EVALUATION OF THE GROWTH, PHYSIOLOGICAL AND YIELD PERFORMANCE OF COMMON BEAN (*Phaseolus vulgaris* L.) VARIETIES UNDER SOIL MOISTURE STRESS CONDTITIONS

M.Sc. THESIS

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HAWASSA UNIVERSITY, COLLEGE OF AGRICULTURE

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ADVISORS APPROVAL SHEET -1

(Submission Sheet -1)

This is to certify that the thesis entitled **“Evaluation of the Growth, Physiological and Yield Performance of Common Bean (*Phaseolus vulgaris* L.)Varieties under Soil Moisture Stress conditions, Hawassa Ethiopia”.** Submitted in partial fulfillment of the requirements for the degree of Masters of Science with specialization in Agronomy of the Graduate program of the school of Plant and Horticulture Science Department, College of Agriculture, and is record of original research carried out by Mitike Mulatu under my supervision, and no part of thesis has been submitted by any other degree or diploma. The assistance and help received during the course of this investigation have been properly acknowledged. Therefore, I recommend that it to be accepted as fulfilling the thesis requirements.

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As members of the Examining Board of the Final MSc Open Defense, we certify that we have read and evaluated the thesis prepared by Mitike Mulatu entitled **"Evaluation of the Growth, Physiological and Yield Performance of Common Bean (*Phaseolus vulgaris* L.) Varieties under Soil Moisture Stress conditions, at Hawassa Ethiopia"** and recommend that it be accepted as fulfilling the thesis requirement for the degree of the Master of Science in **Agronomy.**

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DEDICATION

This research work is dedicated to my Husband, Mr. Enidalikachew Bochora.

STATEMENT OF THE AUTHOR

By my signature below, I state that this thesis is my satisfaction work and that all sources of materials used for this thesis have been greatly recognized. I strongly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

This thesis has been submitted in partial fulfillment of the requirements for the Degree of Masters of Science in Agriculture, specialization of agronomy at Hawassa University college of Agriculture and it is placed at the University library to be made available for users under the rule of the library.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABA	Abscisic acid
ANOVA	Analysis of Variance
CEC	Cation exchange capacity
CSA	Central statistical agency
EC	Exchange capacity
EC	Electric conductivity
FAOSTAT	Food and Agriculture organization statistics
FC	Field capacity
K	Potassium
LAC	Latin America Caribbean
LRWC	Leaf relative water content
LSD	Least significance difference
MARC	Melkassa Agricultural Research Center
N	Nitrogen
P	Phosphorus
PH	Potential Hydrogen
PSII	Photosystem II
PWP	Permanent wilting point
SAS	Statically Analysis Software
VPD	Vapor pressure deficiency
WUE	Water use efficiency

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Evaluation of the Growth, Physiological and Yield Performance of Common Bean (*Phaseolus vulgaris* L.) Varieties under Moisture Stress at lath house conditions

By

Mitike Mulatu (BSc), Andargachew Gedebo (Ph.D.), Temesgen Magule (Ph.D.) and Amsalu Gobena (Ph.D.).

ABSTRACT

Common bean is one of the most important food crops, with significant economic importance and it is suitable for food security due to its short growing cycle and adaptability to different cropping systems. However, its average yield reported at the national levels remains far below the potential due to various biotic and abiotic constraints among which is moisture stress. The study was conducted to evaluate the effects of moisture stress on growth, physiological and yield and yield components of common bean varieties. A pot experiment was conducted under lath house from June to September 2020, at Hawassa University College of agriculture. Seven common bean varieties viz. Gofta, Fedis, Awash-2, Tinike, Awash-1, Dursitu and Nasir were grown under three irrigation intervals/moisture level viz. watered every day (waterlogging stress), watered every four days (control) and watered every eight days (moisture deficit), in factorial combination using Completely Randomized Design with three replications. The main and interaction effects were significant on Days to flowering, physiological maturity, plant height, leaf number, Shoot fresh weight, Shoot dry weight, root length, Transpiration rate, photosynthesis rate, stomata conductance, water use efficiency, stomata number, stomata width and length, chlorophyll concentration, Proline content, Length of pod, pods plant^{-1}, seeds pod^{-1} and yield gram^{-1}plant^{-1}. However, branch number and Internode length, leaf relative water content, hundred seed weight, total biomass (biological yield), straw yield and harvest index were significantly affected by main effects of moisture levels and varieties but chlorophyll fluorescence was affected by only moisture levels. Moisture stress significantly reduced growth, stomata conductance, photosynthesis, yield and yield components. Varieties performed differently in response to moisture stress. The highest hundred seed weight, biological yield, and straw yield were recorded for Awash-1 and Tinike varieties, respectively in control moisture stress. The highest yield was recorded from the variety Awash-1 and Gofta irrigated every 4 days of interval (control); whereas the lowest yield was recorded from Fedis variety treated with daily irrigation (water logging). Also Awash - 2 varieties is relatively better compared to the Tinike, Fedis, Dursitu and Nasir on yield and yield parameters at all moisture levels. Varieties Gofta, Awash-2 and Awash-1 appeared to be moisture stress-tolerant duo to maximum proline accumulation mechanism, high water use efficiency, low transpiration rate and better photosynthesis and yield performance by using different mechanisms.

Keywords: Common bean, moisture stress, lath house, morphological response, physiological traits, yield component, pot experiment.

1. INTRODUCTION

1.1. Back ground and Justification

Common bean (*Phaseolus vulgaris* L.) is the second most important source of human dietary proteins and the third most important source of calories (Bennink, 2005; Sarikamis *et al.*, 2009Widers, 2006). It is the most important food legume in Latin America and East and Southern Africa. The common bean crop is one of the most traditional foods, with significant social and economic importance. Moreover, it is the most important legume crop for human consumption, accounting for 50% of the grain legumes consumed worldwide (Ayra *et al.*, 2018; Bastos *et al.*, 2016). The ancestors of *Phaseolus vulgaris* L. become visible to have created two distinctive gene pools one in Mesoamerica (Mexico and Central America) and the other in the Southern Andes, a mountain range in South America (Burle *et al*., 2010).

Common bean is particularly suitable for food security due to its short growing cycle (2.5 to 3 months) and adaptability to different cropping systems (Wagara and Kimani, 2007). In Ethiopia, common bean is grown predominantly under smallholder producers as an important food crop and source of cash. It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians (Girma, 2009). Thus, common bean play an essential role in the sustainable livelihoods of smallholder farmers by providing both food security and income generation and have a high potential for reducing malnutrition in poor families (Chekanai *et al.*, 2018).

Common bean is highly polymorphic warm-season crop which has two growth habit: erect herbaceous bushes (determinate) up to 20 to 60 cm height; and twining and climbing vines (indeterminate) up to 2 to 5 m long (Ecocrop, 2013). The crop grows well between 1400 and 2000m above sea levels (Fikru, 2007). Common bean requires a considerable amount of water during its growing season to develop and produce seeds following its genetic potential (Beebe *et al.*, 2013; Broughton *et al.*, 2003; Rao *et al.*, 2013). In the developing world, beans are traditionally a small farmer crop, often grown in complex farming systems in association or rotation with maize, sorghum, bananas or other crops (Broughton *et al.*, 2003).

The East African lowlands are a region of important common bean production and high varietal diversity for the crop (Fivawo *et al.*, 2011). Total national production was estimated at 5137.21 ton in 2014 (CSA, 2014). In Ethiopia, common bean is mainly grown in Eastern, Southern, Southwestern, and Rift valley areas of the country (Habte *et al.*, 2014). In 2011/12, total common bean production in the country was about 387802.301 ton (1.77% of the grain production) on approximately 331,708.15 hectares of land (2.74% of the grain crop area) (CSA, 2011).

Low yield is attributed to various constraints such as moisture stress, absence of improved high yielding varieties, low soil fertility, losses due to insect, pests and disease (Eden, 2002; Ferris and Kaganzi, 2008; Girma, 2009). From these constraints soil moisture is one of the main environmental factors affecting growth and crop yield. Moisture stress reduces the growth and yield of various crops by decreasing chlorophyll pigments, photosynthetic rate, stomatal conductance as well as transpiration rates (Taiz *et al.*, 2015). Plants grown under drought levels have a lower stomatal conductance to conserve water. So, CO2 fixation is reduced and photosynthetic rate decreases, resulting in less assimilate production for growth and yield of plants (Mafakheri *et al.*, 2010). Moisture deficit reduced grain yield of common bean cultivars, by 50 % (Molina *et al*., 2001).

On the other hand, moisture stress is not only due to lack of water, but moisture stress can also be explained in terms of excess water due to inaccessibility to root uptake. Water is chemically important, but, its certain physical properties interfere with free gas exchange and thus can injure and kill plants when they are submerged (Jackson and Ricard, 2003) or even when only the soil is waterlogged. In waterlogged soils, gas exchange between root systems and soil pore spaces are limited due to oxygen diffusion resistance that is around 10,000 times higher in water than in the air (Ashraf, 2012; Borella *et al.*, 2014). Since oxygen diffuses through uninterrupted water much more slowly than a well-drained soil, when soils are saturated, oxygen requirements rapidly exceed available concentrations (Meronuck, *et al*., 2016). As a result, under water logged level, plant roots suffer from hypoxia (deficiency of O2) or anoxia (absence of O2), which reduce nutrient uptake, crop growth and yield (Ashraf, 2012; Houk, *et al*., 2004). Crop damages due to waterlogging include necrosis, stunting, defoliation, reduced N fixation and plant death (Ahmed *et al*., 2013).

In addition to the effect on the roots, excessive rainfall does have destructive effects on plant leaves. Plant responses to flooding include reduced stem growth, inhibition of leaf elongation, chlorosis, reduced rates of CO2 assimilation reduced nutrient uptake and reduced root and shoot growth, the formation of aerenchyma and adventitious roots and increased susceptibility to attack by pathogens and predators(Celik and Turhan, 2011). While, the degree varies from genotype to genotype, the same as to, the previous report indicated that Common bean productivity significantly reduced due to waterlogging and the effect is becoming an increasingly important abiotic stress that seriously restricts crop growth (Yamauchi *et al*., 2018).

Plants have diverse mechanisms for response and adaptation to moisture stress; thus, the determination of their distinct morphological, physiological and agronomic traits for stress tolerance is crucial to ensure efficiency in the selection process (Beebe *et al*., 2013). An early morphological response to moisture deficit is the avoidance mechanism through adjustment of plant growth rates such as a reduction in shoot height, basal diameter and total fresh/ dry mass in the bean species (Lei *et al*., 2006; Kusvuran *et al*., 2011). Root architecture can allow deeper and wetter soil layers to be exploited to escape from moisture deficit, and thus it can be a promising trait for crop performance under stress levels (Vadez, 2014). However, Plants experiencing drought can adjust their morphology to optimize water uptake by the roots while decreasing the rate of photosynthesis by the leaves, thereby changing the production of growth and defense metabolites (Grant *et al*., 2005; Kleine and Mueller, 2014; Koricheva *et al.*, 1998; Nicotra *et al*., 2007). On the other way, Plants have evolved various physiological and metabolic responses to individual stresses, but the nature of such responses strongly depend on whether and how stresses co-occur in the plant‘s environment (Atkinson and Urwin, 2012; Nguyen *et al*., 2016; Suzuki *et al*., 2014). Similarly, Drought resistance mechanisms in plants are also varying based on the potential and sensitivity of plants. Some they avoid moisture stress by sustaining of important physiological processes such as stomata regulation when exposed to mild drought, others they tolerate by osmotic adjustment and osmoprotectant and others they regulate growth period to avoid moisture stress; termed as drought escape (Fang *et al*., 2015; Luo, 2010; Manavalan *et al*., 2009). Physiological aspects, such as lower stomatal conductance, are also considered to be mechanisms of adaptation to water shortage, allowing the plant to reduce evapotranspiration area (Beebe *et al*., 2013; Rao, 2014). Root architecture and malleability play an important role in the adaptation to submergence and waterlogging stress. The formation of aerenchyma and adventitious roots is a morphological characteristic of waterlogging-tolerant species (Fukao *et al*., 2003).

Systems to facilitate the identification of drought tolerant genotypes have become important in modern agriculture (Todaka *et al*., 2015). However, the mechanism of how common bean varieties are adapting to different moisture stress is not well addressed. This study therefore seeks to study the effect of moisture stress at different growth stages on the productivity of common bean and provides to identify tolerant and sensitive common bean varieties. It also focused to evaluate phenotypic variability, physiological traits and morphological responses of common bean varieties under different soil moisture levels and to determine the relationship between these traits and yield components.

1.2. Objectives

General objective

- To study the effect of moisture stress on morphological and physiological traits and productivity of common bean varieties.

Specific objectives

- ✓ To evaluate the effect of different moisture levels on morphological and physiological performance of common bean varieties.
- ✓ To evaluate the effect of different moisture levels on yield and yield components of common bean varieties.
- ✓ To identify well performing common bean varieties under moisture stress conditions.

2. LITRATURE REVIEW

2.1. Common bean

Common bean originated from the New World; two centers of origin were identified Andean and Mesoamerican (Hornakova *et al.,* 2003; Logozzo *et al.,* 2007). Common bean is a diploid (2n=22) annual leguminous plant that belongs to the genus Phaseolus and it is characterized by pinnately compound trifoliate leaves. The domestication occurred independently in South America and Central America/Mexico leading to two different domesticated gene pools the Andean and Mesoamerican respectively (Papa and Gepts, 2003; Petry *et al.,* 2015).This crop is native to Mexico and Guatemala where the greater part of the diversity of varieties is found (Arenas *et al*., 2013). Common bean is the most widely distributed of the related species and has the broadest range of genetic resources (Gomez, 2004) and is frequently used as food crop throughout the world; especially in Latin America and Africa.

Agriculturally, Common bean is important in providing fodder for feeding livestock and it contributes to soil fertility improvement through atmospheric nitrogen fixation during cropping season (Asfaw and Blair, 2014; David, 2016). Common bean is the major source of cash income for African economies by generating foreign exchange earnings and benefitting small-holder farmers and ranks are third as an export commodity in Ethiopia and contributing about 9.5% of the total export value from the agricultural income of the country (FAOSTAT, 2015).

Ethiopia is the third largest producer of common beans in Eastern and Southern Africa and the leading exporter in Africa (CSA, 2003). The country exported 40 percent of its common beans out of the total production in 2010 (FAOSTAT, 2015). The major common bean producing areas of Ethiopia are central, eastern and southern parts of the country (CSA, 2016). Different varieties of common beans grow in different parts of Ethiopia; white beans grow in the central Ethiopia (Shoa) as cash crop, colored beans grow in the southern part of Ethiopia for local consumption and climbing beans grow in the North West (Metekel) and western Ethiopia (Wollega). Climbing type of common bean is planted along fences and on the borders of maize fields (Rahmeto Negash, 2007). Common beans are increasingly becoming an important food security commodity particularly among the smallholders.

Production of common bean is highly constrained by environmental factors such as moisture stress, pests, diseases, and low input farming methods that have resulted in declined soil fertility and productivity (Asrat Asfaw *et al*., 2013). Also soil fertility status, repeated moisture stress, insect pests, weeds and diseases are considered as the principal abiotic and biotic constraints of common bean production in Africa (Amin Mohammed and Tesfaye Amare, 2014; Adam Bekele &Yitayal Abebe, 2015). Among the abiotic factors, Moisture stress during the reproductive development of a crop is usually associated with a large decrease in yield through biomass and low Socio-economic status related to farmer adoption of new technologies, seed distribution and market requirements may also restrict bean production (Negash, 2007).

2.2. Plant Response to Moisture Stress Conditions

Even though drought involves a level where there is a deficiency of precipitation (rainfall) over an extended period of time resulting in a water shortage for some activity, group, it also related to the timing and the effectiveness of precipitation. Moisture deficit is case of the reduction of fresh and dry biomass production of common bean (Zhao *et al*., 2006).

The phenological response of plant is reported by several authors that under stress level plant facilitate their growth and will mature early. Plant responds to moisture stress by facilitating vegetative growth and they flower early (Barnabas *et al*., 2008; Deikman *et al*., 2012; El Soda *et al*., 2010).Varieties which mature early perform better under the stress levels than long duration ones, might be because of their different root system (Singh *et al*., 2010).

