have not yet matured. Most soil types, from light sands to heavy clays used for growth of common bean, but friable, deep and well-drained soils are best preferred.

The national average yield of common beans is low ranging from 1.6 ton/ha, which is far below the corresponding yield recorded at research sites (2.5-3 ton/ha) using improved varieties (CSA, 2015). A tentative recommendation of the results indicated that 40 to 70 kg P/ha and 20 to 30 kg N/ha are optimal for bean production. According to Abebe (2009) although there was an increase in yield up to fertilizer rate of 92 kg/ha P_2O_5 and 36 kg/ha N (200 kg/ha DAP), it was sufficient to apply lower rate [69 kg/ha P_2O_5 and 27 kg/ha N (150 kg/ha DAP)] since this rate also gave a very good yield and no significant difference between the two level of fertilizer in the central rift valley. Common bean requires high levels of N, and the low availability of this nutrient in the soil, coupled with the short cycle and shallow roots of the plant, contribute to its low yield.

Several studies have revealed the radical effect of drought stress on common bean performance. According Graham et al. (1997) as much as 60% of common bean production in the developing world occurs under conditions of significant drought stress. Because of this the average global yield of beans remains low. Some management practices, like irrigation and deficit irrigation can contribute to the increase of grain yield under water stress conditions, thus the development of tolerant cultivars becomes an efficient and economical production strategy.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted at Melkassa Agricultural Research Center (MARC), in East Shewa zone of Oromiya regional state, Ethiopia, from March 2019 to June 2019. This period is considered to be dry season in the area even though, unusual rain falls. This unusual rain fall was adjusted during experiment. Melkassa is located at about 107km from Addis Ababa at 8^o 24'36" N - 8^o 26'26" latitude and 39^o 19'12" E -39^o 19'48" longitude with an altitude of 1550 m a.s.l. The major agro-ecology of the area is characterized as arid to semi-arid climate which is located in Awash River Basin (htt://www.eiar.gov.et/marc, 2019). The area receives average annual rain fall of 763 mm and 1994 mm annual evapotranspiration. Minimum and maximum average annual temperature is 14.1 ^{0}C and 28.9 ^{0}C respectively.

The dominant soil texture in the study area is clay loam. Awash River used as source of irrigation water for the study. Around the study area farmers used this river and rain fall to grow crops three times a year; two times during the dry season from September to May using traditional furrow irrigation method and one during the rainy season from June –September. The dominant crops grown include common bean, maize, onion, pepper, teff, papaya and banana.

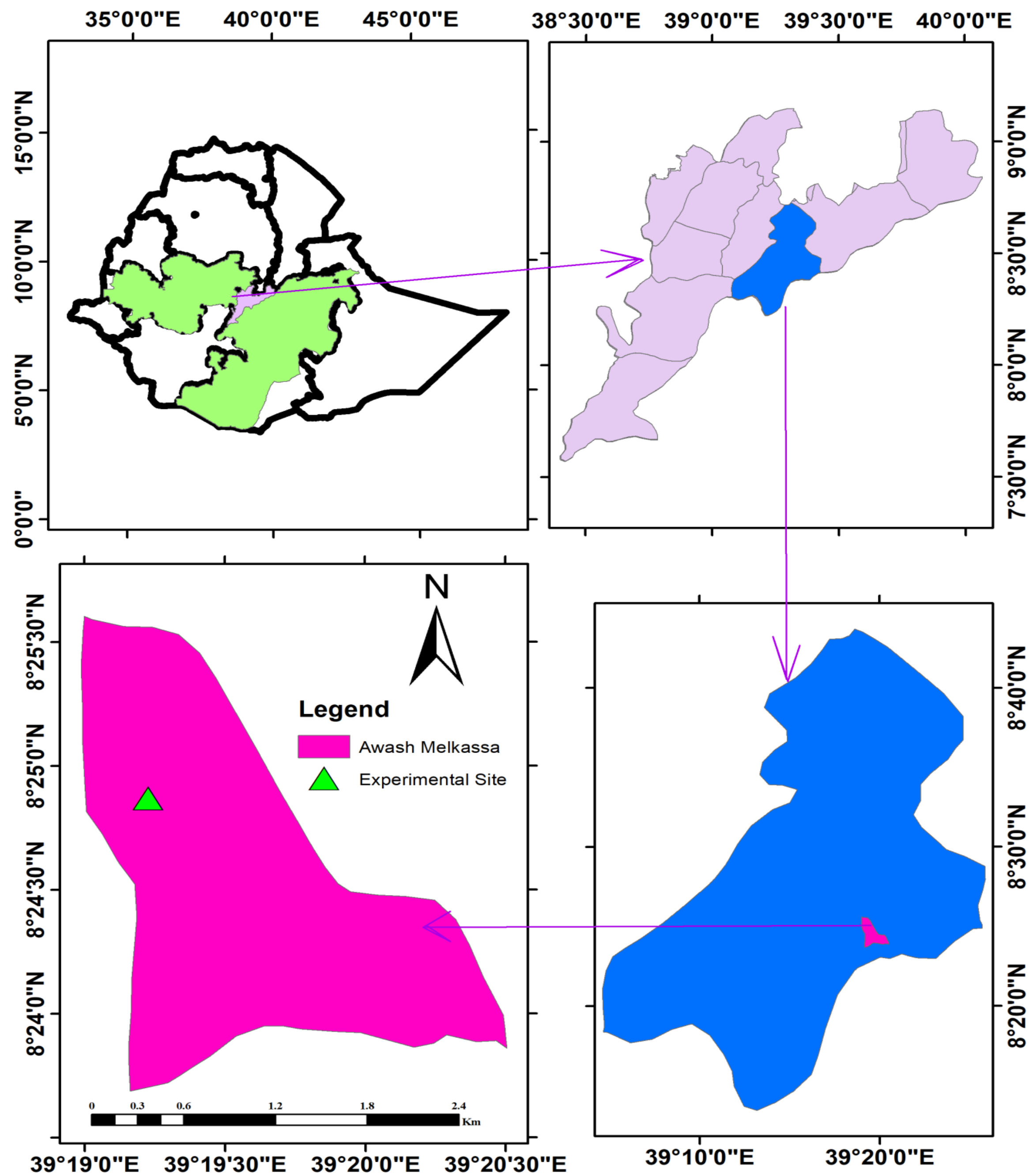

Figure 1 Map of study area

3.2 Experimental Design and Field Layout

The experimental design was split plot design (SPD) with three replications. There are twelve treatments combination with four irrigation water level and three common bean crop varieties. Crop varieties are the main plot whereas irrigation levels are the subplot factors. The treatments were:

Treatments	varieties	Irrigation levels
T1	SER-119	100% ETc
T2	Awash-2	100% ETc
T3	Bio fortified small seed-5	100% ETc
T4	SER-119	85% ETc
T5	Awash-2	85% ETc
T6	Bio fortified small seed-5	85% ETc
T7	SER-119	70% ETc
T8	Awash-2	70% ETc
T9	Bio fortified small seed-5	70% ETc
T10	SER-119	55% ETc
T11	Awash-2	55% ETc
T12	Bio fortified small seed-5	55% ETc

Each experimental plot had 4.60 m length and 4.20 m width with 2 m free space between plots and 3 m wide between replications. Each plot had seven furrows with six ridges and single row common bean. In a single row common bean was planted with spacing of 10 cm between plants and 60 cm spacing between rows each other. The seed of common bean was planted on sides of the ridges. The total area of the experimental sites was 895.2m^2.

