MORPHO-PYSIOLOGICAL AND YIELD RESPONSE OF COMMON BEAN (*Phaseolus vulgaris* L.) VARITIES TO BELNDED FERTILIZER UNDER DIFFERENT MOISTURE LEVELS

MSc. THESIS

ALEM SISAY SAHILE

HAWASSA UNIVERSITY,

HAWASSA, ETHIOPIA

JUNE, 2023

MORPHO-PYSIOLOGICAL AND YIELD RESPONSE OF COMMON BEAN (PHASEOLUS VULGARIS L.) VARITIES TO BELNDED FERTILIZER LEVEL UNDER DIFFERENT MOISTURE LEVELS

ALEM SISAY SAHILE

A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND
HORTICULTURAL SCIENCE, COLLEGE OF AGRICULTURE, SCHOOL
OF GRADUATE STUDIES
HAWASSA UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF
MASTER OF SCIENCE IN PLANT AND HORTICULTURAL SCIENCES
(SPECIALIZATION: HORTICULTURE)

JUNE, 2023

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

ADVISORS'APPROVAL SHEET

(Submission Sheet – 1)

This is to certify that the thesis entitled **Morpho-Physiological and Yield Response of Common Bean (Phaseolus Vulgaris L.) Varities to Belnded Fertilizer Level Under Different Moisture Levels** submitted in partial fulfillment of the requirements for the degree of **Masters of Sciences** with specialization in **Horticulture** Graduate Program of the School of **Plant and Horticultural Sciences**, College of Agriculture, and has been carried out by **Alem Sisay**, **Sahile** under my supervision and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the course of this investigation have been well acknowledged. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Amsalu Gobena (Ph.D.)	____________________	__________________
Name of major advisor	Signature	Date

SCHOOL OF GRADUTE STUDIES
HAWASSA UNIVERSITY
EXAMINERS' APPROVAL SHEET-1
(Submission Sheet-2)

We, the undersigned, members of the Board of Examiners of the final open defense by Alem Sisay Sahile have read and evaluated her thesis entitled Morpho-Physiological and Yield Response of Common Bean (Phaseolus Vulgaris L.) Varities to Blended Fertilizer Level under Different Moisture Levels and examined the candidate. This is, therefore, to certify that thesis has been accepted in partial fulfillment of the requirements for the Master's degree Horticulture.

....	....	....
Name of Major Advisor	Signature	Date
....	....	....
Name of Chairman	Signature	Date
....	....	....
Name of Internal Examiner	Signature	Date
....	....	....
Name of External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent up on the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School of Graduate Committee (DGC/SGC) of the candidate's School

DECLARATION

I seriously declare that this MSc thesis is an original report of my work and that has not been submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others. This thesis is submitted in partial fulfillment of the requirements for MSc. degree at Hawassa University and deposited in Hawassa University library and is made available to users under the rules of the library.

Name: ____________________________________Signature: ___________________

Place: College of Agriculture, Hawassa University, Hawassa

Date of Submission: ________________________________

ACKNOWLEDGEMENTS

Above all, my special and forevermore gratitude goes to Almighty God and his mother St. Virgin Merry for their endless help and generosity in giving me the courage and strength through the course of my studies and studies and study. My deep gratitude extends to my major Advisor, Dr. Amsalu Gobena for his continuous guidance and support during the experimental period. I sincerely appreciate him for his; permanent availability, providing required materials during data collection, scientific guidance, challenging me to think critically and willing to work with my schedule. I deeply cherish the time I have spent working with him. I am grateful to Crop physiology, and Plant biotechnology laboratory workers, Kadija Kadiri, Nedi Dilgassa, for their help, providing me the required experimental materials.

I am grateful to Ethiopian ministry of education and Wachemo University for giving me the opportunity to attend Master‘s program. I also give special thanks to Hawassa University, all the professors whose classes I attended and colleagues I interacted with in my time at Hawassa. You all contributed positively to my experience, and I am deeply grateful to all of you. I also want to thank common bean thematic research for financial support Finally, I want to send my warm gratitude to all individuals out there always wishing to see accomplishment in my academic aspect

DEDICATION

This thesis is dedicated to my beloved mother, Zewudinesh G/Tsadik and my father, Sisay Sahile for their continuing love and support.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLE

LIST OF ABBREVATIONS AND ACRONOYMS

ANOVA	Analysis of Variance
DS	Drought Stress
FC	Field Capacity
IBPGR	International Board for Plant Genetic Resources
SAS	Software Analysis System
SPAD	Soil Plant Analyses Development
CRD	Completely Randomized Design
SWC	Soil Water Content
NPSZnB	Nitrogrn, Phosphores, Zinc, Boron
K	Potassium
AOS	Active Oxygen Species
LRWC	Leaf Relative Water content

Morpho-Physiological and Yield Response of Common Bean (*Phaseolus Vulgaris* L.) Verities to Blended Fertilizer under Different Moisture Levels

Alem Sisay and Amsalu Gobena

School of plant and Horticultural sciences, Hawassa University, P.O. Box 05, Hawassa, Ethiopia

Abstract

Common bean is the most important food legume crop for direct consumption in the world and is the most popular legume of the Americas and Eastern and Southern Africa. In Ethiopia, common bean is grown predominantly under smallholder producers as an important food crop and source of cash. There are biotic and abiotic stresses which causes a decrease losses in crop yield, being the water deficit, and soil fertility are the most limiting factor in the world agricultural production. Therefore, the aim of this study was designed to investigate the effect of blended fertilizer on morpho-physiology, accumulation of reserve compounds and yield of common bean varieties under different soil moisture levels from Feb to May 2021. A factorial combination of 3 different blended fertilizer (0, NPSBZn and NPSBZn+K), 3 common bean varieties (Hirna, Awash Melka, and Haromaya) and 2 moisture levels (30% SWC and 75% SWC) were arranged in CRD design with three replications. Results of the study showed that, morphological parameters such as leaf number, branch number and plant height were influenced by main and two-way interaction effect of varieties and moisture as well as fertilizer and varieties. But leaf area was influenced by three way interactions of variety, moisture and fertilizer levels. in addition, chlorophyll content, chlorophyll fluorescence, Photosynthetic rate, stomatal conductance, water use efficiency, proline content, carbohydrate content, and grain yield were significantly influenced by three way interaction effects of variety, fertilizer and moisture levels. They showed significant decrement under drought stressed conditions. The supplementation of K significantly increased physiological, and yield parameters under drought stress conditions compared to NPSZnB alone and zero fertilizer level. From the result of this study it is indicated morpho-physiology and yield response of common bean varieties varied under water deficit conditions. Hirna and Haromaya performed well under water deficit than Awash Melka variety. Better performances were observed in terms of photosynthesis, water use efficiency, relative water content, and stomata conductance, proline and carbohydrate accumulation in Hirna and Haromaya under drought stress condition. Generally, it was concluded that application of K as a supplement to NPSBZn significantly increased drought stress tolerance and increased yield in all varieties as compared to other treatments. However, further research is needed in an open field condition with different rates of blended fertilizer on mass number of varieties before a generalized conclusion has been drawn.