Plants also respond physiologically by increasing abscisic acid production, decrease in water use efficiency, decline in net photosynthesis due to stomata closure and absence of water (Anjum *et al*., 2011). Decrease in relative water content has also been reported (Nayyar and Gupta, 2006). Generation of reactive oxygen species (Farooq *et al*., 2009) and production of antioxidant enzyme (Horváth *et al*., 2007) also reported as biochemical response.

The main cause of damage under waterlogging is oxygen deficiency, so the plants show wilting even when enclosed by an excess of water, which affects nutrient and water uptake (Sairam *et al*., 2008). When plants are grown underwater or salt stress, the competition is more distinct and roots describe the tolerance of plants against stress (Raiz *et al.*, 2013).Roots in waterlogged soils frequently die of anoxia (oxygen deficiency).

Most trees and shrubs cannot grow for long in waterlogged soil (Halcomb, 2003) roots, suffer hypoxia or anoxia. Moreover, aerenchyma, which thought to contribute to waterlogging tolerance, is developed in the cortex of new and existing roots of some plant species. In the rice crop the aerenchyma well developed and adopt flooded levels (Tepwadee, 2008). Oxygen deficiency inhibits the root respiration of plants, which results in a considerable reduction in energy kind of root cells. Since in the absence of oxygen terminate electron acceptor in aerobic respiration, also Kreb's cycle and electron transport system are blocked (Ashraf, 2012). Waterlogging induced several physiological disturbances in growth, dry matter, photosynthesis and pod formation that resulted in lower yield (Solaiman *et al.*, 2007; Pociecha *et al.*, 2008; Celik and Turhan, 2011; Hasan uzzaman *et al.*, 2016). Waterlogging reduced seed yield primarily by reducing the number of pods per plant and pod setting (Ahmed *et al*., 2002). One of the first plant responses to waterlogging is the reduction in stomata Conductance (Folzer *et al*., 2006). Low levels of O2 may decrease hydraulic conductivity due to hampered root permeability (Else *et al*., 2001).

2.3. Effects of Moisture stress on Growth, Yield and Yield Components Common Bean

The effects of moisture deficit vary depending on the frequency, duration; intensity of stress, growth stages affected and can be amplified by other stresses such as poor soils, disease, and heat (Ambachew *et al.*, 2015; Muñoz- Perea *et al*., 2007; Tilahun *et al*., 2004;). Moisture deficit has also been proved to be a very important limiting factor at the first phase of plant growth and formation through its effects on both elongation and extension growth (Anjum *et al.*, 2003; Shao *et al.*, 2008). This is due to low turgor pressure which suppresses cell enlargement and development leading to significant reductions in fresh and dry biomass production (Farooq *et al.*, 2009). Drought is the second most important factor in yield decrease after diseases (Polania *et al.*, 2016). Yield components such as the number of pods per plant, number of seeds per pod, seed weight, and harvest index more affected by moisture deficit

(Ambachew *et al.*, 2015; Darkwa *et al.*, 2016). Moreover, moisture deficit during flowering and seed formation stages decreased common bean yield (Boutraa and Sanders, 2001). It was noted that post-flowering warmness stress caused yield losses of up to 50% due to reduced seed filling duration (Bernier *et al*., 2007; Beebe *et al*., 2013).

However, extra water is more common and often causes significant yield loss across plant species. According to Richee (2004) waterlogging stress can reduce soybean yield by up to 43% during the vegetative growth stages and 56% during the reproductive stage. Waterlogging during the vegetative and the early reproductive stage is more damaging to grain yield than other stages (Toai *et al.*, 2010). The extended duration of waterlogging resulted in a significant yield reduction (Ren *et al.*, 2014). Waterlogging induced several physiological disturbances in growth, dry matter, photosynthesis and pod formation that resulted in lower yield (Celik and Turhan, 2011; Hasan uzzaman *et al.*, 2016; Pociecha *et al*., 2008; Solaiman *et al.*, 2007). Waterlogging reduced seed yield primarily by reducing the number of pods per plant and pod setting (Ahmed *et al*., 2002). One of the first plant responses to waterlogging is the reduction in stomata Conductance (Folzer *et al*., 2006). Low levels of O2 may decrease hydraulic conductivity due to hampered root permeability (Else *et al*., 2001). However, other factors such as reduced chlorophyll contents, leaf senescence, and reduced leaf area are also held responsible for decreased rates of photosynthesis (Malik *et al.*, 2001). However, plants exhibit a certain adaptation under waterlogging stress to maintain photosynthetic capacity (Li *et al*., 2004). In addition to moisture stress, smallholders are often affected by declining soil fertility due to their marginalized situation and their inability to overcome production constraints (Douxchamps *et al*., 2010).

2.4. Physiological Response of Common Bean to Moisture Stress

In many plants, physiological traits that are associated with drought tolerance when a plant is subjected to moisture deficit include greater cell growth, photosynthesis and biomass accumulation during pre-flowering stress, high pollen viability, seed set and seed numbers at flowering and improved stay green, photosynthesis and seed size during post flowering drought. Photosynthesis is the gas exchange of the plants (as reflected in CO2 assimilation, transpiration and stomatal conductance) is the principal plant process responsible for plant biomass production and for plant adaptation to a change in environment (Lawlor and Tezara, 2009).

The effects of moisture deficit on photosynthesis are attributed to two major components i.e. reduced gas exchange and loss of efficiency in the physiological processes of photosynthesis (Ashraf and Harris, 2013). Existence of genetic variability for gas exchange performance in common bean (Comstock and Ehleringer, 1993; Gebeyehu, 2006; Mencuccini *et al.*, 2000) and soyabean (Fenta *et al*., 2011; Flexas *et al*., 2006a; Liu *et al*., 2005) has already been reported. Furthermore, during the process of photosynthesis, photochemical and biochemical activities occur in the leaf and these activities are seriously affected by moisture deficit (Chaves *et al.*, 2002). Photosynthetic pigments are important to plants mainly for harvesting light and production of reducing power (Jaleel, 2008). Both the chlorophyll a and b are prone to soil dehydration (Farooq *et al*., 2009). Foliar photosynthetic rate of higher plants is known to decrease as relative water content and leaf water potential decrease. Physiological responses to moisture deficit include loss of turgor pressure (Tardieu *et al*., 2014), decrease in stomatal conductance or stomatal closure, reduced leaf water potential, recognition of root signals, a decline in net photosynthesis and reduced growth rates (Xu *et al*., 2010). For the plant leaf, WUE is defined as the ratio between instantaneous net CO2 assimilation rate (A) and transpiration (E) (A/E). Since WUE largely depends on vapors pressure deficit, the ration between CO2 assimilation and stomatal conductance (Gs) (A/Gs), which is termed inherent water use efficiency is usually used as a normalized value when compared to instantaneous water use efficiency (Chaves and Oliveira, 2004; Farquhar *et al*., 1989; Soares-Cordeiro *et al.*, 2009). Absorption of water, physiological adaptation through stomatal conductance, along with satisfactory grain yield in stressed crops (Blair *et al*., 2012).

Stomata traits such as number, length and width are considered to be key determinants of growth rate and water balance in plants (Dillen *et al*., 2008). Stomata traits are strongly controlled by genetic factors (Gailing *et al*., 2008). This phenomenon preserves levels of plasticity in response to different moisture stress levels. At higher moisture stress levels (moisture deficit), plants have smaller stomata with less length and width and with a more stomata density to control transpiration and save water (Belhadj *et al*., 2011; Bosabalidis and Kofidis, 2002; Hetherington and Woodward, 2003).

Leaf temperature of plants under moisture stress is higher than those with adequate water availability. Plants can be evaluated for their leaf water potential correlated to gas exchange, growth, and physiological parameters (Williams and Araujo, 2002). The leaf water potential increased exponentially with increasing water availability in the soil.

2.5. Adaptation Mechanism of Plant to Moisture Stress

When plants are able to survive and produce in periods of dry weather, the mechanism is called drought resistance, which can be grouped into three categories: stress escaping, avoidance and tolerance (Levitt, 1972).

Plant performance is further associated with effective use of water through better root development as a drought avoidance mechanism (Blum, 2011). Previous research has also shown the importance of deep rooting for better performance under drought in beans (Castillo and White, 1991), wheat (Reynolds *et al*., 2007) and rice (Li *et al*., 2005). Therefore, better understanding of root traits would be vital for improving the legume selection strategy to sustain productivity under water-limited levels.

Escaping : is defined as the ability of the plant to complete its life cycle before severe soil and plant moisture deficits occurs, the mechanism involves early maturity and flowering (Amede *et al*., 2004). Drought escape is usually related to earliness in maturity. The second alternative is that although a genotype shows normal maturity under irrigated levels, its maturity date shows plasticity such that drought causes greater acceleration of maturity than occurs in other genotypes. Earliness in flowering and maturity are usually considered as effective drought escape mechanisms resulting in better seed yields in moisture stressed environments (White and Singh, 1991).

Avoidance: When plants can avoid drought through their ability to maintain relatively high tissue water potential, despite a shortage of soil moisture. This is achieved through increased rooting depth, an efficient root system and increased hydraulic conductance. This mechanism ensures that the plant maintains higher water status during that period of moisture deficit and this can also be achieved by reducing transpiration from aerial parts (Levitt, 1980). Unlike other dehydration avoidance strategies (stomatal closure, leaf rolling or abscission), dehydration avoidance through improved root development sustains productivity of plants by maintaining the plant water status and photosynthetic assimilation (Lopes *et al*., 2011).

Tolerance: when Plants have the ability to withstand moisture deficit with low tissue water potential. This is achieved through maintenance of turgor through osmotic adjustment (a process which induces solute accumulation in the cell); increase in cell elasticity and decrease in cell size; and desiccation tolerance by protoplasmic resistance (Beebe *et al.*, 2013). Genetic and physiological mechanisms related to the responses of plants to moisture stress are important for the selection of superior materials for drought tolerance. Another important factor is the timing of water shortage for the evaluation of bean genotypes and according to the reproductive phase is appropriate because of the reduction caused in genotype yield (Didonet and Silva, 2004; Massignam *et al*., 1998; Stone and Silveira, 2012).

3. MATERIALS AND METHODS

3.1. Description of Experimental Site

The experiment was carried out under lath house condition during June to September 2020 at Hawassa University College of Agriculture. The area is located in the Sidama region in Southern Ethiopia, which is 275 km far away from Addis Ababa the capital city of Ethiopia. It is found at an altitude of 1750 m.a.s.l and 7o 3' N latitude with 38o 28' E longitude. According to last 11 (2007 – 2018) data weather station, the mean annual rainfall is about 971.9 mm and average temperature 20.85 (National Meteorology Agency, 2019).

The shade house used for the experiment was fenced with metal wire and the roof was covered by transparent polycarbonate. For this experiment seven released common bean varieties were used. The varieties were: Awash-1, Awash-2, Dursitu, Fedis, Gofta, Nasir and Tinike. Dursitu and Nasir was determinate bush type, whereas Awash-2 was determinate upright bush type and Awash-1, Gofta, Fedis and Tinike was determinate twining (having tendril) varieties. Detail information showed by table below.

Table 1: Common bean varieties used for the experiment

No	Variety Name	Pedigree	Released Year	Seed color	Seed size	Breeder/ Maintainer	Potential Yield
1	Gofta	G-2816	1997	Cream	Medium	HU	3.5
2	Fedis	ECAB0060	2012	pinto	Large	HU	3.6
3	Awash-2	-	2013	White	Small	MARC	3.1
4	Tinike	RXR-102	2012	purple	Large	HU	2.7
5	Awash-1	Extrico-23	1990	Cream	Medium	MARC	2.4
6	Dursitu	DOR-811	2008	Red	Small	HU	2.2
7	Nasir	Dicta-105	2003	Red	Small	MARC	2.3

3.2. Experimental Design and Treatments

The pot experiment was laid out as a completely randomized design arranged as a factorial combination of different moisture levels and varieties containing three replications.

The main treatment included three moisture levels (waterlogging stress , Optimum and moisture deficit) and seven common bean varieties (Awash-1, Awash-2, Dursitu , Fedis, Gofta, Nasir , and Tinike) in 7 x 3 factorial arrangement, formed twenty one treatment combination with three replications (63 experimental units) (Table 2). One pot contains one plant. Therefore, nine pots per experimental unit were considered as one plot so that 567 total pots were used for the experiment. For effective use of irrigation water and optimum growth of common bean cultivars, 75% water treatment levels was advisable (Abiot Molla, 2018). Actual moisture treatment was imposed at 21 days after planting, as soon as the commencements of three trifoliate leaves.

3.3. Experimental procedures and management

Top soil was collected from Hawassa University College of agriculture, plant science department field demonstration site up to 30cm depth and 3kg soil composite were prepared for soil analysis. Then, the composite soil air dried for 21 days to have constant weight. Then, a total of 567 experimental pots having 5 litters volume with perforated at the bottom to allow air and water movement and it filled 3 kg soil up to5cm left above the pot and the water was applied 2 days before planting. The next day physically pure two seeds of each genotype were directly planted per experimental pots and two weeks after planting the seedlings were thinned. The irrigation interval treatment was applied after 20 days from sowing. The soil moisture content at field capacity was determined by using moisture censer. The treatment was 8 days interval for moisture deficit, 4 days interval for optimum/control and daily watering interval for water logging /flooding level with seven common bean varieties.

Table 2. Description of the experimental treatments combination

Moisture levels	**Varieties**	**Description of treatments**
Moisture deficit	Gofta Fedis Awash-2 Tinike Awash-1 Dursitu Nasir	Pots were watered with in the interval of eight days to control the treatment was become wilting stage
Control	Gofta Fedis Awash-2 Tinike Awash-1 Dursitu Nasir	Pots were watered with in the interval of four days to control the soil moisture at field capacity(optimum
Water logging	Gofta Fedis Awash-2 Tinike Awash-1 Dursitu Nasir	Each pot was placed on a bowl to hold the drained water through the bottom of the pot and the Water was applied daily and to maintained at fill the pot Throughout the Experimental period (Flooded)

3.4. Physico-chemical Properties of the Experimental Soil

Initial physico-chemical properties of the experimental soil sampling and preparation of 3kg composite Soil for Laboratory Analysis are necessary. The composited samples were dried and grounded to pass through 0.2 mm sieve before laboratory analysis, and the samples were analyzed for parameters relevant to the study at Hawassa soil laboratory. Soil analysis was made as per the normal laboratory procedure. The soil pH values were determined in soil water suspension 1:2.5 using glass electrode pH meters (Jackson, 1967). Based on the oxidation of organic carbon with acid potassium dichromate, Organic matter content was determined using Walkely‘s and Black methods respectively (Jackson, 1967). The chemical and physical properties of the soil before planting are presented in Table -3. Common bean prefers well-drained, sandy clay, or sandy loam soils, with balanced fertility and moderate acidity pH 5.8-6.5 (Liebenberg, 2009). Common bean performs best on deep, friable, and well-aerated soil types with an optimum pH range of 6.0 to 6.8.

Table 3 : Physico - chemical Characteristics of the Experimental soil before planting

Properties	Values
Sand (%)	54
Clay (%)	14
Silt (%)	32
Class	Sandy loam
Organic carbon (%)	4.67
Total nitrogen (%)	0.26
Available phosphorus (ppm)	13
PH-(H2O)	7.54
PH-(KCL)	6.62
EC(µs)	5.04
CEC(MEQ/100gsoil)	35.73
FC (%)	25
PWP (%)	18

3.5. Metrological Data

The lath house used for the experiment was enclosed with metal wire to protect the entrance of any undesirable body. The roof of the lath house was covered by transparent grooved tin. The meteorological measurements recorded during the experiment are: air temperature, leaf temperature, and relative humidity

3.5.1. Air temperature and relative humidity

Temperature and relative humidity data were recorded on randomly selected 30 days using mini data loggers (Testo 174, Version 5.0.2564.18771, and Lenzkirch, Germany). The data logger was hanged closer to the plant canopy (30cm above the ground) and covered from the top with a flat carton to avoid direct sun and moisture. Data were measured for 10days.