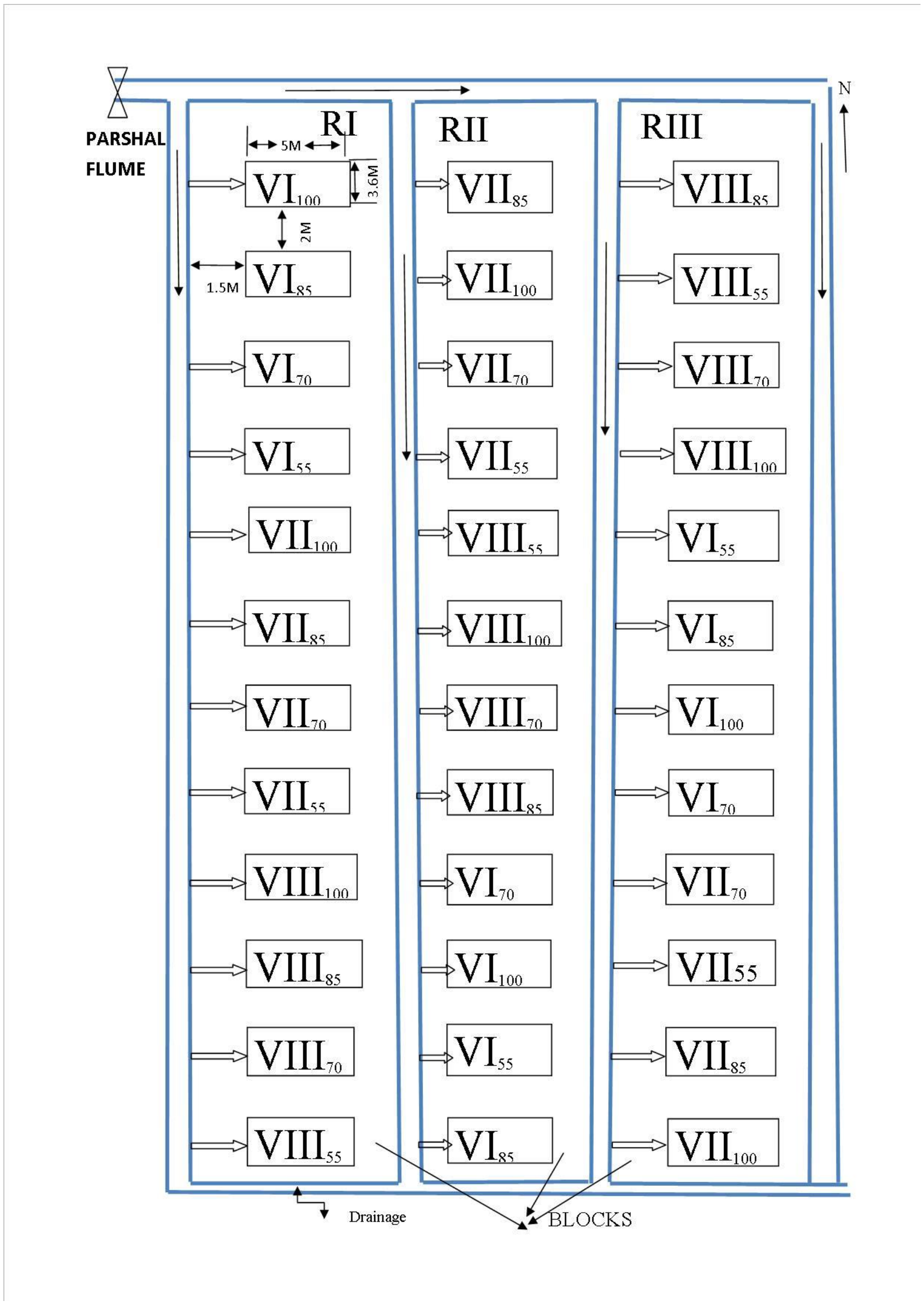

Figure 2 Experimental plot randomization

Description:VI = Awash-2,VII=Biofortified small seeded-5,VIII = SER-119,100%ETc =Full irrigation for varieties (control), 85%, 70%,& 55% = deficit irrigation levels for varieties.

Water application levels above100% ETc and below 50% of ETc were intentionally excluded from treatments owing to the fact that common bean crop is quite sensitive to extreme soil moisture stresses which severely affect various growth and biochemical parameters that also severely affect yield and yield components. Application of water above 100% ETc produce loses of water and water logging.

3.3 Data collection

The following data were collected before and during the experimental time from the middle of the experimental unit to avoid boarder effect.

3.3.1 Soil texture and bulk density

Soil samples were taken at three locations in the diagonal of the experimental block for randomization and analyzed in the Melkassa Agricultural Research Center soil laboratory. The samples are collected by standard soil auger at 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm. Hydrometer methods were used for analyze of particle size distribution and determination of textural class based on percent of sand, silt and clay in textural triangle. The textural of the soil profile was determined using USDA textural triangle.

The soil bulk density was determined from undisturbed soil samples using core sampler at similar location with sample collected for textural analysis. The core soil sample was dried at 105 ℃ for 24 hours and the bulk density was calculated using the following equation (Arora, 2003).

$$\rho_b = \frac{W_s}{V_c} \tag{9}$$

Where: - ρ_b is soil bulk-density (g/cm^3), W_s is mass of dry soil (g) and V_c is volume of soil in the core (cm^3).

3.3.2 Soil moisture determination

Determination of moisture content of the soil was carried out during the experiment using gravimetric method. The soil samples were collected at different root depth based on the growth stage because root depth increase with growth stage. Critical soil moisture content in the control treatment was also checked. Common bean water uptake occurs mainly in the first 0.5–0.7 m of root depth (Beebe et al., 2013). Accordingly the average soil moisture was taken from 0-60 cm depth in Melkassa .The wet soil samples were placed in an oven dry set at a temperature of 105℃ and dried for 24 hrs. Its gravimetric water content was determined using the equation 10 (Shukla et al., 2014).

$$\theta_m = \frac{(W_w - W_d)}{W_d} \times 100 \tag{10}$$

Where: θ_m is water content on weight basis (%), W_d is weight of dry soil (g), and W_w is weight of wet soil (g).The moisture content in weight base was converted to volumetric base by multiplying it with bulk density (Shukla et al., 2014)

$$\theta_v = \theta_m \times \frac{\rho_b}{\rho_w} \tag{11}$$

Where: θ_v is volumetric moisture content in (%), ρ_b is soil bulk density (g/cm^3), and ρ_w is water density (g/cm^3)

3.3.3 Field capacity and permanent wilting point

For determination of moisture content at field capacity (FC) and permanent wilting point (PWP) , soil samples were collected from four depths (0-15 cm, 15-30 cm, 30-45 cm and 45-

60 cm) at three similar location of the experimental plot diagonally. In the laboratory, Soil samples were analyzed for field capacity (FC) and permanent wilting point (PWP) using pressure plate apparatus at 1/3 and 15 bar respectively and oven dry to determine the weight of the water.

The total available water (TAW) was calculated using equation 12. (Allen et al., 1998)

$$\mathrm{TAW} = 1000 \sum (\theta_{\mathrm{FC}} - \theta_{\mathrm{PWP}})\, \mathrm{Z_d} \qquad (12)$$

Where: TAW is the total available water in the root zone (mm/m),

Z_d is root depth (m)

θ_{FC} is volumetric moisture content at field capacity (m^3/m^3)

θ_{PWP} is volumetric moisture content at permanent wilting point (m^3/m^3)

3.3.4 Agronomic Data

Crop parameters were measured at different growing stages. Crop phenology and growth parameters including plant height (cm), pod length (cm), branch number per plant, dry plant biomass were measured. Crop yield and yield component per plot were recorded from central rows. Data such as 50% days to flowering, 50% days to maturity, depth of water applied, stand count at harvest and date of maturity also recorded. Some of collected data were measured from five plants at physiological maturity which were randomly sampled from the middle rows of each treatment.

3.3.4.1 Crop phenology and growth parameters

Plant height (cm):- The height of the main stem from the soil surface to the tip of the plant was measured using meter rule before harvest.

Pod Length (cm):- The measurement of height of the flowering part (grain filling part)

Branch number per plant:- It was determined by counting the number of branches, when the plants reach anthesis stage and then average branch number was be determined.

Dry Plant Biomass: - During harvest time all part of plant above the ground was determined and weighted by sensitive balance.

Days to 50 % flowering: - number of days from sowing to 50 % of the plants in the plot gives flower was recorded.

Days to maturity: - the number of days from planting to the date when 75% of the plants became yellow.

3.3.4.2 Yield and yield components

From six rows only four of the internal rows of the plots were harvested by hand cutting at soil level, oven dried, weighed, and threshed for yield and biomass estimations, excluding 0.3 m on both sides along the length of the plot to avoid border effect. 1000-seed weight (g) it was counted with the seed counter machine randomly after the sun dried capsules of each plots and weighed using a sensitive balance. Then average 1000-seed weight was determined. Total grain yield (t/ha): Grain yield in gram per plot at 12.5% moisture content was recorded and translated to (ton/ha). This was determined using equation 13 after seed yield per plant was estimated.

$$\text{Seed yeild}(\text{tha}^{-1}) = \frac{\text{Seed weight (ton)of plot} * 10000\text{m\^{}2}}{\text{harvested plot area(m\^{}2)}} \quad (13)$$

Yield Response factor is the relative yield decrease to relative evapotranspiration deficit using equation 15 (Doorenbos and Kassam, 1979)

$$(1 - \frac{Y_a}{Y_m}) = K_Y(1 - \frac{ET_a}{ET_m}) \quad (15)$$

Where Y_a is actual yield (kg/ha), Y_m is maximum yield (kg/ha), ET_a is actual evapotranspiration (mm), ETm is maximum evapotranspiration (mm), and k_y is yield response factor

3.3.4.3 Water Use Efficiency

Water use efficiency (WUE) (%) is the ratio of economical yield to amount of water used. WUE was computed based on grain yield and total above ground biomass yield obtained and the total amount of water used using equation 16 (Bramley et al., 2014).

$$\text{water use efficiency} = \frac{\text{Economical yield}}{\text{Amount of water used}} \text{x}100 \quad (16)$$

3.4 Computation of Irrigation Water Requirement

Crop water requirement is the depth of water needed to meet the loss through evapotranspiration of a disease free crop growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment.