Keywords, drought stress, NPSZnB+K, common bean, drought stress

1. INTRODUCTION

2.1. Background

Common bean (*Phaseolus vulgaris* L.) is the most important food legume crop for direct consumption in the world and is the most popular legume of the Americas and of Eastern and Southern Africa (Darkwa ., 2016). It is growing in the tropics and subtropical region and has large coverage due to its low input agricultural systems, and as an export crop (Darkwa *et al*., 2016). It 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). It is an annual crop which belongs to the family Fabaceae. It grows best in warm climate at temperature of 18 to 24℃ (Teshale *et al*., 2005).

In Ethiopia, common bean is grown predominantly by smallholder producers as an important food crop and source of cash. It contributes to the national economy both for food and as export commodity and providing job opportunity for the community (Tumsa *et al*., 2014). It ranks third as an export commodity in Ethiopia, contributing about 9.5 % of total export value from agriculture (FAOSTAT, 2010). As legume crop it also contributes to soil fertility enhancement through atmospheric nitrogen fixation (Broughton *et al* ., 2003).

There are biotic and abiotic stresses which causes a decrease in crop yield, being the water deficit is the most limiting factor in the world agricultural production (Yadav , 2020). Drought is a major abiotic stress that affects agricultural systems and food production. It induces several physiological, biochemical and molecular responses which give rise to excess concentrations of active oxygen species (AOS) resulting in oxidative damage at cellular level (Foyer and Noctor, 2002). It inhibits the photosynthesis of plants causing changes of chlorophyll contents, damages the photosynthetic apparatus, and decreases the activities of Calvin cycle enzymes (Monakhova and Chernyadev, 2002). Generally, the environmental stresses especially drought stress, give rise to accumulation of soluble carbohydrates, proline and free amino acids as well as antioxidant compounds.

It is the world's most important food legume and is considered as nearly perfect food mainly because of its high protein content and abundant fiber, complex carbohydrates, and other daily food needs such as vitamins (folate) and minerals (Cu, Ca, Fe, Mg, Mn, Zn) (Miklas et al., 2006). Beans provide an important source of protein (~22%), (Broughton *et al*., 2003). However, the composition of bean mainly influenced based on environmental factors and resource utilization potential of the genotypes. In many plant species better performance of crop depends upon availability of water and nutrient during active growing stages (Jamal *et al*., 1996). Grain quality, amount of reserve compounds and yield are greatly influenced by environmental factors(Prasad and Staggenborg, 2008). Producing micronutrient-enriched cultivars (biofortification), particularly those with increased Zn and Fe either agronomically or genetically and improving the bioavailability of these minerals are considered a promising and cost-effective method to manage micronutrient deficiencies.

According to Rosales *et al*. (2012), above 60% of the bean's production occurs in agricultural land prone to water deficit, without irrigation systems, where dry periods result in losses that may reach a yield reduction of up to 80%. A major effect of drought on plant is therefore reduction of vegetative growth, yield and quality of seed due to lower up take of macro and micronutrient from soil. Previous report indicated that, water deficiency affects plant and seed uptake and utilization of most macro- and micro-nutrients (Munoz-Perea *et al*., 2005). Also, it was reported (Castaneda-Saucedo *et al*., 2009) that drought stress reduced accumulation of seed reserves between 8% and 12%. Report from Thomas *et al*. (2009) also indicated that, soil moisture conditions during soybean growth influenced nutritional quality of seeds. Similarly, Teran and Singh (2002) and Frahm *et al*. (2004) believed that mild to high drought stress reduces plant growth, seed yield and quality of dry bean. Under prolonged drought condition plant leads to interrupted reproductive development, premature leaf senescence, wilting, desiccation, and death (Neumann, 2008). Plant exposed to prolonged water deficit, has reduced leaf relative water content (RWC) and leaf water potential which induces stomatal closure, and reduction in the rate of photosynthesis, nutrient uptake, and water use efficiency (Bota *et al*., 2004).

In Ethiopia, new common bean cultivars have been developed through selection and incorporation of various physiological, phenological and morphological characteristics that improve yield under drought conditions (Beaver *et al*., 2003). However, the performance of genotypes on nutrient uptake and nutritional value accumulation not well documented at Ethiopian condition. Nitrogen, iron (Fe), Phosphorous (P), Zinc (Zn) and other macro and micro nutrient deficiency is the most prevalent problem in the world that affects over 2 billion people which most of them depend on beans as staple food (Welch and Graham, 1999). De Souza *et al*. (1997) studied the effect of water deficit on leaf characteristics and concluded that severe drought accelerated leaf senescence by reducing leaf nitrogen (N) and chlorophyll contents. Plant growth depends on soil mineral elements, a lack of which results in reduced nutrient accumulation leading to poor growth and resistance in plants. Plants accumulate large amounts of nutrients, including nitrogen (N), phosphorus (P), and potassium (K), which are stored in the different part of plant organs including seeds at the end of the growing season.

Potassium is the most abundant inorganic cation in non-halophytes, contributing up to 6 % of plant dry weight. As a major inorganic osmolyte, K^+ is crucial for cell osmoregulation and turgor maintenance and, hence, for cell expansion, stomatal function, tropisms, and leaf movement (Shabala, 2003). Being an activator of many enzymes, K^+ plays a key role in photosynthesis, protein synthesis, and oxidative metabolism. It also affects phloem transport and provides charge balance during vectorial ion transfer across cellular membranes (Marschner, 1995).

Drought is a significant limiting factor for agricultural productivity and generally inhibits plant growth through reduced water absorption and nutrient uptake. Decreased water availability generally results in reduced growth and final yield in crop plants. Potassium ions contribute significantly to the osmotic potential of the vacuoles even under drought conditions (Marschner, 1995). Adequate K fertilizer application for plants may facilitate osmotic adjustment, which maintains turgor pressure at lower leaf water potentials and can improve the ability of plants to tolerate drought stress (Lindhauer, 1985; Mengel and Arneke, 1982).

Phosphorus (P) is a key element required for normal plant development, but its low mobility in soil results in poor uptake by plants, which consequently inhibits growth and metabolism. The majority of soil types, including fertile soils, have low available P, because the rate of absorption in the rhizosphere exceeds the rate of its replenishment in soil solution (Suriyagoda *et al*., 2011). Previous studies suggest that phosphorus contributes for the extension of root system and P deficiency will exacerbate drought stress (Cramer *et al*., 2009; Sardans and Penuelas, 2012). The use of P fertilizer reduces its deficiency in soil, increases the stress-tolerating ability of plants (Cortina *et al*., 2013) and results in adjustments of physiological, morphological, and biochemical processes that increase plant growth (Liu *et al*., 2015).