3.5.2. Leaf temperature

The daily leaf temperatures were recorded three times a day (morning, midday and evening) on randomly selected 10 days using infrared thermometer during the experimental period from June to September 2020.

3.6. Agronomic Data Collection

Data were collected throughout the experimental period at different stages to evaluate the effects of moisture stress on the growth and physiological performance of varieties. Consequently, during the experimental period Initial soil physical and chemical property, climate data, phenological, growth, physiological trait and yield and yield components were measured and the average number of each parameter was subjected to statistical analysis.

3.6.1. Crop Phenology

Days to emerge were recorded by counting the number of days taken from sowing to the above ground appearance of 50% emerges. Days to Flowering was recorded by counting the number of days taken from planting to when 50% of the plants per plot open flower. Days to physiological maturity was determined as the number of days from date of planting to the date when 90% of the plants in each plot attained physiological maturity when the pods had lost their green pigmentation (Beebe *et al*., 2011).

3.6.2. Growth and Morphological parameters

Average plant heights of five randomly reserved plants from each plot were measured from the top of the pot to the tip of the plant (meristem) at 50% flowering. Branch number per plant was counted for all five randomly selected plants. Number of leaf per plant was recorded as counted average of all leaves of five randomly selected plants per plot. Average internode length was measured from randomly selected five plants of each unit at pod setting stage. Average tap root and lateral root length was measured from randomly selected five plants of each unit at the vegetative stage before flowering and collar tap root diameter was measured through the average of five randomly selected plants by caliper. Shoot fresh weight was measured using sensitive balance at pod filling stage before leaf defoliation. Shoot dry weight was measured by electronic sensitive balance after the samples had been oven-dried and got consistent weight (48hr at 75°C).

3.6.3. Physiological parameters

Stomata number, length and width

Stomata number, length and width were measured by using the protocol proposed by Xu and Zhou (2008) at the pod setting stage. A thin layer of transparent nail polish was uniformly stained on the lower surface of fresh intact leaves and waited for 10 minutes until the nail polish dried to capture the epidermal imprint of the leaves, thereafter, a thin layer covering a surface on the leaves were peeled off using transparent tape and attached on the microscope slide. Automated Upright Leica Microscope DM5000 B with a 40x magnification lens fixed with a digital Leica DFC425/DFC425C image processing camera was used to count the stomata number and to measure the aperture. For each sample, stomata number (per mm^2), stomata width (μm), and length (μm) were measured.

Gas exchange parameters

Photosynthetic rates were measured using a Li-6400 portable photosynthesis system (LICOR Inc., Lincoln, NE, USA). Photosynthesis (A), Stomata conductance (gs), and transpiration rate (E) were measured at vegetative growth stage (40 Days after planting) on fully developed leaves. Measurement was done between 10:00 AM and 12:00 PM by maintaining the following specifications: Leaf surface area $4.5cm^2$, Water use efficiency was determined as the ratio between net CO2 assimilation rate (A) and transpiration rate (E) (Bertolde *et al*., 2012).

Determination of leaf chlorophyll concentration

Leaf chlorophyll concentration was measured at the mid-pod fill stage on fully expanded young leaves of three plants in each plot (unit). Sampling was done at 8:00 AM and leaves were placed in a bag sealed with aluminum foil and transported to the plant cell laboratory immediately. 0.5g of fresh leaf discs were placed in 15-mL tubes containing 95 %(v/v) ethanol and homogenized with ethanol using a pestle and mortar. The homogenized sample mixture was centrifuge for 10,000 rpm for 15min at room temperature in dark. The supernatant was separated and 0.5ml of each concentration levels was analyzed in triplicate for Chlorophyll-a and Chlorophyll-b at an absorbance of 664nm and 648nm wavelength region, respectively in spectrophotometer UV-2450 (Hitachi, Tokyo, Japan).

The following equations were used for the quantification of Chlorophyll-a and Chlorophyll-b (Lichtenthaler and Buschmann, 2001).

Ch a (μg/ml) = 13.36 A664 – 5.19 A648

Ch b (μg/ml) = 27.43 A648 – 8.12 A664

Total chl (μg/ml) =chl a + chl b

Where; A = Absorbance, Ch a = Chlorophyll a, Chb = Chlorophyll b

Determination of leaf chlorophyll fluorescence

To evaluate the performance of the plants, maximal photosystem II efficiency (Fv/Fm) of well-developed leaves at third node from randomly selected vegetative plants at age of thirty days after planting (ten days after the start of the treatment). Measurement was done in the evening between 4:00am to 6:00pm with a Handy-*PEA* fluorimeter (Hansatech, Kings Lynn, UK) following the methodology of (Strasser *et al.*, 2004). Before measurement, leaves were dark-adapted in the leaf clip for 30 min. Light was then provided by an array of three high-intensity light-emitting diodes and adjusted to 1500 µmol m-2 s-1 to ensure that the photosynthesis was saturated during the measurements.

Determination of proline concentration

At pod filling stage leaf samples from each unit were collected for determining proline content using the method of Bates *et al*.(1973). First, 50 mg fresh leaf samples were placed in 1ml of ethanol and allowed to overnight at 4℃; following day the samples were centrifuged at 14000g for 5minutes. 100µl of reaction mix [(1% ninhydrin (w/v) + 60% Glacial acetic acid (v/v) + 20% ethanol (v/v)] was pipetted to each and the sample was heated at 95℃ for 20 minutes. After cooling at room temperature the supernatant was centrifuged down quickly (1min.2500rpm). Then 100µl of the supernatant was transferred to a micro plate reader and quantified at 520nm using Multisken FC. Proline concentration was determined using a standard of calibration curve and expressed as µg/g leaf fresh weight.

Relative Leaf water Content (RLWC)

Three fully expanded leaves were collected from representative plants and 5 leaf disks(9mm in diameter) were collected from each leaf and immediately weighted (leaf fresh weight), then the samples were immediately hydrated to full turgidity for 24 h by immersing in double distilled water in a closed 15-ml tube under room temperature (25℃). Afterward, hydrated the water droplet on the surface of the leaf disc was carefully removed with tissue paper and reweighted to obtain fully turgid mass (leaf turgid weight). Samples were oven-dried at 75°C for 24 h until constant dry mass (leaf dry weight) was obtained. Finally the relative leaf water content was calculated as RLWC = [(leaf fresh weight – leaf dry weight)/ (leaf turgid weight – leaf dry weight)] × 100.

3.6.4. Data collection on yield and yield component

Yield and yield component parameters were collected at physiological maturity, when 90% of the pods had lost their green color and changed their color from green to yellow (Munoz *et al*., 2006). The Average numbers of pods per plant were determined by counting pods of the five randomly selected plants per plot. The Average number of seeds per pod was determined by dividing number of seeds per plant by the number of pods per plant.

The weight of 100 seeds was determined by carefully counting the grains and weighing them using a sensitive balance after equal seed moisture content. The average grain yield in gram was measured from five randomly taken plants after harvesting the crop in each plot by a digital electronic balance; with a precision scale of +0.00001g after seed moisture was corrected to 14 % . Biomass yield was measured by weighing the sun dried total above ground plant biomass (straw + grain) of the net plot. Straw yield was measured by subtracting the grain yield from the total above ground biomass yield after threshing.

3.7. Statistical Analysis

All collected data were elaborated statistically using analysis of variance (ANOVA) using SAS software version 9.3, 2018. Mean separation was made based on LSD test at ($P \leq 0.05$). The degree of association between parameters was performed by adopting simple Pearson correlation analysis.

4. RESULTS AND DISCUSSONS

4.1. Weather Conditions

Air temperature: From the result, it was observed that the daily average temperature at the lath house was 32.1℃, while the maximum and the minimum were 33.5℃ (at 2:30 pm) and 30.1℃ (at 10:30 am) respectively (Table 4). Abebe *et al*. (2005) reported that common bean grows best in a warm climate at a temperature range of 18°C to 24°C, showing the temperature at the lath house was relatively high for the crop.

Relative humidity: The daily maximum relative humidity (66.62%) was recorded at 6:18 am which was coincided with lath house minimum temperature (30.13℃) and minimum vapor pressure difference (2.14). Likewise, lath house daily minimum relative humidity (50.22%) was recorded at 12:18 pm which was coincided with maximum daily temperature (33.5^oc) and maximum daily vapor pressure deficit (3.56).

Table 4 : Temperature, relative humidity (RH) and vapour pressure deficit (VPD) of the lath house measured on randomly selected 15 days (Average of 15 days)

Hours	Temperature (℃)	RH (%)	VPD (KPa)
11:30:00am	32.13	56.34	2.78
12:30:00pm	31.8	64.83	2.61
1:30:00pm	30.86	65.8	2.25
2:30:00pm	30.13	66.62	2.14
3: 30:00pm	32.43	58.91	2.71
4:30:00pm	32.83	58.8	2.86
5:30:00pm	32.36	61.71	2.85
6:30:00am	32.06	61.86	2.87
7:30:00am	31.33	61.26	2.82
8:30:00am	32.66	60.07	3.04
9:30:00am	33.1	56.02	3.04
10:30:00am	32.63	56.58	3.02
11:30:00:am	32.36	58.41	2.98
12:30:00pm	32.6	55.9	3
1:30:00pm	32.26	58.55	2.68
2:30:00pm	33.5	50.22	3.56
3:30:00pm	30.46	65.3	2.7
4:30:00pm	32.03	6.2	2.81
5:30:00pm	33.1	56.69	2.86
6:30:00am	32.03	58.61	3.14
7:30:00am	31.93	64.18	2.83
8:30:00am	32.5	56.8	3.06
9:30:00am	32.9	55.33	2.93
10:30:00am	33.1	52.8	3.42

4.2. Crop Phenology

4.2.1. Days to emergence

There was no significant difference between the varieties on days to emergence.

4.2.2. Days to flowering

Days to flowering was significantly ($p<0.001$) influenced by variety, moisture levels and the interaction between variety and moisture levels (Appendix Table-1). Accordingly, the shortest days to flowering were recorded from Gofta variety (32 days), and followed by Awash-1 variety (35days) and Awash-2 variety (38days) regardless of moisture deficit. The longest days to flowering were recorded from Nasir variety (51 days) treated with daily irrigation (Table-5), exceeding the earliest variety Gofta by 19 days. SO, moisture deficit shortened days to flowering compared to the control growing with no moisture deficit and waterlogging stress. Previous report indicated that flowering of different crop genotypes was significantly influenced by different levels of soil moisture deficit (Boutraa and Sanders, 2001; Molina *et al*., 2001).

Similar findings were reported by Araus *et al*. (2002) who renowned that flowering time is an important trait related to drought adaptation, where a short life cycle can lead to drought escape. Beruktawit *et al*. (2012) also reported that significant differences were detected among varieties of common bean on days to flowering due to adaptive mechanisms. Advancing the flowering cycle due to drought might be one of the strategy for the crop to escape from moisture stress (Heschel and Riginos, 2005; Wu *et al*., 2010).

According to Caruso (2006) a plastic response to drought would mean that the plants modify their phenotype by increasing avoidance or escape traits in drought relative to non-drought levels. In this study it was observed that the shortest days to flowering through Gofta, Awash-1 and Awash-2 varieties had stronger plasticity to modify the phenological stage according to the signal obtained from the environment compared to Fedis, Tinike, Dursitu and Nasir varieties. Therefore, our result was observed that days to flowering are different among varieties; this might be due to different genetic potential of the varieties to escape moisture stress.

4.2.3 Days to Physiological Maturity

Result analysis in appendix table 1 indicated that variety, moisture levels and the interaction between variety and moisture levels significantly ($p \leq 0.01$) on days to physiological maturity. The earliest days to physiological maturity were recorded from Gofta variety (62 days) under moisture deficit treatment, but Awash-1(76), Fedis (77) and Tinike (78days) varieties were late matured when they exposed to daily irrigation because they are not statistical significant (Table-5.). In this result the time required for maturity of common bean in the present study ranged from 62-78 days and the difference was 16 days. Days to physiological maturity were extended to78 days in all varieties treated by logging stress. This finding similar to Acosta *et al.*, (2009) who reported that a short growing cycle has been previously familiar as a significant escape mechanism from drought in common bean. Similarly Rao *et al*. (2013) described drought tolerance of early-maturing genotypes, given their lower net water requirement throughout their plant life cycle compared with late-maturing genotypes. Ashraf, 2012 found that plants exposed to waterlogging stress exhibit stomata closure, limited water uptake, oxygen deficiency and great decline of photosynthetic rate.

Waterlogging stress is also known to induce changes in physiological mechanisms and cause adverse effects on several physiological and biochemical process of plants, due to the deficiency of essential nutrients like nitrogen, magnesium, potassium, and calcium (Ashraf, 2012). Away from each other stomatal limitations, photosynthesis rates can also be determined by non-stomatal factors, such as mesophyll conductance (Jones, 1985; Flexas and Medrano, 2002).

Table 5 : Interaction effect of varieties and soil moisture levels on days to flowering and days to physiological maturity

Moisture levels	Varieties	Days of flowering	Days of physiological Maturity
Moisture deficit	Gofta	32^{m}	62^{j}
	Fedis	42^{hi}	69^{h}
	Awash-2	38^{k}	65^{i}
	Tinike	43^{ghi}	74^{def}
	Awash-1	35^{l}	73^{efg}
	Dursitu	46^{cd}	71^{g}
	Nasir	48^{b}	$7g^{g}$
Control	Gofta	38^{k}	65^{i}
	Fedis	40^{j}	65^{i}
	Awash-2	43^{hi}	69^{h}
	Tinike	43^{hi}	66^{i}
	Awash-1	40^{j}	72^{fg}
	Dursitu	44^{efg}	69^{h}
	Nasir	47^{bc}	72^{fg}
Water logging	Gofta	40^{j}	75^{cd}
	Fedis	45^{def}	77^{ab}
	Awash-2	42^{i}	75^{cd}
	Tinike	50^{a}	78^{a}
	Awash-1	39^{jk}	76^{abc}
	Dursitu	46^{cde}	74^{def}
	Nasir	51^{a}	72^{fg}
CV		2.22	1.47
LSD		1.56	1.74

Note: means with the same letter are not statistically significant difference

4.3. Growth Parameters

4.3.1. Leaf number and plant height

Result analysis in Appendix Table 1 indicated that variety, moisture levels and the interaction between variety and moisture levels significantly ($p \leq 0.01$) on leaf number.

The highest leaf number was recorded from Awash-1 variety (55) treated with control; whereas the lowest leaf number was recorded from Nasir variety (19) and Fedis variety (19) subjected to waterlogging stress (Table-6.). Regarding to four day interval irrigated treatment, leaf number was significantly increased than daily irrigated (waterlogging stress) and eight day irrigated interval (moisture deficit). However, under waterlogging stress and moisture deficit; Awash-1, Awash-2 and Gofta varieties gave relatively higher leaf number as compared to Fedis, Tinike, Dursitu and Nasir. Both waterlogging stress and moisture deficit significantly reduced leaf number; this could be as a result of accelerated leaf senescence and defoliation occurred during moisture stress (Ahmed and Suliman, 2010). This result was in accordance with Boutraa *et al*. (2001) who reported that low irrigation levels reduces the total number of leaves per plant and also flooding irrigation.

Plant height was significantly ($p < 0.01$) affected by varieties, moisture levels and interaction effect of variety and moisture levels (Appendix Table-1).

The tallest plant height (56.13cm) was recorded from Awash-1variety treated by control, while the shortest plant height was measured from Awash-2 (12.3cm) variety grown by moisture deficit treatment. There was a great variation between common bean varieties and moisture levels in their potential to elongate plant height, the difference of these two treatments were levels in their potential to elongate plant height, the difference of these two treatments were 56.13 cm -12.3 cm = 43.83cm (Table-6).