Reference evapotranspiration (ET_O) is the rate of evapotranspiration from reference surface with no shortage of water. It was estimated using Penman-Monteith method from climatological data (precipitation, maximum and minimum temperature, wind speed, relative humidity and sunshine hour) collected from Melkassa station using CROP WAT 8.0 model. Evapotranspiration of the crop (ETc) was calculated from the reference evapotranspiration and the crop coefficient using equation 8. That is ETc = ETo x Kc. The crop coefficient was adopted from FAO 56 (FAO, 1998). Based on the evapotranspiration of the crop and soil moisture depletion level, the amount of water to be applied was calculated. The amount of water consumed was also monitored based on the water balance equation. Soil moisture content measured using gravimetric methods. Total seasonal water requirement is the water depletion from planting to harvesting plus irrigation and rainfall if any during the same period calculated based on equation 17.

$$\mathrm{ET} = \mathrm{I} + \mathrm{P} - \mathrm{D} \pm \Delta\mathrm{S} \tag{17}$$

Where: ET is evapotranspiration (mm)

I is irrigation depth (mm)

P is precipitation (mm),

D is deep percolation (mm)

ΔS is change in soil water storage in a given time period within plant rooting zone.

However in this study, deep percolation losses below the root zone were insignificant and neglected. Irrigation applied is only to replace the depletion in moisture content in the root zone. After the readily available water (RAW) depleted, the irrigation water was applied. In order to know crop water use and soil moisture condition regular soil moisture measurement was done before irrigation and after irrigation. The total available water (TAW) in mm, stored in a unit volume of soil was determined by taking the difference between the water content at FC and at PWP as indicated by equation 18.

$$\mathrm{TAW} = \quad (\mathrm{FC} - \mathrm{PWP}) \times \frac{\mathrm{BD_s}}{\mathrm{BD_w}} \times \mathrm{D_Z} \qquad (18)$$

Where: FC and PWP are soil water content in % (weight basis)

$\mathrm{BD_s}$ and $\mathrm{BD_w}$ are the bulk density of the soil and water in gm cm^{-3}

Dz is the maximum effective root zone depth in mm.

The RAW is the amount of water that crops can extract from the root zone without experiencing any water stress. For maximum crop production, the irrigation schedule should be fixed based on RAW. Common bean to produces high yield, soil water depletion should not exceed 40% - 50% of the TAW (Doorenbos and Kassam, 1979). Thus RAW was computed from the equation 19.

$$\mathrm{RAW} = \rho \times \mathrm{TAW} \qquad (19)$$

Where; RAW in mm,

ρ is in fraction for allowable permissible soil moisture depletion for no stress (40-50%) and TAW is total available water in mm.

RAW was taken as applied depth at that age of crops or 100% ET_c requirement. This was given to control groups and all other application level.

3.4.1 Determination of net irrigation water requirement

The net irrigation water requirement is a the water required by irrigation to satisfy crop evapotranspiration and auxiliary water needs that are not provided by water stored in the soil profile or precipitation. It is obtained using equation 20

$$\mathrm{Fn} = \mathrm{ETc} + \mathrm{AW} - \mathrm{Pe} - \mathrm{GW} - \Delta\mathrm{SW} \qquad (20)$$

Where: Fn is net irrigation requirement for period considered (cm)

ETc is crop evapotranspiration for period considered (cm)

Aw is auxiliary water—leaching, temperature modification, crop quality

Pe is effective precipitation during period considered (cm)

GW is ground water contribution

SW is change in soil-water content for period considered. In this study auxiliary water and ground water contribution is not considered because they are insignificant. The depth of irrigation supplied at any time is obtained from a simplified water balance equation as indicated on equation 21(Doorenbos and pruitt, 1977).

$$\mathrm{Fn} = \mathrm{ET_c} - \mathrm{P_e} \qquad (21)$$

Where; Fn is the net irrigation depth in mm, ET_c is the crop water requirement in mm and P_e is the effective rainfall in mm.

3.4.2 Determination of effective rainfall (Pe)

The effective rain fall is only the rain water that retained in the root zone and can be used by the plant. The effective rainfall is, therefore, the difference between the total rainfall and the losses (Runoff, evaporation and deep percolation). The fraction of effective rainfall depends on the climate, soil texture, soil structure and depth of the root zone. There are various approaches that can be used to estimate the effective rainfall from the total monthly rainfall. However, FAO was developed a formula based on analysis carried out for different climates (Brouwer and Heibloem, 1986). It is calculated based on equation 22 and 23.

$$P_e = 0.6P_{dep} - 10 \qquad \text{for } P_{dep} < 70 \text{ mm} \tag{22}$$

$$P_e = 0.8P_{dep} - 24 \qquad \text{for } P_{dep} > 70 \text{ mm} \tag{23}$$

Where: Pe is Monthly effective rainfall (mm), P_{dep} is Monthly dependable rainfall (mm). Dependable rainfall is defined as a rainfall with a probability of exceedance (P) of 80%.

3.4.3 Determination of gross irrigation water requirement

Gross water requirement (GIR) is the actual amount of water supplied to meet crop evapotranspiration and or percolation/seepage observed under field conditions. Taking application efficiency of a short, end diked furrow as 60% (Brouwer and Prins, 1989), the gross irrigation requirement using equation 24

$$GWR = \frac{Fn}{Ea} \tag{24}$$

Where: Fn is the net irrigation depth in mm and Ea is the furrow application efficiency (%).

3.5 Discharge Measuring using Parshall Flume

The Parshall flume is an economical and accurate way of measuring the flow of water in open channel and non-full pipes. A Parshall flume has particular dimensions. Three inch Partial flume was used for measurement of water delivered to each plot. The duration of irrigation time is calculated according to the following equation (Kandiah, 1981).

$$T = \frac{AD}{6Q} \quad (25)$$

Where: T is time in minutes, A is plot area (m^2), D is application depth (mm) or amount of water that needs to be applied to an irrigated system when soil water was reduced to the specified depletion level and Q is discharge rate ($l\ s^{-1}$).

The parshall flume was installed near the entrance of the plot to minimize water loss during conveyance and distribution. The height change is the difference in height between the upstream and downstream water heights. For three inch parshall flume

$$Q = 0.992Ha^{1.547} \quad (26)$$

Where: Q is Flow Rate in m^3 and Ha is Height in M

3.6 Irrigation water productivity of crops

Water productivity is refers to the ratio between output derived from water use and the water input (value of water derived).The irrigation water productivity was calculated by dividing harvested yield in (kg/ha) by net amount of seasonal irrigation water (m^3/ha) used by crops. It was calculated using equation 31.

$$WP = \frac{Y}{\text{net irrigation water}} \quad (31)$$

Where, WP is water productivity (kg/m^3), Y is yield produced (kg/ha) and net irrigation is in (m^3/ha).

3.7 Data Analysis

3.7.1 Economic Analysis

In order to evaluate the cost and benefits related with different treatments the partial budget techniques were used. It was described by international maize and wheat improvement center (CIMMYT, 1988), which had been applied on the yield results. Economic analysis was done using the principal market prices during experimentation at the time the crop was harvested. Ethiopian birr on hectare basis (birr/ha) was used for calculating both cost and benefit. The different costs of experiment that includes cost for irrigation water and labor cost to irrigate are variable costs (VC) among the different treatments. The adjusted yield was obtained by reducing the average yield by 10 percent as indicated in (CIMMYT 1988). The average costs of the local people were paying for daily labor was 60.00 birr per day. The farm gate price of water for common bean taken was 1.00 birr per 10 m^3 of water (own assumption). The net income (NI) was calculated by subtracting total variable cost (TVC) from total return (TR).It is calculated using equation 32.

$$\mathrm{NI} = \mathrm{TR} - \mathrm{TVC} \qquad (32)$$

Marginal analysis is the process of calculating marginal rates of return between treatments proceeding in steps from a lower cost treatment to that of next higher cost and comparing those of rates of return to the minimum rate of return acceptable (CIMMYT, 1988)

The marginal rate of return (MRR) in percent was calculating by the following formula

$$\mathrm{MRR} = \frac{\Delta \mathrm{NI}}{\Delta \mathrm{VC}} * 100 \qquad (33)$$

Where: MRR is marginal rate of return, ΔNI is difference in net income, ΔVC additional unit of expense in birr

3.7.2 Statistical Analysis

The collected or measured data were subjected to analysis of variance for split plot design using statistical analysis system (SAS version 9.0 statistical packages). Mean separation was executed using Least Significant Difference (LSD) at 5% probability level to compare the statistical difference among treatment means. To quantify the relation between or among water use efficiency, irrigation levels and yield and yield components regression analysis were work out.