Nitrogen is an essential nutrient in the plant production. For many plant species, a strong correlation was observed between leaf N and CO2 assimilation (Baker and Rosenqvist, 2004). A large part of N in the plant is allocated to leaves and a large amount of leaf N is allocated to photosynthetic system. Photosynthetic activity is related to leaf N and the net photosynthetic rate increases with higher levels of leaf N. Generally, drought decreases leaf N content leading to a decrease in photosynthesis (Nakayama *et al*., 2007).

Among different mineral nutrition it is well known that Boron nutrient is essential for crop growth, development, production, and seed quality (Pilbeam and Kirkby, 1983). Boron deficiency in soil due to biotic or abiotic stress factors results in yield loss and poor seed quality. For instance B is involved in nitrogen fixation (Bolanos *et al*., 1996), nodules (Carpena *et al*., 2000), nodulin protein (ENOD2) in nodule parenchyma cells and malfunction of oxygen diffusion barrier (Bonilla *et al*., 1997). However, the availability and uptake of Boron is mainly affected by different environmental and genotypic factors.

Sulfur (S) is recognized as the fourth major nutrient after nitrogen (N), phosphorus (P) and potassium (K). It is not only improves crop yield but also influences the quality due to its key role in protein synthesis (Usmani *et al*., 2020). It was reported that, S is the only macronutrient that accumulates in the xylem sap of water stressed maize plants (Ernst, L. *et al*., 2010)

Similarly, Zinc (Zn) is an essential micronutrient that plays fundamental roles in crop resistance against the drought stress by regulating various physiological and molecular mechanisms. Under drought stress, Zn application improves seed germination, plant water relations, cell membrane stability, osmolyte accumulation, stomatal regulation, water use efficiency and photosynthesis, thus resulting in significantly better plant performance (Hassan *et al*., 2020).

To develop resistance and high yielding variety it is necessary to aware the morpho-physiologcal characteristics of the variety which helps to screen a variety which performs well under drought stress conditions. Techniques which facilitate the screening of drought-tolerant, high nutrient uptake and high yielding varieties have become important in crop production. Therefore, the research was conducted to investigate the effect of blended fertilizer on morpho-physiology, and yield of common bean varieties under different soil moisture levels.

1.1. Objective

1.2.1 General Objective

- To study the effect of blended fertilizer and water deficit on growth, physiology and yield of common bean varieties.

1.2.2. Specific Objective

- To study the physiological response of common bean varieties to blended fertilizer and water deficit
- To evaluate common bean genotypes under blended fertilizer and water deficit condition
- To identify the common bean variety that performs well under drought stress conditions

2. LITERATURE REVIEW

2.1. Origin and domestication of 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). 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. Different races have been described in gene pools differentiated for morph-agronomical traits. It was distributed widely in all parts of Europe and the Mediterranean area where many landraces and varieties evolved that were grown to provide dry seed or fresh pods (Logozzo *et al*., 2007). The species was perhaps introduced to the eastern part of Africa by Portuguese traders in the sixteenth century (Wortmann *et al*., 2004).

2.2. Uses of common bean

Common bean is the most commonly consumed legume worldwide, and it is the most important for direct human consumption, with a commercial value exceeding that of all other legume crops combined (Ssekandi *et al*., 2016). Extractions of common bean as well as some of its individual components have been reported for their effects in reducing appetite and body weight and blood glucose in rats. Common bean is gaining increasing attention as a functional or nutraceutical food, due to its rich variety of phytochemicals with potential health benefits such as fiber, polyphenolic compounds, lectins, unsaturated fatty acids, trypsin inhibitors, phytic acid, among others (Guzman-Maldonado *et al*., 2000). This crop is essential in Nitrogen fixation to improve the soil fertility as well as increase crop production and livelihoods of farmers (Gebre-egziabher Murut *et al*., 2014). In Ethiopia, common bean has been one of the most important crops grown by small scale farmers in different parts of the Region, in the central rift valley of Ethiopia; the crop is used as one of the cheapest source of protein apart from being the major source of cash income. It is usually consumed in the form of boiled grain, which is locally known as Nifro farmers also prepare a local stew known as shiro wot from some bean cultivars (Zelalem Zewdu, 2014).

2.3. Production Constraint

Mostly, production of common bean is highly constrained by environmental stresses such as drought, pests, diseases, and low input farming methods that have resulted into declined soil fertility and productivity (Asrat Asfaw *et al*., 2013). Socio-economic factors related to farmer adoption of new technologies, seed distribution, and market requirements may also restrict bean production. The small-scale farmer's main cost and biggest problem is often the purchase of high-quality seed, production inputs such as fertilizer, pesticide, etc. and adoption of new technology (Frehiwot Mulugeta, 2010).Soil fertility status, recurrent water stress, insect pests, weeds and diseases are considered as the principal abiotic and biotic constraints of common bean production in Africa (Tesfay and Amin, 2014; Yitayal and Adam, 2015). There are several serious insect pests that attack the common bean, depending on the geographic location, but predation by a wide range of arthropods aphids, beetles, caterpillars, Leafhoppers, whiteflies, mites and thrips is seen worldwide (Beebe *et al*., 2009; Fikere Mulusew *et al*., 2010).

2.4. Effects of Moisture Stress on Morpho Physiology and yield of Common Bean

A significant drying is predicted in the future and certainly leading to an increased frequency and severity of extreme droughts. Moisture stress or water deficit is an edaphic stress that affects plant growth and dramatically limits agricultural productivity in many parts of the world (Comas *et al*. 2013). This stress induces a range of physiological and biochemical responses in plants, which undesirably affects the growth of above-and below-ground tissues and photosynthesis activities finally affecting the dry matter accumulation (Khalili *et al*. 2016). Common bean is an important crop which is sensitive to water deficit when compared to other crops (Cruz *et al*. 1998). Drought inhibits the photosynthesis of plants causing changes of chlorophyll contents, damage the photosynthetic apparatus and decreases the activities of Calvin cycle enzymes (Monakhova and Chernyadev, 2002).

Drought is a major environmental factor impairing many physiological and metabolic processes in plants, which may lead to suppression of plant growth and development, reducing crop productivity, or even lead to plant death. Across plant species, drought imposes various physiological and biochemical limitations and adverse effects (Casson and Hetherington, 2010; Pirasteh-Anosheh *et al*., 2013; Bouranis *et al*., 2014; Saed-Moucheshi *et al*., 2014; Chen *et al*., 2015). Cell growth is the process that is most affected by water deficit. Taiz and Zeiger (2002) reported that under more severe drought conditions inhibition of cell division, inhibition of wall and protein synthesis, accumulation of solutes, closing of stomata, and inhibition of photosynthesis were observed. Stomatal closure in response to drought stress primarily results in decrease in the photosynthesis rate. The results of Mutava *et al*. (2015) revealed that under drought stress, stomatal conductance of soybean is responsible for reduced photosynthetic rate. It disrupts photosynthetic pigments and reduces the gas exchange leading to reduction in plant growth and productivity (Anjum *et al*., 2011).