Strong reduction in plant height was observed from common bean treated with moisture deficit and followed by waterlogged treated plant. This might be due to the reduction in plant water status which reduces shoot elongation, leaf expansion, and inhibition of cell division or cell enlargement. The result was similar with Emam *et al*. (2010) and Shenkut and Brick (2003) they observed that plant height was affected by the severe influence of moisture stress than unstressed. The observed reduction in plant height was associated with a decline in cell elongation and rapidly senescenceing of leaves in under moisture stress (Bhatt and Srinivasa Rao, 2005). Furthermore, Uddin *et al*. (2013) found that plant height decreased for mungbean grown under no irrigation and it increased with the number of irrigations.

4.3.2 Shoot fresh weight and shoot dry weight

Shoot fresh weight and Shoot dry weight were significantly ($P<0.01$) influenced by variety, moisture levels and the interaction of variety and moisture levels (Appendix Table-1). Among the measured varieties, the maximum shoot fresh weight (50.7in gm) was recorded from Awash-1 variety with four day irrigation interval and the minimum shoot fresh weight (3.43in gm) was measured from Nasir variety subjected to daily irrigation (Table-6).

The highest shoot dry weight (10.33) was also recorded from Awash-1 variety treated in control (four day irrigation interval), while the lowest shoot dry weight was measured from the Nasir (1.063), Dursitu (1.43) and Tinike (1.33) varieties which treated in logging stress (Table-6). Regarding moisture levels, Control treatment produced highest shoot fresh weight and shoot dry weight than waterlogging and moisture deficit treatment. According to Farooq *et al.* (2009) waterlogging stress and moisture deficit significantly reduced shoot fresh and dry weight of common bean varieties; this could be due to low turgor pressure which suppresses cell expansion and growth leading to significant reductions in fresh and dry biomass production.

Under the control level (four day irrigation interval), the maximum shoot fresh weight (50.7gm) and dry weight (3.43gm) producing varieties were able to give the highest grain yield. The result agreement to (Lei *et al*., 2006; Kusvuran *et al*., 2011) who reported that an early morphological response to moisture deficit is the avoidance mechanism through adjustment of plant growth rates such as a reduction in shoot height, basal diameter, and total fresh and dry bio mass in the bean species.

Table 6 : Interaction effect of common bean varieties and soil moisture levels on number of Leaf, Plant height, Shoot fresh weight and Shoot dry weight

Moisture levels	Varieties	Number of Leaf	Plant height	Shoot fresh weight	Shoot dry weight
Moisture deficit	Gofta	33^{fg}	28^{fg}	22.36^{ef}	4.3^{gh}
	Fedis	27^{jk}	21.83^{i}	26.86^{de}	4.86^{dfg}
	Awash-2	31^{ghi}	12.3^{m}	19^{f}	4^{gh}
	Tinike	28^{ijk}	8.43^{ef}	34.5^{c}	4.56^{fgh}
	Awash-1	51^{b}	36.66^{d}	40.66^{b}	8.2^{b}
	Dursitu	28^{jik}	14.23^{klm}	34.66^{c}	5.73^{cdf}
	Nasir	33^{fg}	13.33^{lm}	23.83^{def}	3.73^{hi}
Control	Gofta	40^{c}	31.66^{e}	26^{de}	5.36^{def}
	Fedis	29^{hij}	26.1^{gh}	38.3^{bc}	5.6^{e}
	Awash-2	37^{cd}	16.83^{j}	36.6^{bc}	6.66^{c}
	Tinike	39^{cd}	45.33^{c}	39^{bc}	7.66^{b}
	Awash-1	55^{a}	56.13^{a}	50.7^{a}	10.33^{a}
	Dursitu	32^{gh}	16.41^{jk}	37^{bc}	5.97^{cd}
	Nasir	38^{cd}	20.66^{i}	28.5^{d}	5.4^{def}
Water logging	Gofta	25^{kl}	24.33^{h}	10.16^{ghi}	2.4^{jk}
	Fedis	19^{n}	27.66^{g}	11.46^{gh}	2.63^{jk}
	Awash-2	28^{ijk}	13.23^{m}	5.13^{ij}	1.86^{kl}
	Tinike	21^{mn}	37.23^{d}	7.33^{hij}	1.43^{l}
	Awash-1	35^{e}	53.33^{b}	13^{g}	3.1^{ij}
	Dursitu	23^{lm}	17.3^{1j}	9.33^{ghi}	1.33^{l}
	Nasir	19^{n}	15.6^{jkl}	3.43^{j}	1.067^{l}
CV		6.01	5.28	13.6	11.89
LSD		3.2	2.3	5.5	0.89

Note: means with the same letter are not statistically significant

4.3.3. Branch number and internode length

Analysis of variance revealed significant ($P<0.001$) effect of varieties and moisture levels on branch number but the interaction of varieties and moisture levels did not significant ($P>0.05$) on Branch number (Appendix Table-1).

Among the measured varieties, the maximum branch number was recorded from Fedis variety (4) and Awash-1 variety (4) under control (four day irrigation interval) and the minimum branch number was measured from Tinike variety (2) under water logging level (Table-7). In the case of moisture levels, the highest branch number was recorded varieties from control (four day irrigation interval) and relatively higher branch number was recorded varieties from drought growing level and the lowest branch number recorded varieties from daily irrigation (water logging) (Table-7).

Internode length was significantly ($p<0.01$) influenced by varieties and moisture levels but the interaction of varieties and moisture levels doesn‘t show significant ($P>0.05$) difference on internode length (Appendix Table-1).

The longest internode length was recorded from Awash-1 variety (7.83cm) and the shortest internode length measured from Nasir (2.71cm) and Dursitu (2.84cm) varieties (Table -7). The longest internode (Awash-1) variety is characterized by having tendril and the shortest Nasir variety not having tendril. This result is in agreement with the previous report of (Kelly, 2000) who stated that determinate plants also have shorter internodes and fewer nodes compared to indeterminate plants. This finding is in line with Desclaux (2000) that reported moisture deficit during vegetative stages reduced the average internode length of soya bean.

Similarly, Patil (2008) indicated that moisture stress reduce internode length of sugarcane throughout growing period. In the case of moisture levels, the longest internode length was recorded subjected to control growing level as compared to waterlogging stress and moisture deficit. The exposure of waterlogging stress and moisture deficit had a similar impact on internode length (Table -7).

Table 7 : Impact of variety and soil moisture levels on number of branch and length of internode.

Variety	Number of branch	length of internode
Gofta	3^{b}	6.16^{b}
Fedis	4^{a}	4.16^{b}
Awash-2	3b	3.51^{d}
Tinike	2^{c}	3.84^{d}
Awash-1	4^{a}	7.83^{a}
Dursitu	3^{b}	2.84^{e}
Nasir	3^{b}	2.71^{e}
Variety	***	***
LSD	0.67	0.39
Moisture levels		
Moisture deficit	3^{b}	4.16^{b}
Optimum	4^{a}	4.99^{a}
Logging stress	2^{c}	4.36^{b}
Moisture levels	***	***
Interaction	Ns	Ns
CV	21.6	19.18
LSD	0.43	0.26

Note: means with the same letter are not statistically significant difference

4.3.4. Tap root length, lateral root length and tap root collar diameter

Root length and root collar diameter were significantly ($p<0.01$) influenced by varieties, moisture levels and their interaction effects (Appendix Table-1).

The mean comparison showed that the highest average root length (64cm) was recorded from Awash-1variety at drought growing level, whereas Nasir variety had the lowest value (11.66cm) of average root length at waterlogging stress and the difference of both varieties were 52.44cm (Table- 8). The highest reduction in root length was observed in waterlogging treatment than control and moisture deficit treatment.

It was due to deficiency of oxygen which affects the translocation of growth regulators and transpiration which may decrease hydraulic conductivity due to hampered root permeability during waterlogging stress. The result accordance with Shaw (2015) who found more excess soil water levels in plant root zone result in decrease in soil oxygen flux and concentration and hence oxygen levels limit optimal root length and plant function.

Similar result was observed by Else *et al*. (2001) who obtained roots in waterlogged soils frequently die of anoxia (oxygen deficiency). The deeper rooting under moisture deficit could be mechanisms of crops respond to moisture deficit to contribute to greater water uptake; it was clearly stated that plants develop strategies for maintaining turgor by increasing root depth or developing an efficient root system to maximize water uptake, and by reducing water loss through reduced stomatal conductance, reduced absorption of radiation, by leaf rolling or folding, by dropping leaf and reduced leaf area (Mitra, 2001).

This result is in agreement with the previous report which noted that a greater root length under moisture deficit levels contributes to improved drought resistance of the common bean (White and Castillo, 1992; Polania *et al*., 2009). Moreover, Lynch and Brown (2012) indicated that under drought levels; roots extend their length, increase their surface area, and deplete immobile nutrients. According to Fenta *et al*. (2011) and Mohamed *et al*. (2002) also shown that a deep and dense root system in common bean and high root mass correlates with effective water use under drought levels. Also, the result indicated that lower leaf temperatures linked to higher root length as Awash -1 variety recorded the lowest leaf temperature and higher root length under moisture deficit treatment. It is probably due to varieties that deep rooter were able to maintain cooler temperatures by accessing deep water reservoirs thus maintaining water potential in adverse levels. This result is supported by the previous finding of Pinto *et al*. (2015), who stated that, the cool ‘varieties under moisture stress, showed a deeper root system allowing the extraction of 35 % more water from the 30–90 cm soil profile.

Table 8 : Interaction effects of common bean varieties and soil moisture levels on tap root length, lateral root length and collar diameter

Moisture levels	Varieties	Tap root length	Lateralroot length	Tap root collar diameter
Moisture deficit	Gofta	30.66^{bcd}	31.23^{bcd}	3.53^{c}
	Fedis	21.66^{e-h}	25.13^{ef}	2.96^{h}
	Awash-2	27^{cde}	30.7^{b-e}	3.33^{d}
	Tinike	18.33^{f-i}	34.4^{bc}	2.83^{ij}
	Awash-1	64^{a}	54.16^{a}	4.53^{b}
	Dursitu	20.66^{e-h}	24.8^{d-g}	3.03^{g}
	Nasir	19^{e-i}	22.76^{d-h}	3.13^{f}
Control	Gofta	23.33^{d-g}	21.66^{e-i}	3.23^{e}
	Fedis	25^{c-f}	37^{b}	2.63^{l}
	Awash-2	31.66^{bcd}	26.7^{c-f}	2.86^{i}
	Tinike	21.33^{egh}	28.4^{b-f}	2.53^{m}
	Awash-1	36.33^{bc}	58.46^{a}	4.63^{a}
	Dursitu	32.33^{bcd}	21.66^{e-i}	2.63^{l}
	Nasir	30.66^{bcd}	20.4^{f-j}	2.73^{k}
Water logging	Gofta	15.33^{ghi}	23.33^{d-h}	2.63^{l}
	Fedis	18^{f-i}	22.33^{d-h}	1.83^{o}
	Awash-2	19.33^{e-i}	14.5^{hij}	2.23^{n}
	Tinike	14^{hi}	20^{f-j}	1.53^{r}
	Awash-1	21^{e-h}	15.6^{g-j}	2.8^{j}
	Dursitu	13.33^{hi}	12.53^{ij}	1.63^{g}
	Nasir	11.66^{i}	12.33^{j}	1.73^{p}
CV		20.76	20.94	1.11
LSD		8.4	9.2	0.0513

Note: means with the same letter are not statistically significant difference.

4.4. Physiological Response

4.4.1. Effect of moisture levels on stomata anatomy

The result indicates that stomata number, length and width were significantly ($P \leq 0.001$) responded to effect of varieties, irrigation interval and their interaction (Appendix Table-2).The highest stomata numbers were recorded from Dursitu variety (25) with eight days irrigation interval and the lowest stomata number were recorded from Awash-2 varieties (7) with daily irrigation interval. The longer stomata length was observed from Gofta variety (133.76nm) and Fedis variety (131.13nm) with daily irrigation interval and four days irrigation interval (control) respectively whereas the shortest stomata length was recorded to Awash-1 variety (89.23nm) with eight days irrigation interval. However, wider stomata width was recorded with Awash-1(12.6nm) obtained to daily irrigation interval besides narrowest stomata width was recorded with gofta variety (6.23nm) in eight days irrigation interval (Table- 9). So, varieties had different stomata anatomy in different irrigation interval. Therefore in this study Awash-1, Gofta, Awash-2 and Dursitu varieties shows that different stomata anatomy in different moisture levels.

Previous report states that reduction of stomata width and length result in the reduction of transpiration and photosynthetic rate and the level leads to reduction in growth of the whole plant (Belhadj *et al.*, 2011). Similarly Dutra *et al.* (2015) indicated that, plant exposed to moisture deficit significantly reduced stomata opening and transpiration rate as compared to unstressed plant. However, Stomata closure limit transpiration; which in turn limit CO2 influx and leading to decreased photosynthetic activity (Yang *et al*., 2006). Furthermore, the Partial closing of the stomata under moisture stress level is one of the strategies for plant to tolerate moisture stress. This might be through decreasing the transpiration rate, preserving leaf water content, and reduces the risk of dehydration, and eventual death by desiccation (Peak *et al.*, 2004). According to(Pirasteh *et al*. (2016) reported that in addition to stomata closure, plants can also reduce stomata size in response to prolonged water lack and it can adjust their number, length, and width.

Table 9 : Interaction effects of varieties and soil moisture levels on stomata aperture of common bean

Moisture levels	Varieties	Stomata Number	Stomata Length	Stomata Width
Moisture deficit	Gofta	8^{hi}	99.67^{e-i}	6.23^{ijk}
	Fedis	9^{gh}	100.26^{d-h}	7.42^{i}
	Awash-2	7^{i}	101.65^{d-h}	9.85^{d-g}
	Tinike	8^{h}	119^{bc}	9.23^{e-h}
	Awash-1	9^{gh}	89.23^{i}	9.99^{c-f}
	Dursitu	7^{i}	111.67^{cd}	10.58^{b-e}
	Nasir	9^{gh}	104.5^{def}	11.03^{bcd}
Control	Gofta	15^{e}	103.25^{defg}	10.48^{b-e}
	Fedis	8^{hi}	131.13^{a}	8.73^{ghi}
	Awash-2	9^{gh}	95.9^{fghi}	11.01^{bcd}
	Tinike	11^{f}	123.33^{ab}	9.6^{e-h}
	Awash-1	19^{cd}	108.93^{cde}	10.82^{bcd}
	Dursitu	21^{c}	92.05^{ghi}	10.58^{cde}
	Nasir	11.33^{f}	91.6^{hi}	11.09^{bcd}
Water logging	Gofta	14^{e}	133.76^{a}	11.76^{ab}
	Fedis	10^{fg}	124.8^{ab}	9.13^{fgh}
	Awash-2	19^{d}	111.4^{abc}	6.4^{i}
	Tinike	15^{e}	126.05^{ab}	7.91^{hi}
	Awash-1	19^{cd}	109.95^{cde}	12.6^{a}
	Dursitu	25^{a}	96.95^{f-i}	9.91^{d-g}
	Nasir	22^{b}	130^{ab}	11.1^{bcd}
CV		1.64	11.6	9.05
LSD		7.5	6.36	6.85

Note: means with the same letter are not statistically significant

4.4.2 Leaf gas exchange parameters

Photosynthetic rate and Transpiration rate

Analysis of variance result revealed that photosynthesis rate and transpiration rate were significantly ($p<0.01$) influenced by varieties, moisture levels and interaction of varieties and moisture levels (Appendix Table-2).

Photosynthesis (A) μmol m-2s-1

Among measured varieties, the highest Photosynthesis rate (10.43) was obtained with Gofta variety treated by four day irrigated treatment whereas the lowest Photosynthesis rate reported with Nasir variety (3.5) subjected to waterlogging stress. (Fig-1)

Photosynthesis depression at moisture deficit probably results from the increase in Vapor pressure deficit (leaf-air) and high temperature (Breshears *et al*., 2013; Seversike *et al*., 2013). Similar findings were reported by (Romero *et al*., 2013) were Plants grown under severe moisture stress reduce the photosynthesis rate substantially. Under waterlogging stress; Tinike, Fedis and Nasir varieties showed a significant decline as compared to Awash-2, Awash-1 and Dursitu varieties. This might be duo to; plants subjected to waterlogged levels exhibit certain alterations in physiological performance, and a prominent decrease in PSII photochemistry, which indicated the inability of the plants to regenerate rubisco under stressful levels (Smethurst *et al*., 2005).