4. RESULT AND DISCUSSION

4.1 Climatic Data

Climatic data obtained during field experiment was as shown in the table 1. Maximum and minimum temperatures are almost the same among the months during the experiment. The wind speed and solar radiation shows difference in the four months. Although, there is some rainfall the effective rain fall was 20 mm in April months. The maximum evapotranspiration during the experiment was in March and followed by May month. The lowest was in month of April.

Table 1 Average climatic data for the crop growing season (March-June/2019)

Month	Min.Tem ℃	Max.Tem .℃	Humidity %	Wind speed km/day	Sunshine hours	Radiation/m/day	ET_O	Rainfall mm/day
March	17.0	33.0	47.0	239.0	9.8	24.4	6.64	0.0
April	16.8	32.3	59.0	107.0	8.6	22.8	5.12	20
May	16.0	32.4	54	197.0	9.2	23.1	5.85	0.0
June	17.4	30.4	59	222	7.9	20.6	5.3	0.0

As shown from figure 3 daily ETo was high from mid-March to mid-April and first fifteen days of May months. In June months ETo was not similar but it can change from day to day.

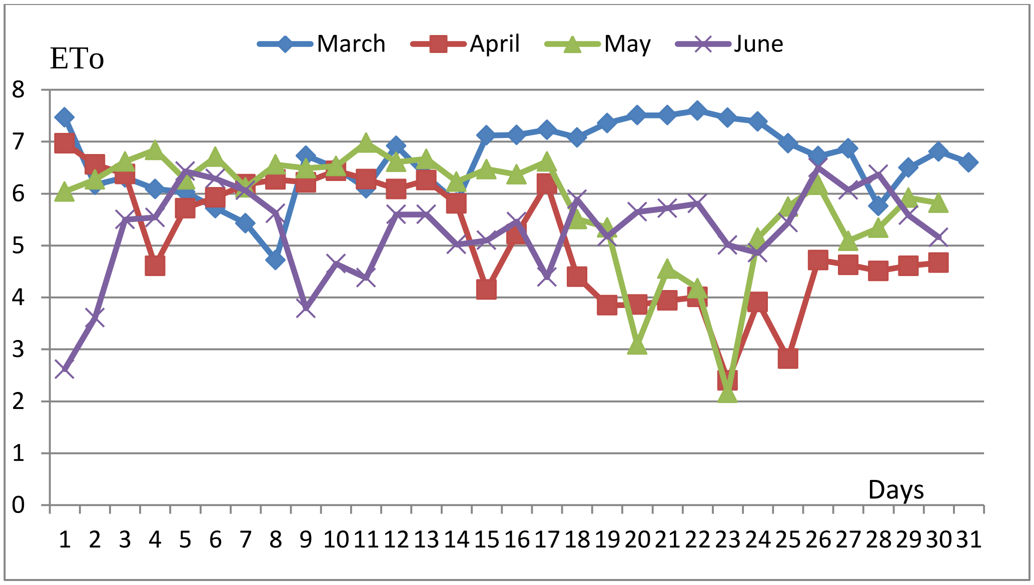

Figure 3 Daily reference ETo of experimental site during off season (March-June)

4.2 Soil Physical and Chemical Characteristics

The result of soil physical and chemical analysis considered for soil profile was presented in the table 2. Soil textural classification was found to be clay loam. The top surface has relatively less bulk density due to relative higher organic matter content which had the average bulk density 1.1 g/cm^3.This bulk density is good for plant growth because it does not inhabit root growth as it was less than ideal bulk density. Ideal bulk density that may affect root growth is 1.60 g/cm^3 (USDA, 2003).The average FC and PWP for 0-60 cm was 35.83% and 19.71% respectively. The total available water (TAW) was 167.15 mm/m. The water holding capacity of the soil relatively decreases from (0-60cm) as organic matter decrease from top to lower depths of soil profile. Clay and sand content of the soil shows inconstant variations from (0-60cm).This may be as result of translocation of fine texture sample collected from experimental site. PH of the soil is 6.65. The PH result agreed with result of Demelash (2018). The optimum range of PH of a soil for production of common beans is 6.0 to 6.8.Common bean performs best on deep, friable and well aerated soil types. The electrical conductivity of soil (ECe) and electrical conductivity of water (ECw) at 25℃ gained from analyzed soil sample was 0.2ds/m and 0.33ds/m respectively.

Table 2 Soil physical and chemical characteristics of experimental site

Soil property		Soil depth (cm)				
		0-15	15-30	30-45	45-60	Average
Particle	Sand (%)	34.99	34.84	35.02	34.31	34.79
Size	Silt (%)	30.51	29.68	28.57	30.22	29.75
Distribution	Clay (%)	34.5	35.48	36.4	35.47	35.46
Textural class		Clay loam	Clay loam	Clay loam	Clay loam	clay loam
Bulk density (g/cm3)		1	1.1	1.1	1.2	1.1
FC (vol. %)		37.98	34.95	34.76	35.65	35.8
PWP (vol. %)		21.41	19.78	18.69	18.69	19.7
TAW(mm/0.6m)		25.41	25.23	25.17	24.48	100.29
PH		6.45	6.68	7.03	6.45	6.65
ECe(ds/m)		0.3	0.2	0.2	0.3	0.2
P(ppm)		12.52	13.72	12.56	10.2	12.2
%OC		5.6	5.5	3.2	2.54	4.2
%OM		9.6	5.5	5.5	4.37	6.2
%TN		0.4	0.2	0.252	0.24	0.27

Ph-soil acidity and base level, ECe is electrical conductivity of soil, OC is organic carbon in percent, OM is organic matter in percent, TN is total nitrogen in percent and P is phosphorous

4.3 Crop Water Requirement

Applied net irrigation requirement, gross irrigation requirement, crop water requirement and effective rain fall throughout growing season was indicated in the table 3. Unexpected rain fall during experimental season was subtracted from net irrigation water requirement depth. Application efficiency used to calculate growth irrigation requirement was 60% which was applied for short and small furrows. The crop water requirement (ETc) throughout growing season was calculated based on equation 8 above.

Table 3 Net Irrigation Requirement (Fn), Gross Irrigation Requirement (GIR), Crop Water Requirement (ET_C) and Effective Rain Fall (Pe)

Date of irrigation	Fn (mm/m)	GIR (mm/m)	ETc (mm/irrigation)	CWR (mm/irrigation)	Pe (mm/day)
5-March	23.02	38.37	-	-	-
12-March	27.18	45.19	22.78	22.78	0.00
22-March	32.94	54.90	27.18	27.65	0.00
1-April	38.77	64.627	32.93	32.82	0.00
12-April	45.19	42.52	18.77	18.68	20.00
18-April	48.69	81.16	46.47	49.26	0.00
30-April	55.69	92.83	49.05	55.05	0.00
8-May	60.36	100.60	55.62	61.62	0.00
17-May	65.61	109.36	60.61	65.61	0.00
22-May	-	-	65.51	65.51	0.00
Total	397.44	619.55	378.92	398.98	-

As shown in the table 3 seasonal ET_C obtained to be 378.92 mm. Cumha et al. (2013), point out that common bean needs 300 to 600mm water depth to obtain high yield. In the April-12 irrigation interval some amount of required water is satisfied from effective rain fall. The recorded seasonal effective rain fall was 20 mm. The seasonal growth irrigation water requirement calculated during the experiment was 619.55 mm. From this, GIR the percentages of deficit irrigation for treatment was calculated based on percentage of the deficit. The net irrigation water depth applied during growing season for each irrigation day to each plot was presented in the table 4.

Table 4 Net irrigation depth of control and each deficit plots

Date of irrigation	FN(mm/m) 100%	FN(mm/m) 85%	FN(mm/m) 70%	FN(mm/m) 55%
5-march/2019	23.02	19.57	16.11	12.66
12-march	27.18	23.10	19.03	14.95
22-march	32.94	28.00	23.06	18.12
1-April	38.77	32.95	27.14	21.32
12-April	45.19	38.41	31.63	24.85
18-April	48.695	41.39	34.09	26.78
30-April	55.69	47.34	38.98	30.63
8-may	60.36	51.31	42.25	33.20
17-may	65.615	55.77	45.93	36.09
Total	397.46	337.84	278.22	218.60

4.4 Vegetative Growths Parameters

To evaluate the effect of deficit irrigation on common bean vegetative grows parameters such as; plant height, number pod per plant, pod length and branch number per plant were analyzed and presented in table 5 and 6.