Jaleel *et al*. (2009) stated that drought stress affects plant growth and development through changes in plant structure, and changes in various physiological and biochemical processes. Losing the turgor pressure is the first effect of drought conditions that influences cell expansion rate and its final size, resulting in a reduction of growth rate (Kumar and Purohit, 2001). Since water and mineral nutrients are taken up by the root, its growth and development may be affected by drought. (Abd Allah *et al*., 2010). In soil water deficit conditions, guard cells lose their turgidity resulted in stomatal closure. Then, the rate of CO2 diffusion through the stomata is limited and the photosynthetic rate declines (Sikuku *et al*., 2010). Drought stress affects photosystem efficiency and decreases the electron transport rate and the effective quantum yield of photosystem II (PSII) photochemistry (Ahmed *et al*., 2002; Zlatev and Yordanov, 2004).

Some previous studies have investigated the effects of drought stress on different properties of a variety of cultivars of common bean plant. For instance, Cristina Lanna *et al*. (2016) have studied physiological responses of two Brazilian common bean genotypes to drought stress. Their results showed that the main physiological indicators of tolerance of common bean plants to water deficit were the robustness of the root system and osmotic adjustment. In another study, the evaluation of drought stress adaptation of common bean genotypes in Ethiopia showed that for all the investigated traits including plant height, chlorophyll content, yield data, and drought intensity, susceptibility, and tolerance indices, the different genotypic responses to drought stress were observed (Darkwa *et al*. 2016). Castaneda Saucedo *et al*. (2012) studied the alteration of some carbohydrates such as sucrose, glucose, fructose and starch in the leaves, pods and seeds of

P. vulgaris under drought stress. They reported an increase in the concentrations of glucose and fructose and a decrease in starch and sucrose in mature leaves, under stress condition.

In a study on two Iranian cultivars of common bean (Talash and Daneshkadeh), it was found that in terms of drought resistance in different growth and development stages including vegetative, flowering and pod filling stages, the tolerance and stress susceptibility indices there was a significant differences between two cultivars (Rafiiolhossaini *et al*., 2016). Ghanbari *et al*. (2013) investigated the leaf responses of eight common bean cultivars to water deficit stress. Their results showed that water deficit induced a decrease in the relative water content; leaf wet weight, leaf dry weight, leaf area index, and plant leaf numbers. In another study investigating the effect of irrigation intervals on some physiological and morphological characteristics of red bean it was found that delay in irrigation decreased leaf relative water content, chlorophyll content, plant height, number of lateral branches and seed yield and increased electrolyte leakage, leaf prolin and soluble sugar content (Saeidi Aboueshaghi *et al*., 2014).

There are reports that common bean is susceptible to drought stress or water deficit and it has been reported accelerated maturity of crop along with reducing grain yield and mean weight of hundred seeds following water stress, have been reported Nielsen (1998) and Molina *et al.* (2001). Furthermore, common bean cultivar has reported to respond differently to soil moisture stress depending on the severity of water stress (Boutraa *and Sanders* 2001). Emam *et al*. (2010) and Rosales-Serna *et al*. (2004) also reported that plant dry weight was decreased significantly by increasing water stress. Barrios *et al*. (2005) also reported that leaf dry weight of common beans reduced when plants are exposed to drought stress.

2.5. Effect of Blended Fertilizer on Morpho Physiology and Yield of Common Bean

Genetic and physiological potential of different crop plants vary on nutrient use efficiency (Fageria, 2009, Nigussie *et al*., 2015). A lot of diversity among common bean varieties in nutrient use efficiency was presented by Kasinath *et al*. (2015). Different authors reported NPKSB nutrients requirements for common bean growth and yield (Rahiman *et al*., 2014, Tadele, 2017 and Wossen, 2017). As reported by IPI, (2016) increases K has on root numbers and volumes, increasing the chances for root hairs to intercept the soil bacteria which initiate nodulation. K and P deficiency as a major constraint for nodulation in common bean (Baijukya and Mazanda 2015). Effect of S and B on nodule growth, nodule formation and functioning were reported by (Pacyna *et al*., 2006, Varin *et al*., 2009, and Flores *et al*., 2018). Similarly, significantly increasing biomass production with increasing rate of blended NPKS Mg Zn fertilizer application in common bean was reported by (Wossen, 2017). Combined applications of NP fertilizer, high nitrogen rate and increase in P2O5 application resulted in enhanced dry biomass production on common bean (Abebe, 2009, Tadesse and Dechasaa, 2012). Similarly, also observed beneficial effect of fertilizer potassium on dry matter production and distribution in common bean plants was probably associated with the maintenance of better water relations in the plants due to potassium application (Islam *et al* .,2004).

Production of crops using sulfur containing fertilizer enhances concentration of sulfur-rich proteins, cysteine and methionine (Pandurangan *et al*., 2015). Total number of nodules and active nodules increased with the increase in application of S up to 20 kg ha-1 (Ganeshamurthy and Reddy, 2000). In addition sulfur assimilation and nitrogen fixation is interdependent

(Kalloniati *et al*., 2015). Pod fresh weights of green bean could increase from the application of sulfur containing fertilizer (Kovács *et al*., 2013).

Phosphorus is an essential nutrient for various metabolic processes such as photosynthesis, respiration, and signal transduction, among others. Phosphorus application for on common bean consistently showed a positive response on yield, shoot dry matter and number of pods (Turuko and Mohammed, 2014; Fageria and Baligar, 2016). Nodule number, weight and volume also increased with the addition of P, indicating more effective N2-fixation (Singh *et al*., 2008; Rifat *et al*., 2008).

3. MATERIALS AND METHODS

3.1. Description of study area

The experiment was carried out under shade house condition from Feb 2021 –June 2021 at Hawassa University, College of Agricultural. The area is in Sidama Region which is 275 km far from Addis Ababa, capital city of Ethiopia. The site lies at 7°05′ N latitude, 38°47′ E longitude with average altitude of 1750 m above sea level. According to last 11 years (2007-2018) data obtained from the weather station, the average annual rain falls and temperature (maximum and minimum) of the area is 971.9 mm and 27.9°c and 13.8°c, respectively (NMASNNPSMCHB, 2019).

3.2. Experimental Material

Three common bean genotypes (Hirna, Haromaya , and Awash Melka) and blended fertilizer of (NPSBZn and NPKSBZn) and pots were used.

Table 1 description of common bean varieties.

Variety	Maturity(days)	Color	Years of release	Origin
Hirna	90	Red	2012	Ethiopia
Haromaya	80	Slight white	2006	Ethiopia
Awash Melka	75-80	White	1999	Ethiopia

3.3. Experimental Design and procedures

The experiment have three levels of fertilizer type (No fertilizer, NPSBZn and NPSBZn + K) and two levels of moisture (30% SWC and 75% SWC) and three common bean genotypes (Hirna, Awash Melka and Haromaya varieties) arranged in a factorial scheme 3 x 2 x 3 in a completely randomized design which encompasses (18 treatments) in total with three replications of total (54 Experimental units) and nine plants were planted per treatment. 22 cm x 16 cm pots were used for crop production. It had five pores of equal size in the bottom for drainage. The two levels of moisture were 30% and 75% SWC (Abiot, 2018). During the experiment, the atmospheric condition (minimum and maximum temperature, relative humidity) of shade house was recorded. Fertilizer application and moisture level adjustment was carried out after the crop attainment of two to three leaves (10-12 days). The specific management practices and amount of water to be applied was calibrated empirically based on the treatments and field capacity of the soil.