Besides, waterlogging stress might impair the photosynthetic electron–transport chain, and as a result limit the rate of CO2 assimilation. Moreover, Ashraf and Arfan. (2005) also reported that a decrease in transpiration and photosynthesis rate is attributed to stomata closure and such reduction in photosynthesis rate might be used as a strategy to escape from stress level. In plant photosynthetic reactions, molecular oxygen is involved as a catalyst to facilitate the assembly of energy compounds leading to the production of glucose. However, under a variety of stress levels, plants reduce photosynthetic efficiencies, growth, and development, and yields as an avoidance strategy (Barickman *et al*., 2019).

The damaged mesophyll cell ultrastructure of functional leaf induced by waterlogging would lead to a decline in leaf photosynthetic ability, resulting in grain yield reduction. This finding confirms the previous study of Silva *et al*. (2010), who reported that under the high soil water levels, oxygen deficiency occurs, causing stomata closure, photosystem II damage, and photosynthesis reduction.

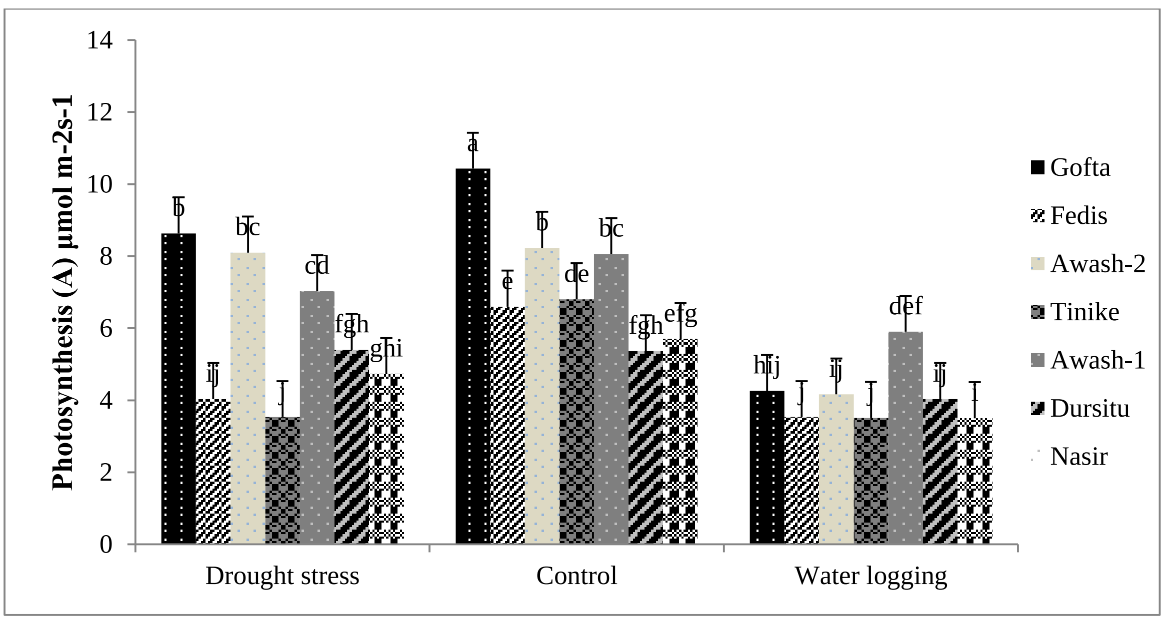

Figure 1 : Interaction effects of varieties and moisture levels on transpiration rate under lath house 2020

Transpiration rate (E) mmol $m^{-2}s^{-1}$

The highest transpiration rate (5.42) was observed from Gofta variety treated by optimum (four day irrigated treatment) whereas the lowest was recorded from Awash-1 variety (2.25) and Awash-2 variety (2.3) varieties subjected to moisture deficit. In overall varieties, control (four day irrigated treatment) produced the highest Transpiration rate than waterlogging stress and moisture deficit (Fig-2). Possibly, water loss from plant shoot increases the vapor pressure incline between the ambient air and leaf and so, increased the transpiration rate.

A similar finding was reported by (Hongbo *et al*., 2005) shows that with a plant species, genotypes differ in photosynthesis rate, stomatal conductance, and transpiration rate, thus, expressing different degrees of responses to moisture stress. Reduced photosynthesis and transpiration rates due to a decrease in the leaf water content were observed.

However, a significant decline in the transpiration rate was observed from moisture deficit treatment. The result agreement with Lima and Silva (2008) that obtained the physiological responses of common bean submitted to moisture deficit and found reductions up to 90% in the transpiration rate of non-irrigated plants compared to irrigated ones. Correspondingly, Silva *et al*. (2010) indicated that the reduction in the transpiration rate is a response to moisture stress by plants. So, in this study Awash-1 variety and Awash-2 variety shows high reduction of transpiration rate according to moisture levels.

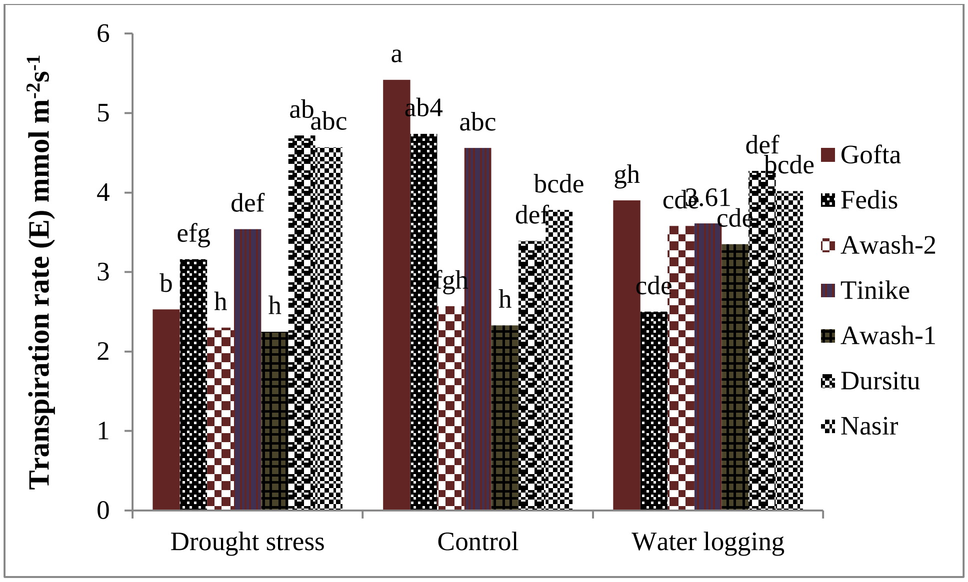

Figure 2 : Interaction effects of varieties and moisture levels on transpiration rate

Stomata conductance and Water use efficiency

The result indicated that, stomatal conductance and water use efficiency of different common bean variety were significantly ($P \leq 0.001$) influenced by main effect of variety and moisture levels and interaction of varieties and moisture levels (Appendix Table-2).

Accordingly, Stomatal Conductance (gs) mmol m^{-2}s^{-1}

The maximum stomatal conductance recorded in Tinike variety (193.67) treated with control moisture levels, while the lowest stomatal conductance observed with Awash-1 variety (65.33) subjected to moisture deficit (fig-3). In moisture stress levels, root hydraulic conductivity typically decreases and results in stomata closure to reduce water loss. This could be due to the reduced amount of water in the cell which leads to turgor loss and closure of stomata (Kamara *et al*., 2003). Furthermore, lower stomatal conductance is also considered to be the mechanism of adaptation to water shortage, allowing the plant to reduce the evapotranspiration area (Beebe *et al*., 2013; Rao, 2014). Significant loss of stomatal conductance was also observed under waterlogging stress growing levels. Previous research stated that stomata conductance reactions could be due to hypoxia stress-induced responses related to ethylene production which possibly caused stomatal closure (De Martinis *et al*., 2015; Bashar *et al.*, 2019).

In line with this finding, Dutra *et al*. (2015) state that, in response to moisture deficit, plants reduce stomata opening, influencing other variables such as photosynthesis rate and transpiration rate, with negative consequences on growth and development, directly affecting their yield, which justifies the reductions in the growth variables. Additionally, Taiz and Zeiger (2002) reported that under more severe drought levels inhibition of cell division, inhibition of wall and protein synthesis, accumulation of solutes, the closing of stomata, and inhibition of photosynthesis were observed. Similar observation also investigated by (Arve *et al*., 2011), who reported that plant reduced stomata conductance has a potential to reduce water loss through transpiration and this can be mechanism to tolerate drought than plant failed to regulate stomata conductance.

Other recent evidence suggests leaf ABA may also affect leaf hydraulic conductance, which could amplify changes in leaf turgor sensed by stomata (Thomas, 2017).

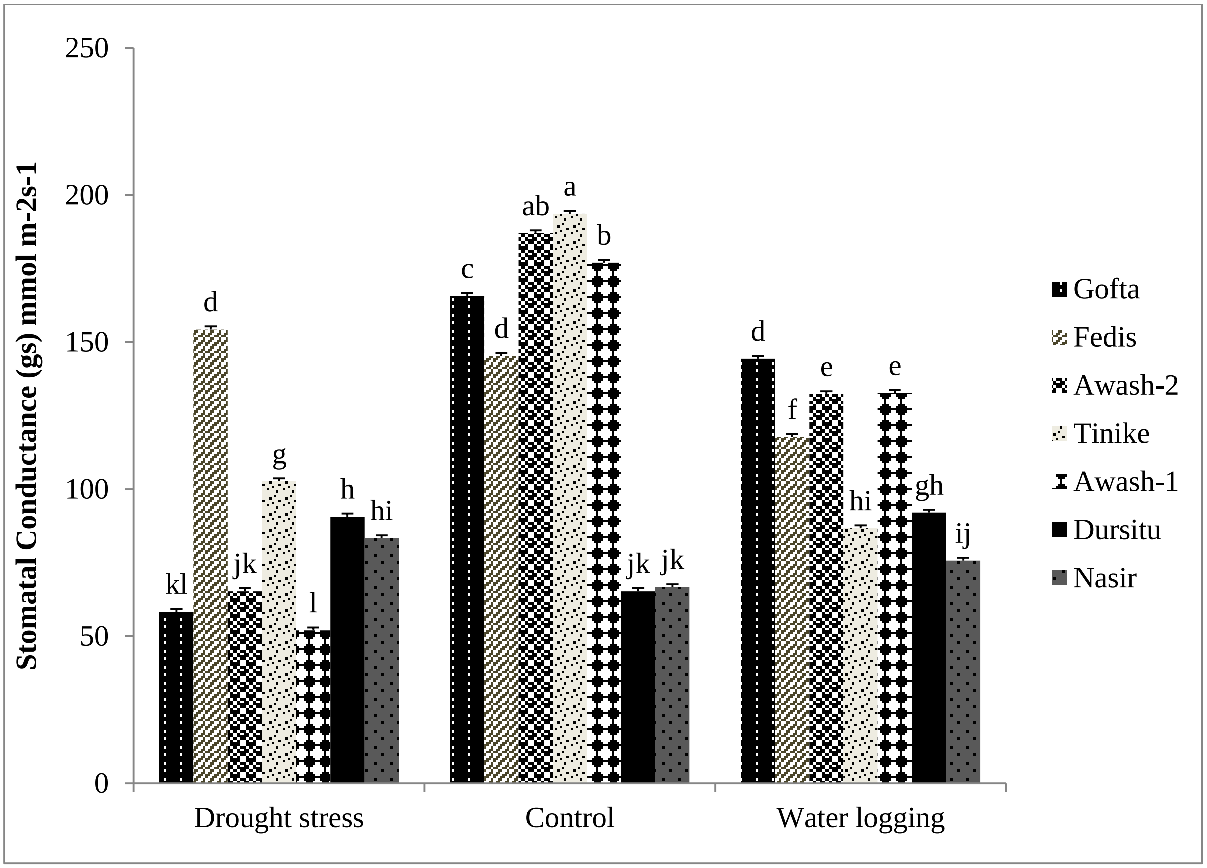

Figure 3 : Mean value of stomata conductance of seven common bean varieties as influenced by different soil moisture levels grown under lath house, 2020.

Instantaneous Water use efficiency (IWUE)

Maximum water use efficiency was recorded from Awash-1 variety (3.95), Awash-2 variety (3.85) and gofta variety (3.57) which treated with control (four day irrigation interval). While, Fedis (1.02) variety with moisture deficit and Tinike (1.09) variety with water logging stress were observed the lowest water use efficiency .Whereas; Gofta, Awash-1,Awash-2 and Dursitu varieties were recorded relatively higher water use efficiency than other varieties which treated with moisture stress(Fig- 5).

This result similar to Broeckx *et al*. (2014) and Roel *et al*. (2011) reported that the reduction in stomatal conductance was correlated with an increase in the water use efficiency, which indicates that stomatal closure contributed to optimizing water use efficiency in plants under stress, which may have enabled plants to absorb carbon by decreasing the loss of water in the moisture stress level, contributing to photosynthesis maintenance. In line with this finding Boutraa *et al.* (2010) reported that again Instantaneous water use efficiency in wheat cultivars declined significantly when plants were subjected to moisture deficit.

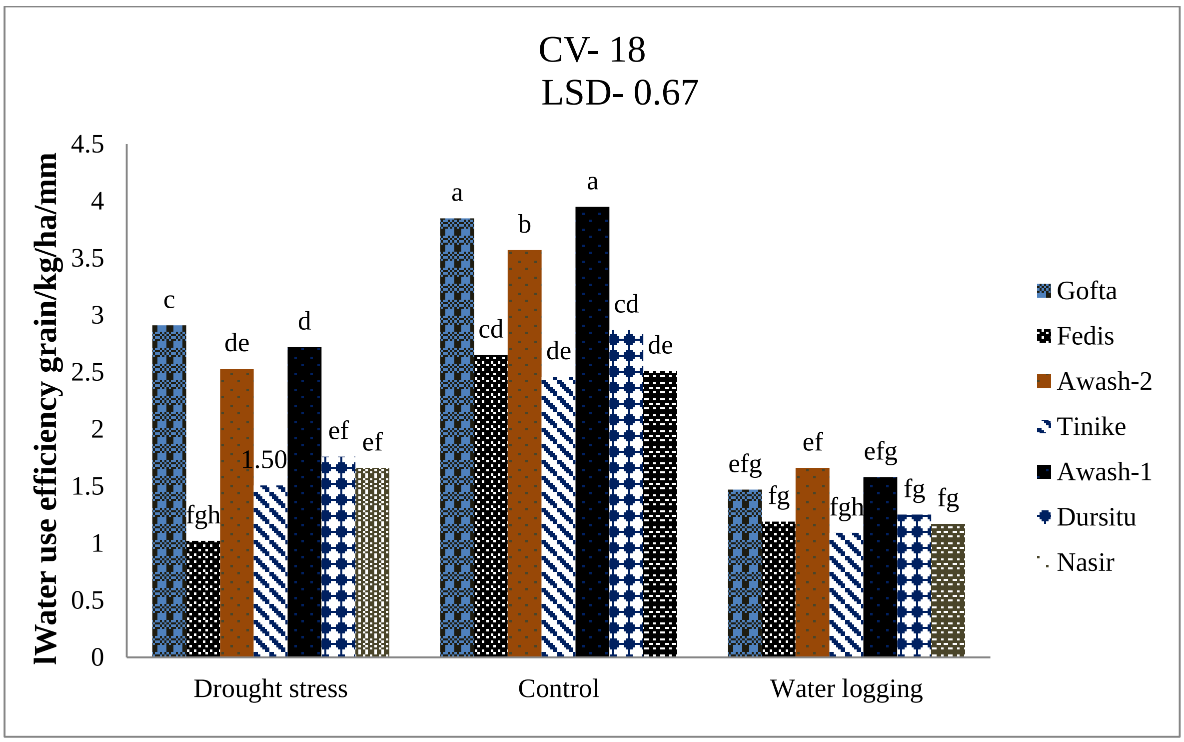

Figure 4 : Mean value of water use efficiency of seven common bean varieties that treated by different soil moisture levels grown under lath house, 2020

4.4.4. Leaf relative water content

Leaf relative water content was significantly (P<0.01) affected due to the main effect of varieties and Moisture levels. However, the interaction effect of varieties and moisture levels did not significantly (P>0.05) influenced the relative water content of common bean varieties (Appendix Table-2).