4.4.1 Plant height

Means of plant height (tables 5 and ANOVA table 2 in appendix) illustrate that effect of deficit irrigation on plant height. Plant height was statistically significant at 5% probability level. The maximum plant height at physiologically maturity was measured at full irrigation (74.64 cm) and the minimum were from 55% deficit irrigation treatment (67.21cm). Irrigating common bean with (85%ETc) and (70%ETc) irrigation levels show plant height variation which had length of 72.69 cm and 69.57 cm respectively. This may indicate that effect of water stress that affects vegetative growth of plant, which in turn affects both dry matter and grain yield. In line to this result Emam et al. (2010) found that plant height of two common bean cultivars was significantly affected by soil moisture treatment. The study was more coincides with study of Abiot, (2018) which also reported that plant height of two common bean cultivars was significantly affected by high water stress level. Water stress had also significant effect on other crops plant height. Means of plant height had no significant difference under three common bean varieties (tables 6). Interaction of irrigation level and common bean varieties was also not statistically significant at 5% of probability on Plant height (table 7). But the tallest plant height (75.46cm) was obtained from interaction of 100% ETc irrigation level and Awash-2 variety were as the shortest height (66.3cm) was gained from 55% deficit irrigation and SER-119.

Table 5 Effect of deficit irrigation on vegetative grows parameters of common bean.

Treatments	Plant Height(cm)	No of pod/plant	Pod length (cm)	Branch No/plant
100%ETc	74.64[a]	33.42[a]	9.89	4.59[a]
85%ETc	72.96[ab]	29.94[ab]	9.90	4.40[ab]
70%ETc	69.57[bc]	28.15[b]	10.09	4.16[bc]
55%ETc	67.21[c]	24.28[c]	9.65	3.98[c]
CV	9.5	18.37	5.18	32.1
LSD(0.05)	4.49	4.05	NS	0.4
SE	2.1	1.9	0.48	0.19

Means within each column on yield and yield component followed by different letter are significantly different at P < 5%. NS is non-significant at p < 5%.

Table 6 Effect of selected varieties on vegetative grows parameters of common bean

Treatments	Plant Height(cm)	No of pod/plant	Pod length (cm)	Branch No/plant
SER-119	71.3	31.45	10.70[a]	4.25
BFS-5	71.0	28.93	9.74[b]	4.69
Awash-2	70.8	26.46	9.20[b]	3.89
LSD(0.05)	NS	NS	0.85	NS
SE	2.76	2.17	0.2	0.56

Means within each column on yield and yield component followed by different letter are significantly different at P < 5%. NS is non-significant at p < 5%.

4.4.2 Number of pod per plant

Significant difference (p<0.05) were observed among treatments for number of pond per plant under different water stress level (table 5 and ANOVA table 3 in appendix). The trends' among treatments shows that numbers of pod per plant relatively decrease as moisture stress level increases. Water stress reduced the number of pods per plant. This may be due to low moisture in the soil which inhabit nutritional uptake. Shortage of water prevented the evolution of inflorescence and decreased the number of young pods and seeds (Singn, 2007). Similar report by Saley et al. (2018), Carvalho et al. (2018) and Kanai et al. (2019) reported that number of pods and the grain yield decreased with an increase in water stress at 5% probability. The largest and lowest pod number per plant was obtained from full irrigation water level (33.42 pods) and from 55% ETc treatments (24.28 pods) respectively. But, according to this data control treatment 100% ETc and 85% ETc had nearly the same number of pod per plant; it may be 85% of field capacity was suitable for achieving efficient bean yield. Means of number of pod per plant were didn't shows significant difference under three common bean varieties (tables 6). SER-119 had the largest number of pod per plant (31.45) and smallest number of pod per plant (26.46) was obtained from Awash-2. Interaction of varieties and water stress level had not significant effect on number of pod per plant (table 7). Interaction of 100%ETc and SER-119 gave largest pod number per plant (37.7) and smallest pod number per plant (21.8) was gained from interaction of 55% deficit irrigation and Awash -2 varieties.

Table 7 Effect of interaction of water stress and common bean varieties

Treatments	Plant height(cm)	No of pod/plant	Pod length(cm)	Branch No/plant
100%SER-119	73.8	37.7	10.9	4.53
85%SER-119	73.3	32.5	10.8	4.43
70%SER-119	70.6	28.7	10.7	4.23
55%SER-119	66.3	26.8	10.26	3.83
100%BFS-5	74.66	32.93	9.58	5.06
85%BFS-5	73.53	29.6	9.76	4.53
70%BFS-5	69.40	29.0	9.90	4.63
55%BFS-5	67.66	24.2	9.73	4.53
100%Awash-2	75.46	29.6	9.20	4.16
85%Awash-2	72.0	27.73	9.06	4.13
70%Awash-2	68.73	26.73	9.59	3.66
55%Awash-2	67.68	21.80	8.96	3.6
CV(RP*MP*SP)	6.38	14.1	6.07	9.81
LSD(0.05)	NS	NS	NS	NS
SE	3.7	3.3	1.05	0.69

NS is non-significant at $p < 5\%$.

4.4.3 Branch number per plant

The result of the experiment indicates that branch number per plant shows significant difference for the effect of deficit irrigation (table 5).The highest (4.59) and smaller (3.98) branch number per plant recorded from 100 ETc and 55 ETc respectively. It decreases with increase of water stress. The result was in line Saleh et al. (2018) reported that number of branches per plant increase, when supplied irrigation water was increase. However, means of branch number per plant had no significant difference under three common bean varieties. SER-119 had relatively highest branch number per plant (4.25) were as Awash-2 had smallest number of branch (3.89). Moreover, branch number per plant was not statistically significant at 5% of probability with interaction of irrigation level and common bean varieties (table 7).

4.4.4 Pod length (cm)

Significant difference ($p<0.05$) were not observed among treatments for pod length of plant under different water stress level (table 5).The result was contradicted with finding of Saleh et al.2018, who mentioned that pod length increase up to moderate deficit irrigation (80%ETc). Difference of the result was due to difference of selected genotype materials. Pod length had significant difference under selected common bean materials (table 6 and ANOVA table 4 in appendix).This may be due to genotypes of varieties. These advantages of genotypes may rises from improved uptake of water, restriction of evapotranspiration and water storage. Interaction of 100% ETc and SER-119 gave longest pod length (10.9cm) were as shortest pod length (8.96cm) was gained from interaction of 55% deficit irrigation and Awash -2 varieties. Interaction of varieties and water stress level had no significant effect on pod length. Overall, deficit irrigation (moisture stress) and genotypes of crops had considerable impact on vegetative growth parameters of common beans.

4.4.5 Effect of deficit irrigation on 50% days to flowering

There was no significant differences ($p>0.01$) between interaction of deficit irrigation and common bean variety on number of 50% days to flowering. There was significant effect due to water stress on 50% days to flowering ($p<0.01$).Water stress levels had a highly significant effect on the number of 50% days from sowing to flowering (Nepomuscene et al., 2017).

There are also significant difference between varieties ($p<0.01$) as shown in table 8.Manjeru et al., (2007) also stated that there was a significant difference on 50% days to flowering on variety. BFS -5 was taking longest time to flowering and SER-119 and Awash-2 ware taking significantly the same time to flowering.

4.4.6 Effect of water stress and variety on number of 50% days to maturity

Water stress had significant effect ($p<0.01$) on number of days to maturity as shown on table 9. Application of 100% ETc was took longest time to maturity as compared to deficit irrigation. Highest deficit irrigation gave shortest 50% days to maturity due to forced maturity as result of water shortages. There was no significant effect on interaction between deficit irrigation and variety on number of 50% days to maturity. Common bean variety had significant effect on number of 50% days to maturity. BFS-5 was also taking longest days to maturity and SER-119 was took shortest day to maturity (table 8).

Table 8 Effect of the growth varieties on 50% days to flowering

variety	Mean of 50% days to flowering	Mean of 50 % days to maturity
SER-119	52.2^{b}	82.08^{b}
BFS-5	56.9^{a}	86.25^{a}
AWASH-2	51.5b	84^{ab}
L.S.D	1.9	4.09
CV	1.97	2.59

Means within each column on 50% days to flowering and maturity followed by the same letter are not significantly different at $P < 0.01$.