The topsoil up to 20 cm depth was collected from Hawassa University, College of Agriculture, and Plant and Horticultural sciences research site and soil moisture content and field capacity was determined gravimetrically W.H. (1986) on soil dry weight basis. Two uniformly sized seeds were sown 5cm deep in each pot then thinned to one when it attains two leaves. The pots were weighed in two days interval to compensate the water loss by evapotranspiration and therefore, the pot was kept at different days of irrigation interval.

Table 2: experimental treatment combination

Treatment	Varieties	Moisture level	Fertilizer level
1	Hirna	30% SWC	F0
2	Hirna	30% SWC	F1
3	Hirna	30% SWC	F2
4	Hirna	75% SWC	F0
5	Hirna	75% SWC	F1
6	Hirna	75% SWC	F2
7	Haromaya	30% SWC	F0
8	Haromaya	30% SWC	F1
9	Haromaya	30% SWC	F2
10	Haromaya	75% SWC	F0
11	Haromaya	75% SWC	F1
12	Haromaya	75% SWC	F2
13	Awash Melka	30% SWC	F0
14	Awash Melka	30% SWC	F1
15	Awash Melka	30% SWC	F2
16	Awash Melka	75% SWC	F0
17	Awash Melka	75% SWC	F1
18	Awash Melka	75% SWC	F2

Where; F1=NPSBZn, F2= NPSBZnK, F0= Zero fertilizer; w1=well watered W0=drought

3.4. Experimental Soil Sampling and Analysis

The composited soil 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 Horticoop Ethiopia (Horticulture) PLC Soil and water analysis laboratory. The soil pH values were determined in soil water suspension 1:2.5 using glass electrode pH meters Jackson (1967). Determination of particle size distribution (texture) was carried out hydrometrically following the methodology of Day (1965) Soil organic carbon (OC) was determined using the Walkley and

Black wet oxidation method (Walkely's and Black, 1934), and soil total nitrogen by the Kjeldahl as described by Dewis and Freitas (1970), and cation exchange capacity (CEC) by saturating the soil with a neutral 1M NH4OAc method (Chapman, 1965). Available phosphorus was determined using the sodium bicarbonate solution extraction method, and the quantity was measured using a spectrophotometer as defined by way of Olsen *et al*., (1954) Exchangeable potassium was determined with a flame photometer (Hesse, 1971). The available S in the soil samples was determined with monocalcium phosphate extract, while available Zn and B in the soil samples was extracted with diethylene triaminepenta acetic acid (DTPA) and quantified by atomic absorption spectrophotometer. The chemical and physical properties of the soil before planting are presented in Table (3).

Table 3 Physical and chemical properties of the experimental soil before-planting

Properties	Results	Rating	References
Sand (%)	58.4		
Silt (%)	29.2		
Clay (%)	12.4		
Textural class	Sandy loam		
pH (1: 2.5 H2O)	7.34		
Organic Carbon /OC/ (%)	3.32	medium	Tekalign (1991)
CEC (meq/100 g soil)	24.11	medium	Hazelton and Murphy,2007
Total Nitrogen /TN/ (%)	0.24	medium	Murphy (1968)
Available Phosphorus /P/(ppm)	22.86	medium	Olsen *et al*. (1954)
Exchangeable K(cmol($^+$)/ kg	0.58	medium	Ethio SIS (2014)
Available Sulfur /S/(ppm)	10.79	low	Ethio SIS (2014)
Available Boron /B/(ppm)	0.45	low	Ethio SIS (2014)
Available Zinc /Zn/(ppm)	0.37	low	Ethio SIS (2014)

3.5. Data Collection and Measurement

Data was collected throughout the growth and development of the crop at different stages, accordingly morphology and physiological related traits were measured on randomly selected plants per pot (IBPGR, 1982).

3.6. Growth and morphological data

- **Leaf Number (count):** All leaves of five plants per experimental unit were counted at mid pod filling stage
- **Plant height (cm)**: It was measured from cotyledon node up to the upper most point of the plant at mid pod filling stage on sampling plants per pots using meter stick.
- **Leaf Area(cm^2):** The leaf area was measured using in cm^2, by the LI-COR leaf area meter at the mid of pod filling stage from all leaves of three selected plants per experimental unit
- **Branch number (count)**: Average number of secondary branches was recorded from the three randomly selected plants. at the mid of pod filling stage from three randomly selected plants
- **Leaf fresh weight (g):** It was measured using sensitive balance at the mid-pod filling stage from all leaves of three selected plants per experimental unit. **Leaf dry weight (g):** It was measured by electronic sensitive balance after the samples had been oven-dried (48 hr at 75°C).

3.7. Physiological data

Leaf gas exchange parameters:

Leaf gas-exchange 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 20 days after the start of actual treatment on fully expanded intact leaves. Measurement was done between 10:00 AM and 12:00 PM setting instrumental modifications like: leaf surface area was 6.54 cm^2 ambient carbon dioxide concentration 386 µmol mol-1,leaf chamber mass flow rate was 250 µmol s^{-1}, atmospheric pressure 840 bar and photosynthetic active radiation (PAR) was manually fixed to 1200 µmol m^{-2} s^{-1}. Water use efficiency was determined as the ratio between net CO_2 assimilation rate (A) and transpiration rate (E).

Leaf chlorophyll content (µg/ml)

Leaf chlorophyll concentration was measured at the mid-pod fill stage on fully expanded young leaves of three plants in each experimental unit. Sampling was done at 8:00 AM and leaves were placed in a bag sealed with aluminum foil and transported to Hawassa university crop physiology the laboratory. Fresh leaf discs (0.5g) were placed in 15-mL tubes containing 80 %(v/v) acetone and homogenized with acetone using a pestle and mortar. The homogenized sample mixture was centrifuge for 10,000 rpm for 15min at 40°C. The supernatant was separated and 0.5ml of each concentration level was analyzed in triplicate for Chlorophylla and Chlorophyll-b at an absorbance of 663nm and 646nm wavelength region, respectively, in spectrophotometer UV-2450 spectrophotometer (Hitachi, Tokyo, Japan). The following equations were used for the quantification of Chlorophyll-a, Chlorophyll-b (Lichtenthaler and Buschmann, 2001).