Among studied varieties: Dursitu (11.90), Awash-1(11.74), Gofta (11.61) and Nasir (11.36) in percent were recorded the highest relative water content which were statistically similar than Tinike, Awash-2 and Fedis (Table- 10). But Fedis variety was highly declined in leaf water content. Rosales *et al*. (2012) indicated that the superior performance of common bean varieties with tolerance to moisture deficit is also a result of well water use efficiency. Similarly, Plants which maintain the water status (high water potential) have been found to be productive under stress level with low reproductive abortion (Jongdee *et al*., 2002; Pantuwan *et al*., 2002). This result builds the existing evidence which states, the maintenance of RWC above 50% was probably due to stomata closure and leaf scenecense which could have reduced transpiration rates (Bala Subramanian and Maheswari, 1992), thus protecting the photosynthetic apparatus.

Regarding moisture levels, Control (four day irrigation interval) treatment produced significantly different as compared to waterlogging and moisture deficit. However waterlogging stress and moisture deficit reduced relative water content compared to control growing levels. A marked reduction in the leaf water content of plants under waterlogged levels was observed in previous studies (Kuai *et al.*, 2014; Kumutha *et al*., 2008; An *et al*., 2016). Correspondingly, Setter *et al*. (2009) reported that the water content decreased mainly because the root uptake capacity was restrained due to the lack of oxygen caused by waterlogging.

The highest reduction of leaf relative water content was observed from moisture deficit than waterlogging stress (Table -10). In a similar study, Kumar *et al. (*2006), it has been revealed that RWC in bean leaves was diminished under moisture deficit stress. Water deficiency leads to loss of water from the plant and changes the plant water status with a decline in the stomatal conductance and transpiration (Ribas *et al*., 2005). Reducing water loss through stomatal closure, rolling or abscission of the leaf, and increased plant water up-take through enhanced root development are mechanisms playing a role in maintaining the leaf water status (Jongdee *et al*., 2002). Additionally, Turgor loss, decrease in leaf water potential, stomatal closure, decrease in internal CO2 concentration, all of which can lead to impairment of photosynthetic activity (Singh and Reddy, 2011).

Table 10: Main effects of common bean varieties and soil moisture levels on leaf relative water content

Variety	LRWC
Gofta	11.61^{a}
Fedis	9.54^{b}
Awash-2	10.70^{ab}
Tinike	10.55^{ab}
Awash-1	11.74^{a}
Dursitu	11.90^{a}
Nasir	11.36^{a}
Variety	Ns
LSD	1.55
Moisture levels	
Moisture deficit	9.37^{c}
Optimum	13.00^{a}
Logging stress	10.79^{b}
Moisture levels	***
Interaction	Ns
CV	14.7
LSD	1.014

Note: means with the same letter are not statistically significant

4.4.5. Leaf temperature

The average maximum and minimum temperature recorded during the midday and morning were 24.667°C and 18.978°C, for midday and morning, respectively (table-11). Leaf temperature during midday was high (above 24oC) whereas leaf temperature during morning plants was declined (below 19^{o}C) during the experiment. Accordingly, moisture level was significantly difference. But, according to the variety not significantly difference.

Changes in leaf temperature can be induced by water loss due to transpiration. Therefore, changes in the leaf water content and Transpiration can be indirectly reflected by changes in leaf temperature. Moisture deficit treatment raised the leaf temperature in all varieties. The result is in agreement with the finding of Khan *et al*. (2007) who reported that moisture stress resulted in considerable increases in leaf temperature.

According to Liu *et al*. (2014) a certain correlation exists between the leaf water content and temperature; the leaf temperature is not only determined by transpiration but is also correlated with air temperature. Although, Sharkey and Schrader, (2006) reported that Photosynthesis is the most sensitive of plant cell processes to high temperatures; which causes changes in the reduction-oxidation properties of PSII acceptors and reduces the efficiency of photosynthetic electron transport in both photosystems (Mathur *et al*., 2014)

Table 11: The effect of leaf temperature on common bean varieties at moisture stress level

Variety	Morning	Mid-day	Evening
Gofta	19.4^{a}	22.88^{a}	20.52^{ab}
Fedis	19.13^{a}	22.96^{a}	20.62^{a}
Awash-2	18.98^{a}	23.1^{a}	20^{b}
Tinike	19.5^{a}	22.64^{a}	20.63^{a}
Awash-1	19.6a	23.11^{a}	20.8^{a}
Dursitu	19.6^{a}	22.75^{a}	20.7^{a}
Nasir	19.64^{a}	22.75^{a}	20.88^{a}
Variety	Ns	Ns	Ns
LSD	0.7203	0.9433	0.57
Moisture levels			
Moisture deficit	19.85^{a}	24.67^{a}	21.1^{a}
Optimum	19.1^{b}	22.14^{b}	20.37^{b}
Logging stress	19.28^{b}	21.62^{c}	20.33^{b}
Moisture levels	**	***	***
Interaction	Ns	Ns	Ns
CV	3.9	3.8	2.94
LSD	0.4715	0.5461	0.37

4.5. Bio-chemical Parameters

4.5.1. Leaf chlorophyll concentration

The result revealed the existence of variety and irrigation interval and interaction between variety and irrigation interval that showed significant variation in concentration of chla ($p< 0.001$), chlb ($p<0.001$) and chlab ($p<0.001$) (Appendix Table 2).

In the photosynthetic pigment analysis, statistically the joint highest mean leaf chla concentration (2.398µg/ml) was recorded from the variety Gofta (2.4 µg/ml) irrigated every four days interval. On contrary, the lowest leaf chlorophyll a concentration of (0.576µg/ml) was recorded from the variety Awash-2 (0.576 µg/ml) which was irrigated daily (table 11).

The reductions of chlorophyll content and photosynthetic capacity were mainly correlated with the disturbance of chloroplast concentration and ultrastructure of functional leaves. This result was also in agreement with the previous study that waterlogging reduced chlorophyll content, resulting in a decline in crop leaf photosynthesis (Zhou and Lin, 1995, Pociecha, 2008), which indicated that waterlogging affected leaf chlorophyll content of common bean, and weakened the photosynthetic assimilation capacity. This might be due to decreases in soluble protein content and destruction of chloroplast membrane structure (Yordanova and Popova, 2007; Ren *et al.*, 2016). Moreover, decrease in leaf chlorophyll under waterlogging level might be directly related to nitrogen deficiency caused by leaching and de-nitrification of the available nitrogen (Tsai *et al.*, 1992)

Under moisture deficit, also was recorded the lowest chlorophyll- concentration compared to control/ optimum water levels while Awash-1, Awash-2 , Dursitu and gofta varieties was produced almost positive response in other parameters; this might be interpreted as an adaptation mechanism to overcome moisture deficit. Similar finding was stated that, Plants exposed to moisture deficit exhibit acclimation mechanisms, such as decreased leaf chlorophyll content (Chavez *et al*., 2002) and increased proline production (Rosales *et al*., 2012).

Gofta variety also was recorded the highest Chlorophyll b (1.53 μg/ml) and chlorophyll (a+b) (3.93 μg/ml) treated with control moisture levels or four day irrigation interval. Whereas statistically the joint lowest mean chlb concentration subjected to Fedis variety (0.4747 μg/ml) and Tinike variety (0.48 μg/ml) treated with daily irrigated interval. On other hand, Awash-2 variety (11.267 μg/ml) joint the lowest mean of chla+b treated with daily irrigated interval,(table 11).

According to Manivannan *et al.* (2007) and Saeedipour (2011) they indicated that chlorophyll a and b, and total chlorophyll content in sunflower and wheat plants declined in response to moisture stress. This finding Similar with by (Singh and Raja Reddy, 2011) who reported that total chlorophylls content was reduced during moisture deficit in cowpea. Even though the highest chlorophyll concentration was recorded from varieties treated with the control moisture levels, Overall, leaf chlorophyll concentration was higher for all varieties subjected to control treatment, and there was significantly declined for all varieties subjected to logging stress followed by moisture deficit, but the reduction varies among varieties. In contrast Mafakheri *et al*., (2010) revealed that the decrease in chlorophyll under moisture deficit is mainly due to damage to chloroplasts caused by active oxygen species.

This result indicates that the amount of chlorophyll in the bean leaf is related to the water status of the plant, which results in high chlorophyll synthesis, consequently increasing the photosynthetic activity and promoting an increase in the yield of this activity (Pires *et al*., 2004).

Table 12: Interaction effects of common bean varieties and soil moisture levels on chlorophyll a, b and a+b

Moisture levels	Varieties	Chla	Chlb	Chl a+b
Moisture deficit	Gofta	0.93^{ghi}	0.52^{ijk}	3.13^{bc}
	Fedis	1.35^{d-h}	0.68^{fgh}	1.44^{ij}
	Awash-2	1.45^{d-g}	0.64^{g-j}	1.83^{f-j}
	Tinike	0.84^{hi}	0.86^{cde}	1.87^{f-i}
	Awash-1	1.23^{e-h}	0.86^{cde}	2.87^{bcd}
	Dursitu	2.05^{ab}	0.79^{efg}	2.68^{cd}
	Nasir	1.59^{b-f}	0.96^{cd}	2.56^{cde}
Control	Gofta	2.4^{a}	1.53^{a}	3.93^{a}
	Fedis	**2.03^{ab}**	0.94^{cd}	3.33^{b}
	Awash-2	**2.016^{abc}**	0.85^{cde}	2.29^{d-g}
	Tinike	1.23^{e-h}	0.82^{def}	2.3^{def}
	Awash-1	2.13^{ab}	0.99^{c}	2.96^{c}
	Dursitu	1.81^{bcd}	0.95^{cd}	3.12^{bc}
	Nasir	1.76^{b-e}	0.96^{cd}	3^{bc}
Waterlogging	Gofta	1.47^{c-g}	0.62^{h-k}	2.55^{cde}
	Fedis	1.14^{fgh}	0.47^{k}	1.66^{hij}
	Awash-2	0.58^{i}	0.69^{fgh}	1.27^{j}
	Tinike	1.23^{e-h}	0.48^{k}	1.71^{g-j}
	Awash-1	1.25^{e-h}	0.66^{ghi}	1.91^{f-i}
	Dursitu	1.03^{ghi}	0.5^{jk}	1.53^{hij}
	Nasir	0.814^{hi}	0.56^{h-k}	1.373^{ij}
CV		23.02	11.66	15.86
LSD		0.547	0.153	0.585

4.5.2. Leaf chlorophyll fluorescence

Results of Analysis of variance for quantum yield showed that Chlorophyll fluorescence (Fv/Fm) was significantly ($p < 0.01$) influenced by the moisture levels whereas variety and interaction of variety and moisture levels not significantly affected chlorophyll fluorescence (Appendix Table 2.),

Regarding to moisture levels, eight day irrigation interval or moisture deficit (0.586) and four day irrigation interval or control(0.572)were not significantly difference there were recorded higher chlorophyll fluorescence while lowest chlorophyll fluorescence was observed from daily irrigation interval or waterlogging stress (0.48) (Table 11). The declines in Fv/Fm and FPSII were observed in waterlogging stress treatment, indicating that waterlogging damage to PSII of common bean varieties. Moreover, this result similar to Sairam *et al*. (2008) who reported that induced chlorophyll degradation and reduced photosynthesis and chlorophyll fluorescence under waterlogged levels. Thus, the photosynthesis potential energy of PSII was reduced, leading to declines in photosynthetic rate and photosynthetic characteristics (Irfan *et al*., 2010). Similarly as reported in previous study Chlorophyll fluorescence is an efficient tool for indicating changes in functions of photosynthetic apparatus, which can be damaged by waterlogging stress (Mielke *et al*., 2003, Waldhoff *et al*., 2002). In our overall result revealed that Fv/Fm showed a variation between all varieties at different moisture levels. Since both moisture deficit and control grown treatment value are statistically similar, However, Strong reduction in Fv/Fm was observed under waterlogging level.

Table 13: Main effects of common bean varieties and soil moisture levels on leaf chlorophyll fluorescence

Varieties	**FV/FM**
Gofta	0.55[a]
Fedis	0.53[a]
Awash-2	0.55[a]
Tinike	0.55[a]
Awash-1	0.57
Dursitu	0.54[a]
Nasir	0.53[a]
Variety	Ns
LSD	0.07
Moisture levels	
Moisture deficit	0.59[a]
Control	0.57[a]
Water logging	0.48[b]
Moisture levels	**
Interaction	Ns
CV	14.91
LSD	0.508

4.5.3. Proline concentration

Proline content was significantly (P<0.01) affected by Varieties, Moisture levels and Interaction of moisture levels and varieties (Appendix Table-2).

The result indicated that the highest proline content were found from variety Awash-1(0.78) regarding to moisture deficit level, whereas the lowest proline content was observed from

Dursitu (0.154) and Awash-1(0.16) shown in water logging stress level (Table-12). The proline content was positively correlated with moisture deficit. The proline content was significantly increased for moisture deficit treatment; whereas, the value of increment varied among varieties. A relatively significant reduction was observed under waterlogging stress treatment compared to control and moisture deficit treatments on all variety. However, both waterlogging stress and control showed numerically similar. As an average, leaf proline content in bean plants was significantly increased by moisture deficit. High accumulation of proline content of Awash-1 variety suggests a possible high-stress tolerance mechanism as compared to others. Similarly Awash-1 variety had higher seed yield under moisture deficit levels. This result in agreement with Liu *et al*., 2013; Sanchez-Reinoso *et al*., (2014) it has been reported that a higher proline content under moisture deficit levels is useful indicators of plant tolerance, and these features can be used for the selection of tolerant genotypes.

In addition, during moisture deficit, proline plays an important role and acts as a signaling compound to regulate mitochondria function and affect cell proliferation by means of activating particular genes, which are essential for stress recovery (Solanki and Sarangi, 2015). Similarly in other field crops it was reported that proline content was higher after drought in Pea (Alexieva *et al.*, 2001), Chickpea (Mafakheri *et al*., 2010). In the same orientation Vendruscolo *et al*. (2007) reported that proline accumulation in stressed plants is a tolerance mechanism against oxidative stress and it is the main strategy of plants to avoid harmful effects of moisture deficit. Furthermore, the increase in the concentration of organic solutes, such as proline, sucrose, and other soluble sugars may stabilize the cellular osmotic pressure under moisture deficit (Sucre and Suárez, 2011).

Table 10 : Interaction effects of common bean variety and moisture levels on proline Content

Varieties	**Moisture levels**		
	Drought	Optimum	Logging stress
Gofta	0.65^{b}	0.42^{cd}	0.2^{jkl}
Fedis	0.44^{c}	0.25^{hij}	0.18^{kl}
Awash-2	0.63^{b}	0.34^{fg}	0.23^{ijk}
Tinike	0.42^{cd}	0.36^{ef}	0.25^{hij}
Awash-1	0.78^{a}	0.34^{fg}	0.16^{l}
Dursitu	0.37^{def}	0.29^{gh}	0.15^{l}
Nasir	0.39^{cde}	0.27^{hi}	0.19^{kl}
CV	9.1		
LSD	0.524		

Note the same letters are indicated that no significant difference

4.6. Yield and Yield components

4.6.1. Length of pod, pods per plant and seeds per pod

The result of analysis of variance showed that Length of pod, pods per plant and seeds per pod of common bean were significantly ($P \leq 0.01$) affected by the main effect of varieties and moisture levels, and significantly ($p<0.05$) influenced by the interaction of varieties and moisture levels (Appendix Table-3).