Table 9 Effect of water stress on number of 50% days to maturity

Irrigation level	Mean of 50% days to flowering	Mean of 50% days to maturity
100ETc	54.9[a]	87.6[a]
85 ETc	53.8[b]	85.2[b]
70 ETc	53.2[b]	83[c]
55 ETc	52.3[c]	80.4[d]
L.S.D	0.79	1.3
CV	1.09	2.59

4.5. Crops Yield, Biomass and Irrigation Water Productivity

4.5.1 Crops yield

Means of common bean yield and ANOVA tables under effect of irrigation level are presented in table 10 and appendix table 6. The result of the analysis illustrate that the effect of irrigation treatments on grain yield were statistically significant ($p<0.05$). Application of full irrigation gave maximum common bean yield (3.4 ton /ha). Irrigating common bean with 85% ETc deficit irrigation produces fewer yields than full irrigation. But treads of treatment shows that reduction of yield was high with increase of deficit irrigation level (2.4ton/ha).This might be due to low soil moisture level which inhabits the vegetative growth of the crops by reduction of nutritional elements uptake. The result was agreed with result of Sincik et al. (2008) full ET_C level gave higher yield than non-irrigated and deficit irrigation treatments. The result was consistent with the finding of Neama et al. (2016) and Joshua et al. (2017) decrease applied water reduce seed yield of Snap bean and French bean, respectively. Effect of crop varieties' does not shows significant difference on crops yield (table 11). Interaction effect of varieties and deficit irrigation on means of yield was shown on table 12.The result shows that the interaction effect does not have significant effect on grain yield. But the highest yield (3.69 ton/ha) was gained from interaction of 100% ETc and SER-119.The smallest yield (2.37 ton/ha) was also recorded from interaction of 55% irrigation level and BFS-5.

4.5.2 Above ground dry biomass

Above ground biomass shows significant difference with high water level deficit. The highest biomass was gained from full irrigation treatment (5.19 ton/ha) followed by less difference of 85% ETc, 70% ETc and least significantly different at 55% ETc, which was (3.95 ton/ha). This result argued with previous work. As irrigation amount increase the biomass of soya bean increase as reported by Sincik et al., (2008). Moreover Robel et al. (2019) argued that above ground dry biomass weight decrease as increase of soil moisture stress level. Table 11 shows that above Ground biomass does not show that significant difference among common bean varieties. But relatively SER-119 had higher above ground biomass among the varieties. Interaction effect of varieties and deficit irrigation on means of biomass was indicated on table 12. Interaction effect between variety and water stress had no significant effect on above ground biomass. However, the highest biomass yield (5.44 ton/ha) was gained from interaction of 100% ETc and SER-119 were as smallest biomass (3.76 ton/ha) was recorded from interaction of 55% irrigation level and Awash-2.

Table 10 Effect of deficit irrigation (subplot) on yield, total biomass and irrigation water productivity of common bean

Treatments	Yield (ton/ha)	Biomass (ton/ha)	Water productivity (kg/m^3)
100%ETC	3.4^{a}	5.19^{a}	0.83^{c}
85%ETC	3.2^{ab}	5.18^{a}	0.94^{bc}
70%ETC	2.8^{b}	4.74^{a}	1.2^{ab}
55%ETC	2.4^{c}	3.95^{b}	1.33^{a}
LSD(0.05)	0.45	0.6	0.35
CV	15.03	12.8	16.03
SE	0.16	0.29	0.11

Means within each column on yield and yield component and interactions followed by the same letter are not significantly different at P < 5%.

Table 11 Effect of common bean varieties (main plot)

Treatments	Yield (ton/ha)	Biomass (ton/ha)	Water productivity (kg/m^3)
SER-119	3.11	4.82	1.09
BFS-5	2.95	4.74	1.08
Awash-2	2.86	4.73	1.06
LSD(0.05)	NS	NS	NS
CV	13.45	20.93	16.18
SE	0.21	0.4	0.16

NS non-significant at p>5%

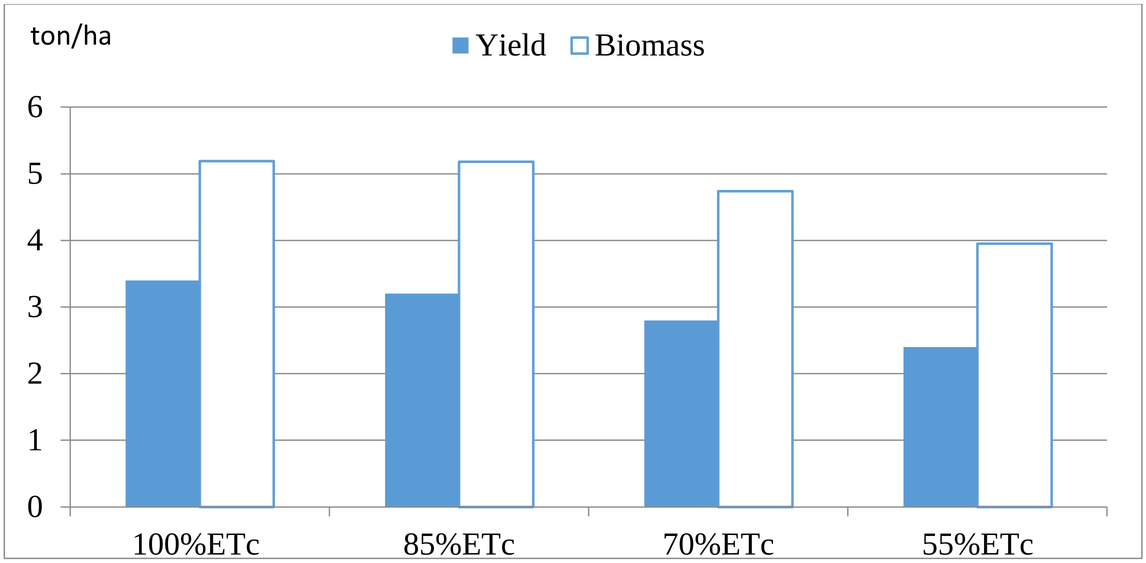

Figure 4 Effect of irrigation level on total yield and total biomass.

4.5.3 Irrigation water productivity

Table 10 and ANOVA table 8 in appendix shows that water productivity was statistically significant at $p<0.05$. Higher water productivity values 1.33kg/m^3 and 1.2 kg/m^3 of common bean was obtained from treatment of 55% ETc and 70% ETc irrigation level, respectively. Smallest water productivity values 0.83kg/m^3 and 0.94kg/m^3 were also gained from full irrigation level and 85% deficit irrigation level, respectively.

Higher water productivity indicates that saved water increase the irrigated areas of downstream to compensate of any yield loss because of the deficit irrigation. On other hand saved water may be used for productive consumption to compensate yield lose as result of deficit irrigation. The result shown that higher water productivity was gained due to less amount of water used during experiment at 55% of irrigation water. Water productivity is improved either by enhancing the crop yield or by reducing amount of irrigation water (Robel et al., 2019). Different studies show that increasing amount of irrigation water with threshold level decrease water productivity (Shariot-Ullah et al., 2010, Geneille et al., 2017 and Eba, 2018). Deficit irrigation saved water but did not reduce yield significantly. In this study high water productivity without significant yield reduction was obtained from 85% and 70% irrigation level compared to the yield indicated in 55% deficit irrigation to promote sustainable water development.

Under a limited water supply situation, the goal was to gain highest possible yield of common bean. Water application of 85% ET_C and 70% ET_C at each irrigation event offers opportunities for water savings.

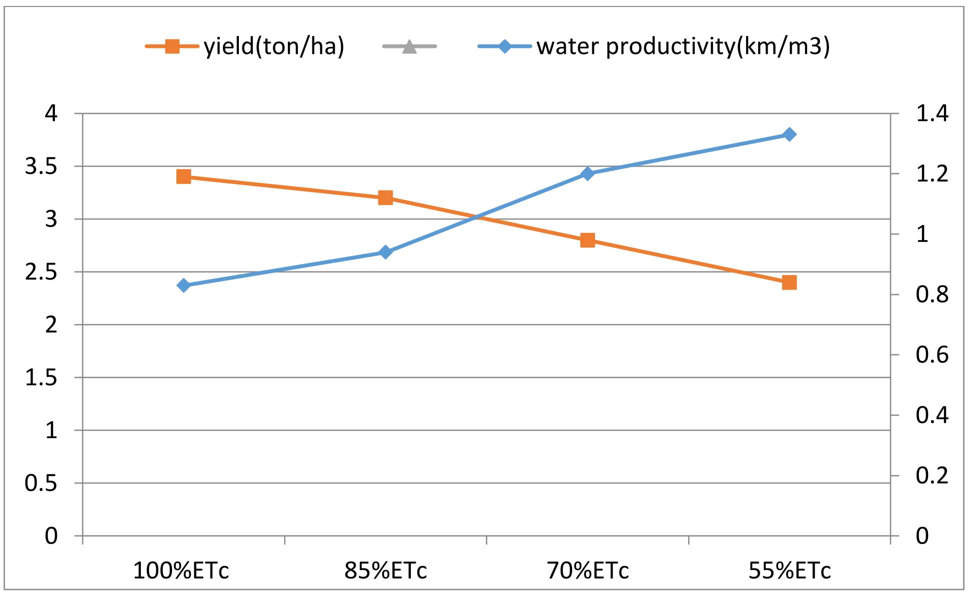

Figure 5 Effect of irrigation levels on water productivity

Interaction effect of varieties and deficit irrigation on means water productivity was shown on table 12. Water productivity was had no significant with the interaction between varieties and irrigation level. Interaction of 55% deficit irrigation level and Awash two gave maximum water productivity were as interaction of SER-119 and 100 ETc gave lowest water productivity.