Chl a (µg/ml) =12.25 (A663) – 2.79 (A646)

Chl b (µg/ml) =21.50(A646) – 5.10 A663)

Total chl (µg/ml) =chl a+chl b

Where; A = Absorbance, Chl a = Chlorophyll a, Chl b = 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 using 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 (µg/gm1FW)

At pod filling stage leaf samples from each experimental 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 14000rpm 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 microplate reader and quantified at 520nm using Multisken FC. Proline concentration was determined using a calibration curve and expressed as µg/g leaf fresh weight.

Stomata anatomy

Stomata anatomy measurement was made using the protocol proposed by Xu and Zhou (2008) at 20 days after the start of the treatment. 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. The resulting molds were then examined using Automated Upright Leica Microscope DM5000 B with a 40x magnification lens fixed with a digital Leica DFC425/DFC425C image processing camera. For each sample, stomata number (per mm2), epidermal cell number (per mm2), stomata width (µm), and length (µm) were measured. Stomata density was expressed as the stomata number per leaf area unit (in mm2).

Relative leaf water content

Three fully expanded leaves were collected from three representative plants and leaf disks(9mm in diameter) were immediately weighed (leaf fresh weight), thereafter the samples were immediately hydrated to full turgidity for 24 h by immersing in deionized water in a closed 15-ml tube under room temperature. Afterward, hydrated samples were well dried with filter tissue paper and reweighed to obtain fully turgid mass (leaf turgid weight). Samples were oven-dried for 24 h at 75°C to obtain dry mass (leaf dry weight). Relative water content (RWC) was calculated following the method developed by Turner. (1981).

$$LRWC\ (\%) = [(F.W - D.W) / (T.W - D.W)] * 100.$$

Where: F.W= Fresh weight; D.W=Dry weight; T.W=Turgid weight

3.8. Yield data

All 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. Five plants per experimental unit were used for sampling.

The number of pods per plant (count): The Average numbers of pods per plant were determined by counting pods of the five randomly selected plants per experimental unit.

The number of seeds per plant (count): Average number of seeds per plant of five randomly selected plants was determined.

Grain yield (g/plant): The average grain yield in gram was measured from five randomly taken plants in each experimental unit after seed moisture was corrected to 10%.

Harvest Index (%): Was determined as the ratio of grain yield to the aboveground biomass

3.9. Data Analysis

Data were analyzed using analysis of variance (ANOVA), by factorial experiment in (CRD) by statistical analysis system SAS software version 9.2 (SAS Institute 2008). The means separation was done using least significant test at p 5% (0.05) level of significance. Pearson correlation analysis was used to know the relationship between variables.

4. RESULT AND DISCUSSION

4.1. Morphological and growth parameters

4.1.1. Leaf area

Analysis of variance showed that the main, two-way, and three-way interaction effects of variety, fertilizer, and moisture levels were highly significantly ($P < 0.01$) influenced leaf area(Appendix table 1). The highest mean value of leaf area was produced by the ' Hirna variety treated with NPSZnB alone and NPSZnB+K grown under well-watered conditions. Whereas, Awash Melka cultivated without fertilizer and subjected to drought stressed had the smallest leaf area (Table 4). The results showed that the blended alone and in combination with K had no a significant effect on leaf area of Hirna, Haromaya and Awash Melka varieties under well-watered conditions. However, under drought stress, additional K application to blended fertilizer (NPSBZn) considerably increased leaf area. Result indicated that leaf area expansion under well watered condition was not significantly influenced by the blended alone and in combination with K. However, supplementary application of K to blended fertilizer (NPSBZn) significantly increased leaf area under drought stress conditions.

This might be due to the supplemented potassium plays a significant role for the increment of the leaf area and adjust the osmotic stress of the leaf. This finding was in agreement with Karim and Abdul, (2004) report that maximum leaf area with the highest dose of potassium under controlled conditions. The lowest leaf areas were recorded on Awash Melka variety no fertilizer and grown under low water stressed condition. This is due to the low moisture level as well as null addition of fertilizer affects the leaf growth and cell expansion. In addition the reduction in leaf area could be attributed to changes in chlorophyll, reducing CO_2 uptake by leaves due water stress and resulting in reduction in photosynthetic ability of plant (Gibberson et al., 2016).

A research by Karim and Abdul (2004) stated that irrespective of the levels of water stress, increasing levels of potassium fertilizer increased the leaf area significantly. The maximum leaf area per plant was recorded with the highest dose of potassium (112.5 kg K ha-1) applied under control conditions. In contrast, the plants with the minimum level of potassium (37.5 kg K ha-1) produced the smallest leaf area under severe water stress conditions. Emam *et al*. (2010) reported that leaf area of dry beans was reduced when the plants exposed to drought stress during vegetative growth stage. Indeed, loss of leaf area, which could be resulted from reduced size of younger leaves and inhibition of the expansion of developing foliage, is also considered as an adaptation mechanisms to moisture deficit (Acosta-Gallegos and White, 1995).

Table 4: Mean value of leaf area of common bean varieties as influenced by different blended fertilizer and soil moisture levels.

Leaf area	Varieties		
Fertilizer with moisture levels	Hirna	Haromaya	Awash Melka
F2 W1	1490.0^{a}	1276.7^{c}	1190.0^{d}
F1 W1	1473.7^{a}	1236.7^{c}	1161.7^{d}
F0 W1	1370.0^{b}	1165.0^{d}	951.3^{e}
F2 W0	951.3^{e}	847.0^{f}	592.7^{i}
F1 W0	871.7^{f}	740.0^{g}	508.7^{j}
F0 W0	762.0^{g}	637.0^{h}	413.0^{k}
CV (%)	2.68		
LSD (0.05)	43.452		

Where; F1=NPSBZn, F2= NPSBZnK, F0= Zero fertilizer; w1=well watered W0=drought stressed Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.1.2. Branch number and Plant height

Branch number is significantly ($p<0.01$) influenced by the main, and two way interactions of variety and moisture and fertilizer and moisture level but not two way interaction of variety and fertilizer and three way interaction variety moisture and fertilizer level (Appendix Table 1). The highest mean value of branch number was recorded from Haromaya variety treated with NPSBZn+K while the lowest mean value of branch number was recorded from Awash Malka variety grown without fertilizer subjected to drought (Table 5). In similar with this finding Mekonnen and Saliha (2018) noted that maximum number of main branches per plant and plant height in common bean were recorded from 100 kg/ha followed by 150 kg/ha NPSBZn applications.

Analysis of variance showed that there was significant difference ($P<0.05$) in plant height due to interaction of variety and moisture level unlike main factors and other interactions (Appendix Table 1).The longest plant (202.98 cm) was recorded from Haromaya variety grown on well-watered condition and the shortest plant was obtained from Awash Melka treated with drought stressed condition (Table 5). The shortest plant height in Awash Melka may be due to reduction in plant water status which reduces shoot elongation, leaf expansion, and inhibition of cell division or cell enlargement. This result agrees with the report of Emam et al. (2010) and Shenkut and Brick (2003) who indicated that plant height was affected by low water stress. Plant height reduction in common bean variety related with cell division and cell elongation (Bhatt and Srinivasa Rao, 2005). Bekele (2021) also reported that plant height of common bean was decreased due to moisture stress condition at the root zone which reduces leaf elongation and leaf expansion, and this reduced photosynthesis activity finally it reduce plant growth.