The longest pod length was recorded by Tinike variety(10.56), it treated with control moisture levels (four day irrigation interval) and the shortest pod length was measured by Dursitu variety(3.36), treated with water logging stress. The maximum number of pods plant-1 was measured by Awash - 2 variety (9) and the minimum number of pods plant-1 was recorded by Nasir variety (1). The maximum number of seeds pod^{-1} recorded by Awash-1 variety (5), but Fedis, Tinike, Dursitu and Nasir varieties (2) were similarly accounted for the minimum number of seeds pod-1 (Table- 13). Four day irrigation interval treatment was reliably better performed than water logging stress and moisture deficit level. The highest number of pods per plant, seeds per pod and length of pod were recorded from control growing level (four day irrigation interval. In link with this finding (Ambachew *et al*., 2015; Darkwa *et al.*, 2016) who reported that Moisture deficit affects the yield components such as number of pods per plant, number of seeds per pod, seed weight and harvest index.

Table 11 : Interaction effects of common bean varieties and moisture levels on Length of pod, pods per plant and seeds per pod

Moisture levels	Varieties	Pod length	Pod number	Seed number
Moisture deficit	Gofta	8.2^{f}	4^{f}	5^{c}
	Fedis	9.56^{c}	3^{g}	4^{d}
	Awash-2	7.36^{k}	5^{e}	6^{b}
	Tinike	9.2^{d}	3^{g}	4^{d}
	Awash-1	7.5^{ij}	6^{d}	6^{b}
	Dursitu	7.6^{i}	4^{f}	4^{d}
	Nasir	7.56^{j}	3^{g}	4^{d}
Control	Gofta	8.56^{e}	6^{d}	^{7a}
	Fedis	9.93^{b}	6^{d}	4^{d}
	Awash-2	8.16^{g}	9^{a}	6^{b}
	Tinike	10.56^{a}	6^{d}	4^{d}
	Awash-1	8.3^{f}	8^{b}	7^{a}
	Dursitu	7.96^{h}	7^{c}	5c
	Nasir	8.16^{g}	5^{e}	5^{c}
Water logging	Gofta	4.56^{n}	3^{g}	3^{e}
	Fedis	3.56^{p}	2^{h}	2^{f}
	Awash-2	5.26^{m}	4^{f}	4^{d}
	Tinike	3.36^{q}	2^{h}	2^{f}
	Awash-1	5.56^{l}	4^{f}	3^{h}
	Dursitu	3.36^{q}	2^{h}	2^{f}
	Nasir	3.76^{o}	1^{i}	2^{f}
CV		0.59	2.65	9.01
LSD		0.07	0.21	0.64

Note: means with the same letter are not statistically significant

4.6.2. Grain yield

The analysis of variance revealed that grain yield significantly ($P<0.01$) affected by the main effects of varieties and moisture levels, and interaction effect of the varieties and moisture levels (Appendix Table-3).

The highest yield was recorded from the variety Awash-1 variety (7.8 g $plant^{-1}$) and Gofta variety (7.36 g $plant^{-1}$) on control moisture levels (four day irrigation interval) whereas the lowest yield goes to fedis variety (1.43 g $plant^{-1}$) from water logging stress level (fig-6). The result showed that yield did not link to pods per plant and seeds per plant, for Fedis variety have large seed size but showed little number of pods and seed per plant and also lowest yield were recorded from this variety, the reason behind was due to their inherent genetic potential and moisture stress.

Decreasing the yield under moisture deficit and water logging stress could be a result of a reduction in photosynthesis efficiency as our data indicated. The reduction of grain yield in moisture stress as compared to the non-stress level may have been attributed to flower abscission and embryo abortion when drought occurred at flowering and pod filling growth stages and severely a decrease in grain yield has resulted from embryo abortion when drought occurred in the pod-forming stage. Similarly Bernier *et al*. (2007) and Beebe *et al*. (2013) reported that post-flowering moisture stress caused yield losses of up to 50% due to reduced seed filling duration. Moreover, (Szilagyi, 2003) indicated that moisture stress during the flowering and pod filling periods reduced seed yield and seed weight and accelerated the maturity of dry bean. These yield losses are attributed to the reduced growth rate, reduced nutrient uptake, a decrease of photosynthetic activity.

The variety of Awash-1, Gofta and Awash-2 generally performs relatively under both waterlogging stress and moisture deficit growing level.

Similar result reported by Tar‘an and Singh, (2002) show that moisture deficit causes a significant reduction on grain yield and biological yield of common bean. In crops such as the common bean, in which the product of interest is the grain, the main criterion for the selection of cultivars tolerant to low water availability is related to the characteristics that result in high grain production (Rosales *et al*., 2012).

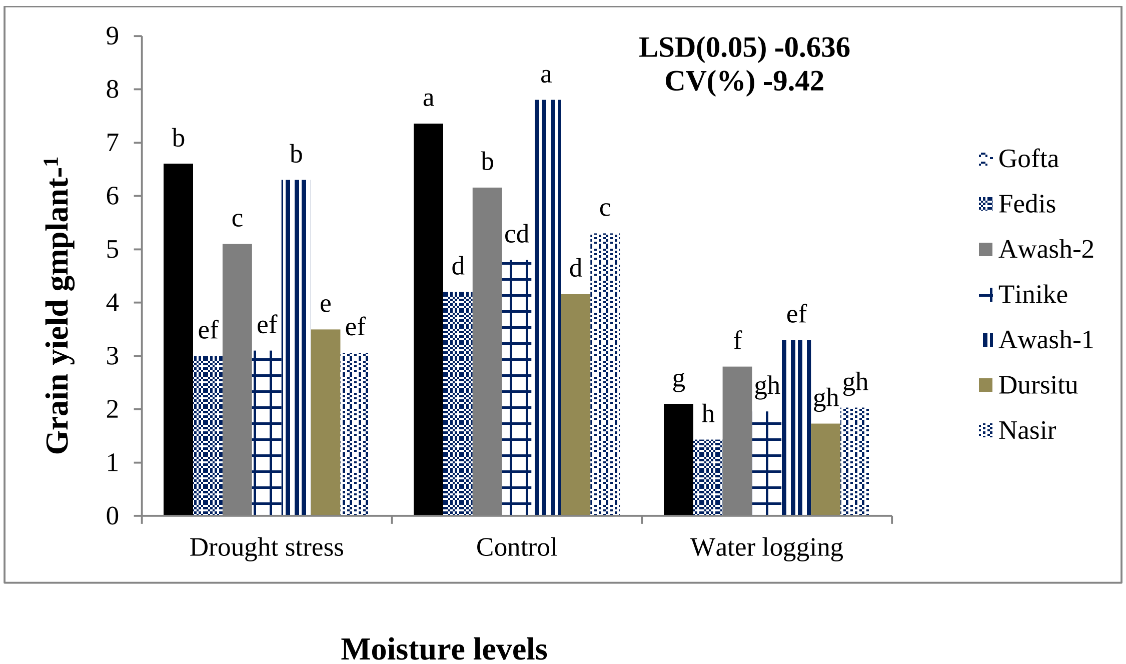

Figure 5 : Interaction effect of common bean variety and moisture levels on grain yield

4.6.3. Hundred Seed weight, biological yield and straw yield

Analysis of variance showed that variety and moisture levels were significantly ($P \leq 0.001$) influenced on hundred seed weight, total biomass (BY) and straw yield (SY), but the interaction of variety and moisture levels were no significant effect on hundred seed weight, total biomass (BY) and straw yield (SY) (appendix - 3) .

The highest HSW per gram (39.48), BY (Plant-1) (17.5) and SY (Plant-1)(12) were recorded in fedis, Awash-1 and Fedis varieties respectively. While, the lowest HSW per gram (16.88), BY (Plant-1)(11.32) and SY (Plant-1)(7.2) were recorded by Awash-2, Nasir and Gofta varieties respectively (Table-14). According to moisture levels, the highest product of HSW per gram, BY (Plant-1) and SY (Plant-1) were recorded in control moisture levels (four day irrigation interval) and moisture deficit (eight day irrigation interval). However, the lowest result of HSW per gram, BY (Plant-1) and SY (Plant-1) were recorded by water logging stress (daily watering) (Table-14). Similar results were reported by Singh *et al*. (1990) that all agronomic parameters showed a highly significant variation for the tested genotypes.

Table 12 : Interaction effects of common bean varieties and moisture levels on biological yield, hundred seed weight and straw yield

Variety	Biological Yield	Hundred seed weight	Straw Yield
Gofta	12.55[bc]	29.71[b]	7.2[d]
Fedis	12.94[bc]	39.48[a]	12.[a]
Awash-2	14.056[bc]	16.88[d]	9.36[bcd]
Tinike	14.71[ab]	32.21[b]	11.4[abc]
Awash-1	17.5[a]	31.28[b]	11.71[ab]
Dursitu	12.2[bc]	20.72[c]	9.28[cd]
Nasir	11.32[c]	20.25[c]	7.85[d]
Variety	***	***	***
LSD	4.129	2.96	2.41
Moisture levels			
Moisture deficit	15.30[a]	28.81[a]	11.01[a]
Optimum	16.99[a]	28.6[a]	12.13[a]
Logging stress	8.54[b]	24[b]	6.35[b]
Moisture levels	**	***	***
Interaction	Ns	Ns	Ns
CV	22.82	15.92	25.72
LSD	2.703	1.9375	1.5768

Note: means with the same letter are not statistically significant

4.6.4. Harvest index

The harvest index was significantly influenced by the main effect of moisture levels and varieties ($p<0.01$) but the interaction of varieties and moisture levels ($p>0.05$) were not significant different (Appendix Table - 3).

Accordingly, variety the highest Harvest Index was recorded in Gofta variety (39.97). While, the lowest Harvest Index were recorded by Nasir variety (23.11) (Table-15).

According to moisture levels, the highest product of Harvest Index was recorded in optimum/ control. However, the lowest result of Harvest Index of was recorded by drought and water logging stress level (Table-15). This result is in line with the previous findings which noted that moisture deficit affects the yield components such as the number of pods per plant, a number of seeds per pod, seed weight, and harvest index (Ambachew *et al*., 2015; Darkwa *et al.*, 2016). Furthermore, Reduction in harvest index was observed as a result of moderate moisture stress in common beans (Kellman, 2008).

Table 13 : Harvest Index of seven common bean varieties as influenced by different soil moisture levels

Variety	Harvest index
Gofta	39.97[a]
Fedis	24.87[d]
Awash-2	35.81[ab]
Tinike	23.11[d]
Awash-1	33.40[abc]
Dursitu	25.36[cd]
Nasir	29[bcd]
Variety	***
LSD	8.3302
Moisture levels	
Moisture deficit	29.24[b]
Optimum	35.47 [a]
Logging stress	26.29[b]
Moisture levels	**
Interaction	Ns
CV	28.96
LSD	5.4534

4.7. Correlation Analysis

Associations between morphological parameters and yield and yield components of common varieties under different soil moisture levels.

The associations of different morphological parameter's with yield and yield components have been determined (Table-18). Correlation analysis indicated that, the relationship of all morphological parameters had significant ($p<0.001$) strong positive correlation with yield and yield components (Table-18).

The relationship of morphological parameters such as plant height, root length and diameter, leaf number and area with fresh and dry weights is might be due to the consecutive processes (Majken *et al.,* 2005). Initially, cell division, enlargement, expansion, differentiation leads to different organs of seedling followed by production and expansion leaf number and area, respectively *(*Jaleel *et al.*, 2009).

Decreased plant height, leaf number, branch number, Internode length, shoot fresh weight and shoot dry weight were observed under the drought levels and water logging levels in common bean varieties. However, the increase and decrease of root length occurred under drought and logging level respectively. Decrease in plant biomass consequences from the moisture deficit in crop plants, mainly due to low photosynthesis and plant growth and leaf senescence during the stress levels (Seyed *et al*., 2012).

Table 14 : Pearson's correlation coefficient among the "morphological traits" and "yield and yield components" of common bean varieties grown under different soil moisture levels

	PH	NL	SF W	SDW	NB	TR L	LIN	LP	NP	NS	GY	HSW	BY
NL	0.93												
SFW	0.85	0.94											
SDW	0.88	0.96	0.98										
NB	0.93	0.94	0.93	0.93									
TRL	0.85	0.95	0.91	0.93	0.89								
LIN	0.93	0.95	0.90	0.93	0.91	0.90							
LP	0.89	0.96	0.95	0.95	0.95	0.91	0.90						
NP	0.86	0.96	0.94	0.96	0.89	0.92	0.9	0.95					
NS	0.86	0.97	0.93	0.95	0.91	0.94	0.91	0.96	0.97				
GY	0.86	0.95	0.92	0.94	0.89	0.93	0.93	0.93	0.93	0.95			
HSW	0.92	0.92	0.88	0.88	0.94	0.87	0.88	0.94	0.87	0.9	0.87		
BY	0.89	0.96	0.94	0.95	0.93	0.93	0.92	0.96	0.94	0.96	0.94	0.92	
SY	0.88	0.94	0.93	0.93	0.95	0.90	0.87	0.96	0.93	0.93	0.88	0.92	0.97

While, *PH= plant height, NL= number of leaf, SFW= shoot fresh weight, SDW= shoot dry weight, NB= number of branch, TRL= tap root length, LP=length of pod, NP= number of pod, NS= number of seed, GY= grain yield, HSW= hundred seed weight, BY biological yield and ST= straw yield.*

Associations between physiological parameters and "yield and yield components" of common varieties grown under different soil moisture levels

Correlation analysis indicated that, the relationship of all physiological parameter's had significant ($p<0.001$) strong positive correlation with yield and yield components (Table-19). All the physiological parameters was higher under control(4 day interval) watering level than prolonged moisture stress and daily watering level except proline content. While, proline content increase in water defect than in control and logging level.

Consequently, yield and yield components had been experienced strong positive relation with physiology. The best example is stomata aperture; stomata serve as both exit and entry points for water vapour and CO2 respectively (Chaves *et al*., 2002). Hence transpiration rate and photosynthesis rate depend on stomatal aperture and closing of the stomata is the first response plants persuade growth and development. Therefore, this is the main mean of regulating carbon assimilation which relates physiological parameter's with yield and yield components even growth and development in plants (Hetherington and Woodward, 2003).

Table 15 : Pearson's correlation coefficient among the "physiological traits" and "yield and yield components" of common varieties grown under different soil moisture levels

	LT	PRO	Gs	A	E	WUE	NP	NS	GY	HSW	BY
PRO	0.92										
Gs	-0.92	-0.79									
A	-0.94	0.92	0.90								
E	-0.95	-0.82	0.91	0.89							
WUE	-0.89	0.72	0.90	0.78	0.89						
NP	-0.91	0.87	0.90	0.95	0.85	0.76					
NS	-0.94	0.95	0.88	0.96	0.87	0.77	0.97				
GY	-0.89	0.91	0.86	0.96	0.83	0.71	0.93	0.95			
HSW	-0.95	0.88	0.92	0.89	0.9	0.87	0.87	0.91	0.86		
BY	-0.94	0.93	0.89	0.95	0.88	0.79	0.94	0.96	0.94	0.92	
SY	-0.93	0.91	0.89	0.91	0.89	0.82	0.93	0.93	0.89	0.92	0.97

Whereas, LT= leaf temperature, pro=proline concentration, gs= stomata conductance A= photosynthesis rate, E=transpiration rate, IWUE= instantaneous water use efficiency, NP=number of pod, NS=number of seed, GY=grain yield, HSW=hundred seed weight, BY=biological yield and SY=straw yield.

5. SUMMARY AND CONCLUSSION

Summary:

Common bean is among the most important legume crops as a source of dietary protein and calories. Its yield is constrained by lack of improved varieties and moisture stress among others. The current study was conducted with the objectives: (1) to evaluate the effect of different moisture levels on morphological and physiological of common bean varieties; (2) to evaluate the effect of different levels of moisture on yield and yield component of common bean varieties (3) to identify well performing common bean varieties under moisture stress conditions.

A pot experiment was carried out under lath house from June 2020 to September 2020, at Hawassa University. Seven common bean varieties viz. Gofta, Fedis, Awash-2, Tinike, Awash-1, Dursitu and Nasir were grown under three irrigation intervals/moisture levels viz. watered every day (waterlogging stress), watered every four days (optimum, or control), watered every eight days (moisture deficit) in factorial combination using Completely Randomized Design with three replications. Data were recorded on 31 plant parameters comprising phenology, growth, physiological, biochemical, yield and yield components.