Table 12 Effect of water stress and common bean variety interaction

Treatment	Yield (ton/ha)	Biomass (ton /ha)	water productivity(kg/m3)
100%SER-119	3.69	5.44	0.82
85%SER-119	3.24	5.31	1.0
70%SER-119	3.03	4.58	1.12
55%SER-119	2.49	3.98	1.4
100%BFS-5	3.19	4.97	0.83
85%BFS-5	3.29	4.93	0.94
70%BFS-5	2.96	4.7	1.36
55%BFS-5	2.37	4.12	1.2
100% Awash-2	3.29	5.15	0.85
85% Awash-2	3.04	5.32	0.87
70% Awash-2	2.69	4.7	1.13
55% Awash-2	2.43	3.76	1.38
CV(RP*MP*SP)	20.57	12.8	16.03
LSD(0.05)	NS	NS	NS
SE	0.36	0.59	0.29

NS non-significant at p<5%

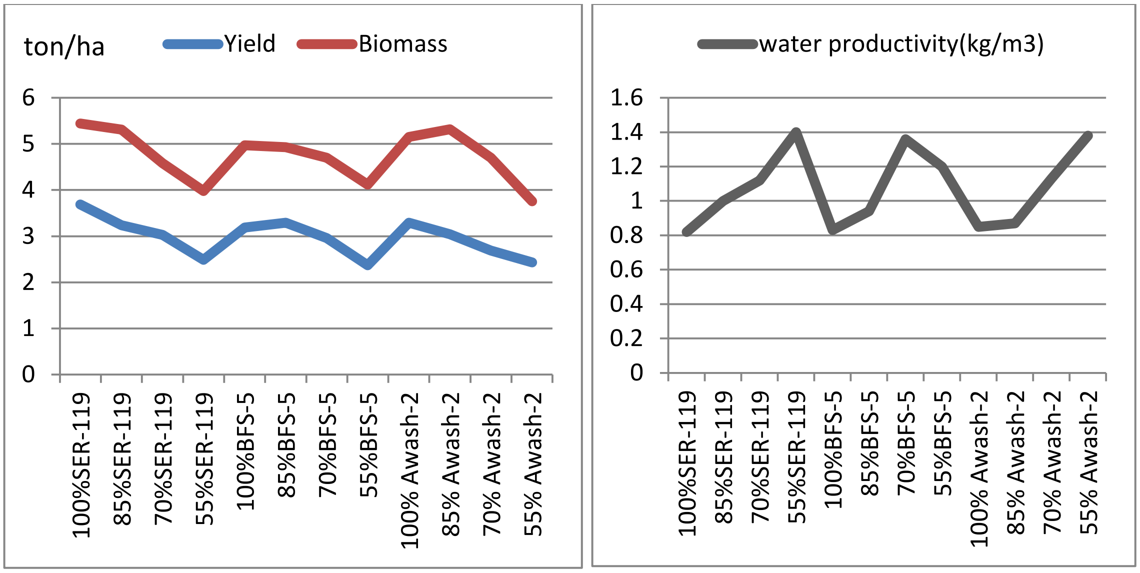

Figure 6 Interaction effect of irrigation and varieties on total yield, biomass and water productivity

4.6 Yield Response Factor (ky)

The relationship between relative yield decrease (1-Ya/Ym) and relative evapotranspiration deficit (1-ETa/ETm) was indicated in table 13. The result obtained is analyzed separately for the variety and then compared with each other. Comparing yield response factor (Ky) of the common bean varieties Awash -2 is more sensitive to moisture stress. BFS-5 shows that less sensitive to yield response factor. Moreover for all varieties table 15 also shows that yield response factor relatively increase as soil moisture stress level increase. Where yield response factor (Ky)<1 crop is tolerant to deficit irrigation, and recovers partially from stress exhibiting less than proportional reduction in yield with reduced water use (Smith et al., 2012). Yield coefficient of determination was 0.8629.

Table 13 Yield response factor of common bean variety

treatment	Yield (Kg/ha)	ETa (m^3/ha)	1- (Ya/ha)	1- (ETa/ETm)	(ky)
100%SER-119	3793.47	3974.6	0.00	0.00	-
85%SER-119	3377.98	3378.4	0.11	0.15	0.73
70%SER-119	3035.37	2782.2	0.25	0.30	0.83
55%SER-119	2195.45	2186	0.42	0.45	0.94
100%BFS	3528.05	3974.6	0.00	0.00	-
85%BFS	3192.7	3378.4	0.10	0.15	0.63
70%BFS	2861	2782.2	0.19	0.30	0.63
55%BFS	2371.7	2186	0.33	0.45	0.73
100% Awash-2	3502.62	3974.6	0.00	0.00	-
85% Awash-2	2959.4	3378.4	0.13	0.15	0.86
70% Awash-2	2564.4	2782.2	0.27	0.30	0.89
55% Awash-2	2001.5	2186	0.43	0.45	0.95

Figure 7 Regression relation of yield and evapotranspiration

4.7 Economic analysis under water limiting condition

The economic analysis was done among the varieties based on applied water and total cost estimated. The adjusted yield was calculated according to CMMYT, (1988) by 10% of actual yield reduction. The result of economic analysis shows that the highest net benefit is obtained from full irrigation of three common bean varieties. These were 41627.6, 35347.0 and 35072.3 birr/ha for 100 % ETc of SER-119, BFS-5 and Awash-2, respectively as compared to their deficit irrigation. The marginal rate of return for these treatments is zero because increases of water more than 100 ETc have no values for grain yield increment. The lowest net benefits of the varieties were gained from irrigating 55%ETc which were 24171.0, 24098.6 and 20100.4birr/ha with the highest marginal rate of return 2277.2, 1178.3 and 1370.6 respectively. However, the marginal rate of return and water productivity was high in the application of 55% ETc and it shows significant effect on grain yield reduction. But irrigating the varieties with 80% and 70%ETc gave moderate marginal rate of return without significant yield reduction of all varieties. These treatments also show high level of benefit cost ratio (table 14). In this study data from table (14) revealed that the MRR is greater than 50%, irrigating common bean with deficit irrigation 85%, 70% and 55% have been economically feasible depending on accessibility of water.

Table 14 Economic analysis under water limiting factor

TRT	Cost water (birr/m^3)	Applied growth irrigation	grain yield(kg/ha)	Adjusted grain yield(kg/h)	Total return(birr/ ha)	Total variable cost (birr/ha)	Net income (birr/ha)	MRR (%)	B/C
100%SER-119	1324.9	3974.6	3793.47	3414.12	44383.6	2756.0	41627.6	-	15.1
85%SER-119	1126.1	3378.41	3377.98	3040.18	39522.4	2342.6	37179.8	1075.9	15.9
70%SER-119	927.4	2782.22	3035.37	2731.83	35513.8	1929.2	33584.6	869.7	17.4
55%SER-119	728.7	2186.03	2195.45	1975.91	25686.8	1515.8	24171.0	2277.2	15.9
100%BFS	1324.9	3974.6	3528.05	3175.25	38102.9	2756.0	35347.0	-	12.8
85%BFS	1126.1	3378.41	3192.7	2873.43	34481.2	2342.6	32138.6	776.1	13.7
70%BFS	927.4	2782.22	2861	2574.90	30898.8	1929.2	28969.6	766.6	15.0
55%BFS	728.7	2186.03	2371.7	2134.53	25614.4	1515.8	24098.6	1178.3	15.9
100% Awash-2	1324.9	3974.6	3502.62	3152.36	37828.3	2756.0	35072.3	-	12.7
85% Awash-2	1126.1	3378.41	2959.4	2663.46	31961.5	2342.6	29618.9	1319.2	12.6
70% Awash-2	927.4	2782.22	2564.4	2307.96	27695.5	1929.2	25766.3	931.9	13.4
55% Awash-2	728.7	2186.03	2001.5	1801.35	21616.2	1515.8	20100.4	1370.6	13.3

5. SUMMERY AND RECOMMENDATION

5.1 Summery

Soil water availability is a major limiting factor in agricultural production system. Deficit irrigation is an effective practice to use scarce water for increasing water productivity in the semi-arid region of central rift valley of Ethiopia. The result of the study shows that deficit irrigation had negative effect on grain yield, above ground biomass and vegetative growth parameters of common bean varieties used for the experiment. In this study the common bean yield increased with increased in irrigation level. Although less application of water produce higher marginal rate of return it reduce significantly the yield of common bean at application of 55% deficit irrigation. It shows that cost of saved water (45%) was greater than net income produced from production of common bean yield (42%). That is ration of cost of saved water to difference between net incomes for 55% irrigation level. To compensate yield reduction and to overcome higher scarce water it must be a solution using moderate soil moisture stress.