Table 5 Interaction effects of Common bean varieties and moisture level on plant height and branch number

Moisture Level	Varieties	Plant Height	Branch Number
W0	Haromaya	132.37^{b}	9.822^{b}
	Hirna	51.82^{d}	6.422^{d}
	Awash Malka	45.98^{d}	4.878^{e}
W1	Haromaya	202.98^{a}	11.533^{a}
	Hirna	84.92^{C}	8.744^{c}
	Awash Melka	58.90^{d}	6.456d
LSD(0.05)		16.75	0.3422
CV (%)		18.22	4.49

Where; F1=NPSBZn, F2= NPSBZnK, F0= Zero fertilizer; w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

Table 6 interactions effects of Fertilizer and moisture level on branch number of common bean varieties

	Moisture level	
Fertilizer level	W1	W0
F2	9.3222^{a}	7.9444^{c}
F1	9.0333^{a}	6.9889^{d}
F0	8.3778^{b}	6.1889^{e}
LSD (0.05)	0.3422	
CV (%)	4.49	

Where; F1=NPSBZn, F2= NPSBZnK, F0= Zero fertilizer; w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.1.3. Leaf number

The analysis of variance showed leaf number was highly significantly ($P < 0.01$) influenced by main effect of variety and moisture level (Appendix Table). All two way, three way and main effect of fertilizer were did not show significant influence on leaf number of common bean variety. Haromaya varieties gave the maximum mean value of leaf number. While, the minimum leaf number was recorded from Hirna and Awash Melka variety (Table 7). The higher leaf number of the Haromaya variety might be from the genetic make-up of the variety. This variety also showed higher plant height than other variety this also may be the reason for higher number of leaf than other variety. This result agree with the finding of Merga, (2020); who reported that the higher leaf number of common bean variety might be because of the genetic make-up of the variety and/ or due to the nature of the variety indeterminate type that makes it to climb and has longer in nature, and as a result of its length there were higher in leaf number per plant. A report by Yunusa *et al*. (2014) showed that reduction of leaf number is caused by decrease of leaf initiation and leaf area so that the activity of photosynthesis is also decreased.

Among the moisture level well-watered plots showed greater leaf number on common bean varieties than stress plants. This could be due to good water and nutrient absorption by the root and maximum physiological activity. According to Ghanbari *et al*. (2019) low moisture level reduces total number of leaves per plant and affect leaf angle and simultaneously influence on photosynthesis and transpiration. According to this author water stress increase leaf angle and it directly affects the flux of solar energy per unit leaf area and is thus an important factor in determining the maximum photosynthetic ability of a plant. Greater leaf angles decrease transpiration, and this leads to heat damage on leaf. In similar with this finding Boutraa *et al.* (2001) noted that low irrigation level reduces the total number of leaves per plant.

Table 7: Varietal and moisture level effect of common bean on leaf number

Varieties	Leaf number
Haromaya	14.31^{a}
Awash Melka	9.18^{b}
Hirna	8.72^{b}
LSD (0.05)	0.75
Moisture level	
W1	11.96^{a}
W0	9.52^{b}
LSD(0.05)	0.61
CV (%)	10.37

Where; w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.1.4. *Leaf fresh weight and leaf dry weight*

Leaf fresh weight and Leaf dry weight were highly significantly ($P<0.001$) influenced by the main effect of variety, fertilizer, moisture levels, and two-way interaction effect of moisture level and variety and fertilizer and moisture level but not significantly influenced by the interaction effect of variety and fertilizer level and three way interactions of variety fertilizer and moisture level (Appendix Table 1). The maximum leaf fresh weight was recorded from Hirna variety under well water condition, and the minimum leaf fresh weight was measured from Awash Melka varieties grown under water stressed condition. The highest leaf dry weight was also recorded from Hirna under well-watered condition; while the lowest leaf dry weight was obtained from Awash Melka variety combined with water stress (Table 8).This could be due to the genotype characteristics or growth habit and water availability in root zone. These results agree with the finding of Emam . (2010) that leaf fresh and dry weight increase with increasing of available water. These authors also indicated that variety had significant influence on fresh and dry biomass.

Varieties treated with NPSZnB+K and well-watered conditions produced highest leaf fresh weight and leaf dry weight than drought stress and no fertilizer treatment. Result indicated that application of K to blended fertilizer (NPSBZn) significantly increased fresh biomass both under drought stress and well watered condition (Table). This may be due to the positive role of K fertilizer. According to (Loha *et al.*, 2023) potassium promotes protein synthesis and cell division. It also has a role in the transport of nutrients, sugars, and water in the plant tissue. The amount of K^+ in the plant tissue controls a number of physiological activities, including the maintenance of turgor under stressful conditions, transpiration, the creation of high-energy molecules, and the translocation of assimilates and also it promotes the synthesis of protein, starch, and legume nitrogen fixation.

Table 8. Interaction effects of common bean varieties and moisture levels on Leaf fresh weight and leaf dry weight.

Moisture level	Varieties	Leaf fresh weight(g)	leaf dry weight(g)
W0	Haromaya	14.639^{d}	3.66^{d}
	Hirna	15.531^{d}	3.89^{d}
	Awash Melka	9.732^{e}	2.44^{e}
W1	Haromaya	21.941^{b}	5.49^{b}
	Hirna	26.310^{a}	6.45^{a}
	Awash Melka	17.962^{c}	4.49^{c}
LSD(0.05)		0.9204	0.28
CV (%)		5.44	6.73

Where; w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

Table 9. Interaction effects of moisture and fertilizer levels on Leaf fresh weight and leaf dry weight.

Moisture level	Fertilizer level	leaf fresh weight	leaf dry weight
W0	F0	10.13^{f}	2.53^{f}
	F1	11.88^{e}	2.97^{e}
	F2	17.89^{d}	4.48^{d}
W1	F0	19.81^{c}	4.83^{c}
	F1	22.58^{b}	5.64^{b}
	F2	23.83^{a}	5.96^{a}
LSD(0.05)		0.9204	0.28
CV (%)		5.44	6.73

Where; F0=zero fertilizer, F1=NPSZnB, F2=NPSZnB+K w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.2. Physiological parameter

4.2.1. Chlorophyll content and chlorophyll fluorescence

Chlorophyll content of common bean leaf (Chla, Chlb and total chlorophyll content) was significantly ($P < 0.01$) affected by main factors, two way and three way interaction of varieties, moisture levels and fertilizer but not the two way interaction of fertilizer and moisture in Tchl (Appendix Table 3). The result indicated that, the maximum leaf chlorophyll content (chl a and chl b) were recorded from Hirna and Haromaya varieties treated by NPSBZn+K and NPSBZn with well-watered condition followed by Awash Melka variety treated by NPSBZn+K and NPSBZn with well-watered condition, whereas the minimum was recorded from Awash Melka variety without fertilizer subjected to drought stress conditions (Table 10). The reduction in chlorophyll content might have resulted from leaves being damaged and turning yellowish due to drought stress. The chlorophyill content of all varieties reduced when subjected to drought stress than the well watered conditions but the reduction is high in Awash Melka variety than the other two. Additionally, Applications of NPSZnB+K and NPSZnB alone increased the chlorophyll content of the varieties under drought stress conditions than the one treated with no fertilizer.