The main effects of variety and moisture levels and their interaction were significant on 22 parameters viz. days to flowering, days to physiological maturity, plant height, leaf number, tap root length, lateral root length, tap root collar diameter, shoot fresh weight and shoot dry weight, concentration of chlorophyll, concentration of proline, gas exchange parameters, Instantaneous water use efficiency, stomata number, stomata width and length, Length of pod,

pods plant^{-1}, seeds pod^{-1} and grain yield. The remaining nine parameters Viz. number of branch, Internode length, leaf relative water content, hundred seed weight, total biomass, and straw yield and harvest index were significantly affected by variety and moisture levels. Whereas, Maximum quantum yield of PSII (Fv/Fm) and leaf temprature were significantly affected by only moisture levels.

Among common bean varieties Awash-1, under both control and moisture deficit levels recorded superior in all growth parameters, transpiration rate, photosynthesis, chlorophyll concentration, proline content, leaf relative water content, pods plant^{-1}, seeds pod^{-1}, grain yield and total bio mass; Under moisture deficit recorded the shortest and narrowest stomata, and lowest stomata conductance. Variety Awash2 under control water level recorded larger number of pods per plant, early flowering, early maturity and relatively larger number of seeds per pod and grain yield; under moisture deficit lowest number of stomata, under water logging level the highest number of pods plant^{-1} was recorded.

Variety Gofta, under water logging level showed higher transpiration rate, photosynthesis, grain yield, early flowering and physiological maturity, longer and wider stomata. Variety Dursitu had large number of stomata in control moisture levels; Dursitu and Tinike recorded the lowest values of pod number under water logging level. Varieties Fedis and Tinike recorded the maximum values of hundred seed weight and straw yield respectively and Tinike also recorded large values of stomata conductance under control moisture levels. Varieties Tinike and Fedis recorded late flowering and physiological maturity and variety Fedis minimum value of grain yield under water logging level.

Regarding to moisture stress, all growth and phenological parameters except days to physiological maturity were significantly decreased with increased moisture stress. Days to physiological maturity significantly increased under water logging level. All physiological factors except leaf temperature and proline content decreased with increasing moisture stress in all varieties. The largest values were recorded from the control for all parameters and relatively larger values recorded from moisture deficit compared to water logging stress.

Correlation analysis indicates that all growth parameters were significantly correlated with physiological variables and yield component. More interestingly, grain yield was significantly and positively correlated with the Transpiration rate, photosynthetic rate, and water use efficiency as expected, clearly showing the role of carbon assimilation in dry mass production.

Conclusion:

Regarding to morphological parameters gofta variety was early flower and matured obtained to moisture deficit, maximum leaf number at water logging stress, longer root length with moisture deficit next to Awash-1 variety. Awash- 1 variety show that longer root length under moisture deficit for deep water reserves. In physiological trait Awash-1 variety had lower value of all physiological parameters except photosynthesis and Awash-2 has reduced stomata at moisture deficit. Awash-2, Dursitu, Awash-1 and Gofta were shows maximum yield at moisture deficit following to optimum water level. All physiological factors except leaf temperature and proline content decreased with increasing water stress in all varieties. The largest values were recorded from the control moisture level for all parameters and relatively larger values recorded from moisture deficit compared to water logging stress: Generally both moisture deficit and waterlogging stresses have resulted in significant reduction of growth, photosynthetic rate, yield and yield components of common bean varieties compared to optimum levels.

From this study Awash-1, Awash-2 and Gofta had better performance for most of evaluated morphological, physiological, and yield and yield component parameters and exhibited adaptive mechanisms under all moisture level. Therefore, these study was the pot experiment and there is not determined yield/ha. So, Further research on field level and other greenhouses level will be needed for valuable the results on various common bean varieties that lasts to the end of common bean plant life cycle involving evaluation of yield and yield component variables accompanied by variety and environment as well as economic analysis under stress conditions before generalized my recommendation.

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7. APPENDICES

Appendix Table 1 : Analysis of variance for phenology and growth parameters of common bean varieties under different moisture levels

Parameters	Source of variance					
	Rep	Variety	Moisture levels	Variety x Moisture levels	Error	CV
DE	6	0.04762ns	0.21164ns	0.08466ns	0.13095	5.28
DF	0.04762	82.683***	173.323***	13.497***	0.892	2.22
DM	4.825	250.111***	68.619***	21.667***	1.111	1.47
PH	1.89	347.7***	1472.61***	49.3***	35.25	5.28
NL	3.30	1084.30***	468.84***	27.97***	3.75***	6.01
SFW	26.29	4309.9***	294.91***	59.45***	11.15***	13.6
SDW	0.194	121***	12.934***	2.742***	0.296***	11.89
NB	0.3016	11.44***	7.7407***	0.4630ns	0.4849***	21.61
TRL	65.063	860.683***	641.423***	258.090***	25.647***	20.76
TRCD	0.0573	9.42587***	3.12481***	0.13902***	0.00097	1.11
LIN	3.8578	3.8578***	31.8747***	0.1074ns	0.1708	9.18
LRL	50.9	1380.54***	580.81***	187.59***	30.97***	20.94

Appendix Table 2 : Analysis of variance for physiological and anatomical parameters of common bean varieties under different moisture levels under lath house

Parameters	Source of variance					
	Rep	Variety	Moisture levels	Variety x Moisture levels	Error	CV
Gs	22.0	16866.7 ***	5419.5***	4728.9***	46.5	6
A	0.4133	53.541***	16.631**	3.4501***	0.5238	12.49
E	0.07639	1.49693***	3.47642***	2.31984***	0.364***	16.84
WUE	0.038	7.5036***	1.443***	3.7269***	0.1615	17.97
LRWC	19.6837	70.509*	6.404***	3.2088ns	2.6431	14.7
PCON	0.00027	0.57846***	0.04226***	1***	0.00101	9.1
NSTO	1.587	597.58***	96.286***	55.36***	0.987	7.5
LS	51.56	1744.73***	646***	423.22***	49.31	6.36
WS	19.07	4182.33***	237.78***	1106.08***	30.06	6.85
LT^{oc}	0.04762	82.683***	173.323***	13.497***	0.892	2.22

Appendix Table 3 : Analysis of variance for yield and yield component parameters of common bean varieties under different moisture levels

Parameters	Source of variance					
	Rep	Variety	Moisture levels	Variety x Moisture levels	Error	CV
LP	0.321	129.983***	2.622***	2.720***	0.002	0.59
NP	6.3492	94.873***	12.73***	0.7063***	0.0159	2.65
NS	1.2857	49.1903***	8.00***	0.4127*	0.1524	9.01
BY	8.460	419.861*	3.005***	5.631NS	9.650	22.82
HSW	33.698	145.093***	593.115**	4.199NS	18.782	15.92
GY	19..8249	65.4016***	12.378***	1.4094***	0.1486	9.42
SY	9.084	197.188***	33.053**	20.168ns	6.398	25.72
HI	300.11	300.11	361**	85.563ns	0.3688	28.96

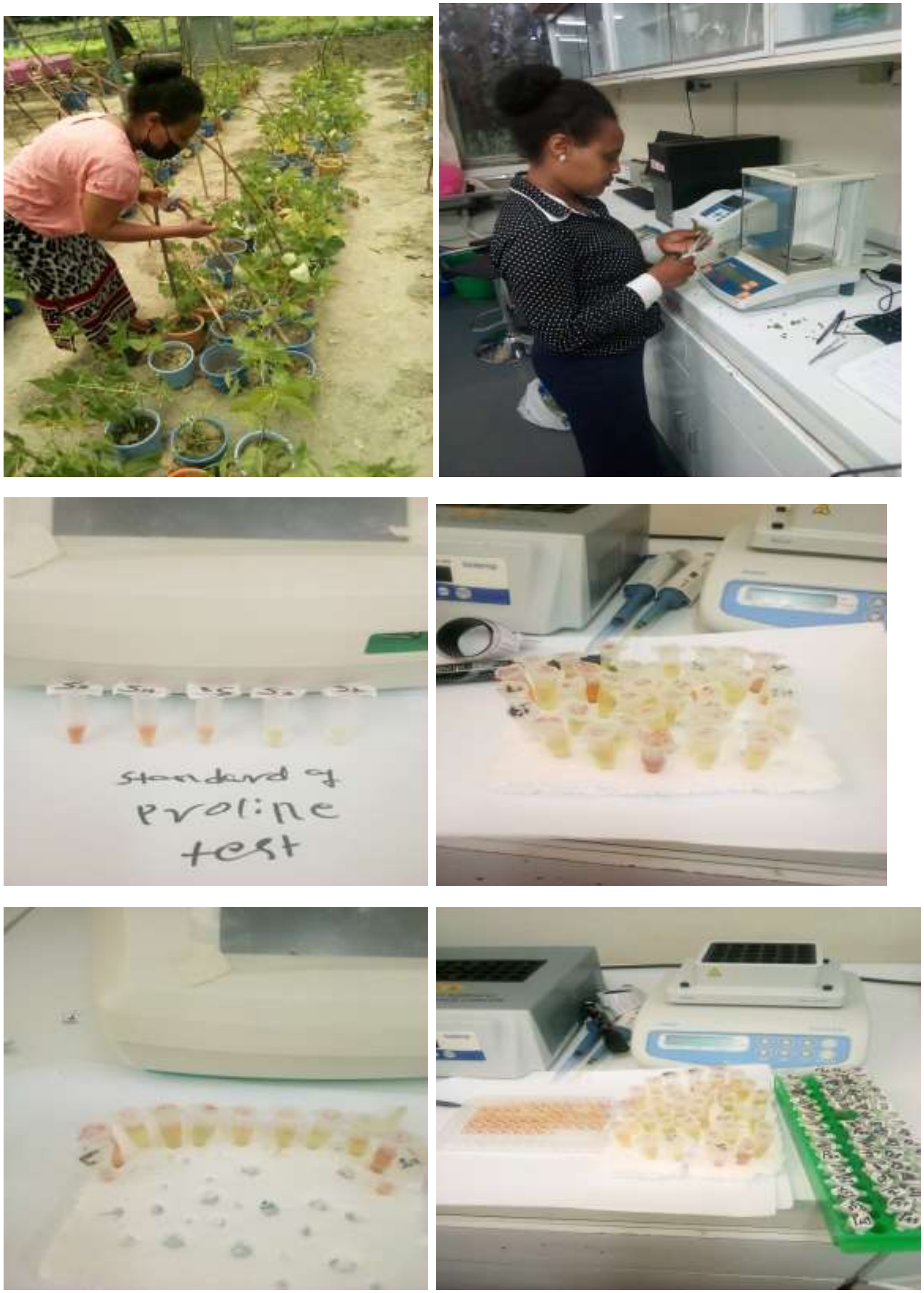
The sign*, ** and *** indicates; Significant at 5% and 1% and probability levels ($P<0.05$), respectively.

Picture in Appendix

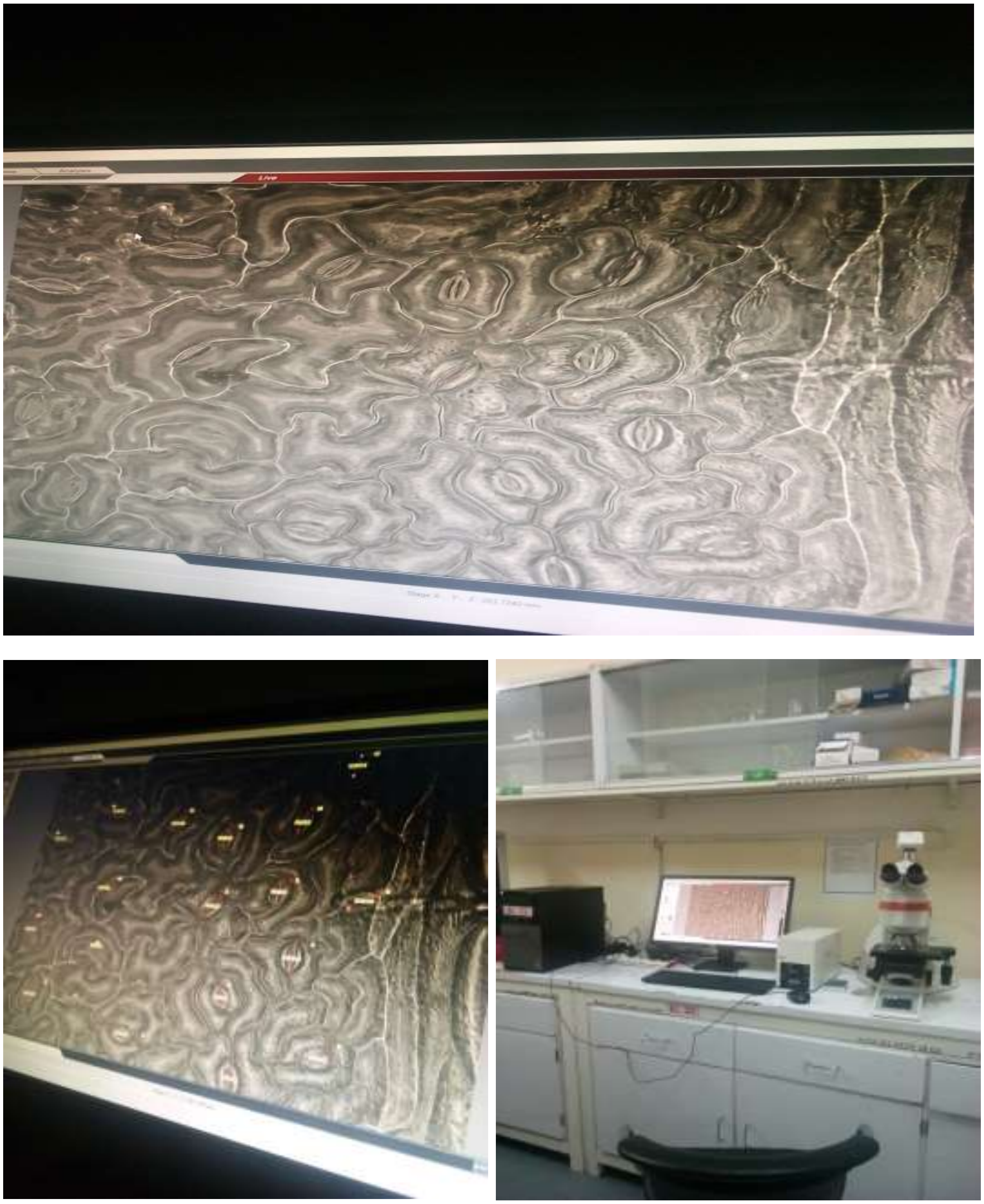
These figures show that field management and data collection of common bean in lath house

Appendix Picture 1: field management of common bean under moisture stress level

Appendix Picture 2: leaf fresh, turgid and dry weight for measuring LRWC of common bean under stress level



Appendix Picture 3: proline extraction of common bean under moisture stress level



Appendix Picture 4: Stomata anatomy (number, length and width) of common bean under moisture stress level

Appendix Picture 5 : yield threshold of common bean varieties that grow under moisture

SKETCH OF BIOGRAPHY

The author, Mulatu Mitike Alemu was born on January 29, 1986 GC at Butajira, Gurage Zone, SNNP regional state, Ethiopia. At age 7 she admitted to grade 1 in 1992 GC and completed her primary education (1-8) at Mekicho primary school. Then after, she attended her high school (9-10) at Butajira secondary school (preparatory school). After completion of her secondary school, she joined Alage TVET Agricultural College in November 2004 to follow her first Diploma and graduated with plant science in July 2006. After her graduation, she had worked at Silite Zone Silite Woreda for two years as Developmental agent (DA). In 2008, she again attended her Bachelor Degree (B.sc) in summer program at Wolaita Sodo University and graduated by plant science in 2015.Then she had been employed at Butajira in Mesikan Woreda Agricultural office as Expert for three years. After serving the farmer at Mesikan Woreda, she has got a chance to attend her Master's program. In 2018, she joined the Graduate program in Agronomy at Hawassa University. The author is marred and with a normal physical level.