Yield response factor also increase as soil moisture stress level increases. This indicates that the sensitivity of common bean to soil moisture stress. The maximum water productivity is archived by application of 55% evapotranspiration for the three varieties. This implies that deficit irrigation can reduce water loss due to deep percolation and run off. The deficit treatments based on crop evapotranspiration enhanced crop water productivity compared to control treatment due to less water consumption. Varieties versus irrigation level interaction had no significant effect on this study. Comparing the yield of variety without significance difference SER-119 was more advantages than the other two varieties. SER-119 was less sensitive to deficit irrigation and produces more yields as compared to the other two.

5.2 Conclusion and Recommendation

From consideration of obtained yield, growths and vegetative parameters, amount of irrigation water applied, water productivity and economic analysis the following points are point out.

- The result of the study shows that when the available water was not a limiting factor irrigating /producing common bean with 100%ETc gives the higher yield than deficit irrigation.
- In semi-arid area the available water is a limiting factor. Irrigating the common bean with moderate deficit irrigation practices can shows an important solution for common bean production. In this study irrigating common bean varieties from 70%ETc to 85% ETc nearly similar grain yields with that of 100%ETc. If availability of water is most scarce resource application of 55% ETc also possible since the marginal rate of return are greater than 50%.
- The experiment was a one season and in one place. Hence, repeating the experiment will improve the validity of findings. The test crop here was small varieties of common bean but, comparison should be extended to more common bean varieties and other commercial crops varieties.

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7. APPENDICES

Table 1 Long term climatic data (1979-2018)

Month	Tmin, ℃	Tmax, ℃	Humidity, %	Wind, m/s	Sunshine, hr	ETo, mm/day	Rainfall, mm
January	10.3	27.9	48.5	5.7	9.3	6.4	16
February	13.4	29.9	48.9	5.9	9.0	6.9	24.1
March	15.5	30.7	46.6	5.6	8.6	7.3	52.3
April	15.9	30.2	55.4	4.9	7.8	6.6	53.9
May	15.7	30.6	54.1	5.0	8.5	6.7	61
June	17.1	29.5	60.0	29.0	8.0	5.3	69
July	16.0	27.0	67.7	6.0	7.2	5.3	204.2
August	15.8	26.7	69.1	5.0	7.2	5.0	183.1
September	14.4	28.2	64.9	3.4	7.9	5.1	99.8
October	12.4	29.5	40.0	4.6	9.0	6.4	39.3
November	11.9	28.8	49.4	5.5	9.3	6.5	12.6
December	10.7	27.9	49.4	19.0	9.7	6.4	9.6
average	14.1	28.9	54.5	8.3	8.4	6.2	824.9

Table 2 Analysis of variance for plant height

Source of variation	Degree of freedom	Sum of square	Mean square	F value	P value
Replication(RP)	2	1.62	0.81		
Variety(V)	2	0.829	0.414	0.01	0.991
RP*V	4	182.92	45.73		
Irrigation level(I)	3	301.00	100.33	4.87*	0.0119
V*I	6	16.24	2.707	0.13	0.9905
RP*V*I	18	370.84	20.603		
Total	35	873.46			

*significant (p<0.05) and V –variety, RP-replication, I-irrigation level

Table 3 Analysis of variance for number of pod per plant

Source of variation	Degree of freedom	Sum of square	Mean square	F value	P value
Replication(RP)	2	7.12	3.56		
Variety(V)	2	42.48	74.75		
RP*V	4	113.13	28.28		
Irrigation level(I)	3	390.13	130.04	7.76	0.0016*
V*I	6	33.16	5.52	0.33	0.9126
RP*V*I	18	301.8	16.76		
Total	35	994.85			

*significant (p<0.05) and V –variety, RP-replication, I-irrigation level

Table 4 Analysis of variance for pod length (cm)

Source of variation	Degree of freedom	Sum of square	Mean square	F value	P value
Replication(RP)	2	0.554	0.277		
Variety(V)	2	13.85	6.929	26.38*	0.005
RP*V	4	1.05	0.262		
Irrigation level(I)	3	0.859	0.286	0.80	0.5119
V*I	6	0.782	0.130	0.36	0.893
RP*V*I	18	6.478	0.359		
Total	35	23.58			

*significant (p<0.05) and V –variety, RP-replication, I-irrigation level

Table 5 Analysis of variance for number of branch per plant

Source of variation	Degree of freedom	Sum of square	Mean square	F value	P value
Replication(RP)	2	1.62	0.82		
Variety(V)	2	42.48	21.24	9.54*	0.03
RP*V	4	8.90	2.226		
Irrigation level(I)	3	0.86	0.287	0.39	0.759
V*I	6	1.95	0.326	0.45	0.838
RP*V*I	18	13.18	0.732		
Total	35	69.04			

* Significant (p>0.05) and V –variety, RP-replication, I-irrigation level

Table 6 Analysis of variance for grain yield

Source of variation	Degree of freedom	Sum of square	Mean square	F value	P value
Replication(RP)	2	0.315	0.157		
Variety(V)	2	0.388	0.194	1.21	0.388
RP*V	4	0.642	0.160		
Irrigation level(I)	3	4.682	1.560	7.78*	0.0015
V*I	6	0.349	0.058	0.29	0.9339
RP*V*I	18	3.609	0.200		
Total	35	9.987			

* Not Significant at (p>0.05) and V –variety, RP-replication, I-irrigation level

Table 7 Analysis of variance for above ground biomass (ton/ha)

Source of variation	Degree of freedom	Sum of square	Mean square	F value	P value
Replication(RP)	2	0.132	0.066		
Variety(V)	2	0.064	0.032	0.03	0.968
RP*V	4	3.987	0.996		
Irrigation level(I)	3	9.118	3.039	8.14*	0.001
V*I	6	0.954	0.159	0.43	0.85
RP*V*I	18	6.721	0.373		
Total	35	20.978			

*significant (p>0.05) and V –variety, RP-replication, I-irrigation level

Table 8 Analysis of variance for water productivity

Source of variation	Degree of freedom	Sum of square	Mean square	F value	P value
Replication(RP)	2	0.141	0.07		
Variety(V)	2	0.006	0.003	0.04	0.96
RP*V	4	0.313	0.078		
Irrigation level(I)	3	1.438	0.479	3.73*	0.03
V*I	6	0.187	0.031	0.24	0.95
RP*V*I	18	2.314	0.128		
Total	35	4.401			

*significant (p>0.05) and V –variety, RP-replication, I-irrigation level

Figure 1 During field preparation and sowing

Figure 2 During vegetative growths of common beans


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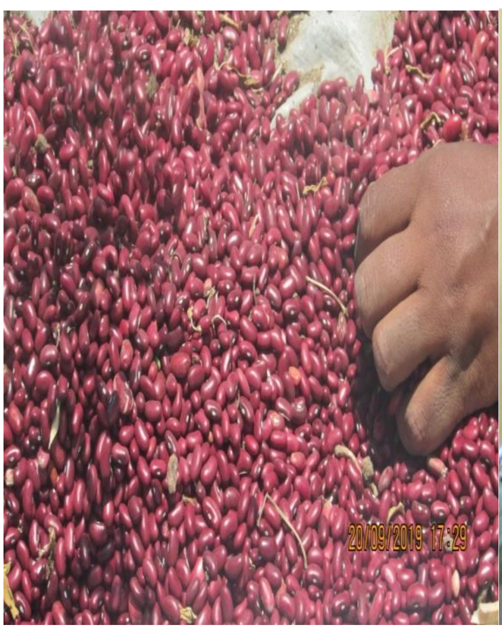
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Figure 3 During plant harvesting and data collection

BIOGRAPHICAL SKETCH

The author was born on June 16, 1987 in Oromiya Region; Bale Zone. He attended his elementary school education at Sinja kebele and Finca'a Bamo Schools and completed his junior and preparatory school at Negade Sefer and Batu Terara in Bale Goba. After taking the Ethiopia school leaving certificate examination (ESLCE), He joined the Wollega University and graduated with B.Sc. degree in water resource and irrigation management in July, 2013. After graduation, he was employed in Ethiopian Institute of Agricultural Research Center and has working as junior researcher since October, 2018. In October 2010, he joined the school of graduate studies at Hawassa university for post graduate in the field of irrigation and drainage Engineering.