In line with this result a research by Mathobo *et al*. (2017) stated that drought stress has a negative impact on chlorophyll content as it reduces the concentration of chlorophyll when the bean is subjected to water stress. Moreover a report by Chaves et al. (2009) and Lizana et al., (2006) stated that drought stress reduces leaf chlorophyll content. Chaves (2002) also reported that drought stress decreased the concentration of leaf chlorophyll content. As report by Rosales *et al*. (2012), indicated that when plants were subjected to terminal drought, a significant decrease occurred in the yield of common bean genotypes. Moreover, Shumi (2018) revealed that increasing of Sulphur level from nil to 40 kg ha^{-1} was found to increase the plant height, leaf area index, chlorophyll content and number of branches per plant of blackgram (*Vigna mungo*). According to Mathobo *et al* . (2017) the decrease in chlorophyll content is resulting from the damage to the chloroplasts caused by active oxygen. Drought stress leads to the production of reactive oxygen species (ROS) such as O_2- and H_2O_2, which lead to chlorophyll destruction.

An increased water stress cycle significantly reduces total chlorophyll contents in rice and supplementation of potassium fertilizer increased chlorophyll content significantly during water stress. If the rate of potassium increased from 80 to 160 kg K_2O ha^{-1} , the chlorophyll content become highest at all water stress treatments (5, 10, and 15) (Mohd Zain et al., 2014). The decrease in chlorophyll content with increased duration of stress was previously been reported by (Tuna *et al*., 2010). Drought stress caused a large decline in the chlorophyll a, chlorophyll b, and the total chlorophyll contents in different sunflower varieties (Manivannan, 2007b). A research by (Guerfel et al., 2009) showed that exposure of two olive cultivars to reduced irrigation led to lower Chl (a + b) contents. These reductions were 29 and 42% for Chemlali and Chetoui, respectively.

The mean value of Leaf chlorophyll fluorescence indicated that the maximum leaf chlorophyll florescence was recorded from Hirna and Haromaya varieties treated with NPSBZn+K and NPSBZn under well watered condition. But the minimum record was from Awash Melka variety treated with no fertilizer under drought stress conditions. Hirna and Haromaya varieties showed the highest value of chlorophyll fluorescence. But Awash Melka variety has minimum value of chlorophyll fluorescence efficiency in the drought stress condition (Table 10). This might be due to the genetic potential of the variety for the trait. The chlorophyll fluorescence of all varieties was significantly increased under the application of NPSBZn+K and NPSBZn fertilizers under drought stress conditions as compare to no fertilizer treatment. The chlorophyll fluorescence all varieties increased when treated with NPSBZn+K and NPSBZn than the control one.

In agreement with this result Kıymaz and Beyaz (2019) noted that drought stress adversely affect chlorophyll fluorescence in *P. vulgaris* L. The reduction in chlorophyll content might have resulted from decreasing in leaf area of cultivars by reason of drought stress. These results are in agreement with findings of Mafakheri *et al.* (2010) in chickpea and (Makbul et al., 2011)in soybean who reported that the reduction of chlorophyll fluorescence under drought stress.

(Mathobo *et al.*, 2017) and (Liu et al., 2012) also observed a decline in Fv/Fm ratio in drought stressed plants of two maize cultivars.

Table 10. Chlorophyll content and chlorophyll fluorescence of common bean varities as influenced by different blended fertilizer and soil moisture levels

Variety	Fertilizer with moisture level	Chl a (µg/ml)	Chl b (µg/ml)	Totalchl(µg/ml)	Chlorophyll fluorescence
Hirna	F2 W1	10.720^{a}	9.7033^{a}	20.423^{a}	0.8333^{a}
	F1 W1	10.517^{ab}	9.6200^{a}	20.14^{ab}	0.8137^{ab}
	F0 W1	9.900^{cd}	7.1867^{d}	17.087^{e}	0.7767^{cd}
	F2 W0	9.110^{e}	6.0800^{f}	15.19^{g}	0.7467^{d}
	F1 W0	8.450^{fg}	5.2900^{i}	13.740^{i}	0.7100^{e}
	F0 W0	7.367^{h}	4.6033^{k}	11.970^{k}	0.6503^{f}
Haromaya	F2 W1	10.617^{a}	9.6300^{a}	20.25^{ab}	0.8200^{ab}
	F1 W1	10.26^{abc}	9.6167^{a}	19.877^{b}	0.7933^{bc}
	F0 W1	9.703^{d}	8.3567^{c}	18.060^{d}	0.7667^{cd}
	F2 W0	8.813^{ef}	6.3400^{e}	15.153^{g}	0.7077^{e}
	F1 W0	8.783^{ef}	5.6900^{g}	14.473^{h}	0.6400^{fg}
	F0 W0	8.070^{g}	4.8967^{j}	12.967^{j}	0.6133^{g}
Awash Melka	F2 W1	10.057^{bcd}	8.8963^{b}	18.953^{c}	0.7967^{bc}
	F1 W1	9.987^{cd}	8.8700^{b}	18.857^{c}	0.7900^{bc}
	F0 W1	9.130^{e}	7.1467^{d}	16.277^{f}	0.7100^{e}
	F2 W0	8.677^{ef}	5.5500^{h}	14.23^{hi}	0.6833^{e}
	F1 W0	7.417^{h}	4.6533^{k}	12.070^{k}	0.5333^{h}
	F0 W0	6.620^{i}	3.5633^{l}	10.183^{l}	0.4673^{i}
LSD		0.5291	1.96	0.79	0.0312
CV (%)		3.50	0.5235	0.0911	2.64

Where; F0=zero fertilizer, F1=NPSZnB, F2=NPSZnB+K w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.2.2. Stomata anatomy

Analysis of variance showed that, stomata number, stomata width and stomata length was significantly ($p<0.05$) influenced by variety however, moisture stress, fertilizer and all the interaction effect did not show significant differences on stomata number, stomata width and stomata length (Appendix Table 4). Higher number, longer and wider stomata were observed from the Haromaya variety. Variety with higher density, longest and widest stomata seems to have the highest photosynthetic, proline content, transpiring and metabolic rate resulting in high production of dry matter. From this experiment minimum number, shortest stomata length and narrow stomata width were recorded from Awash Melka variety (Table 11). Stomata anatomy has a great influence on transpiration and photosynthetic rate, and it causes finally reduce growth of the whole plant (Belhadj *et al*., 2011). Dutra *et al*. (2015) reported that, in response to water deficit, plants reduce stomata opening. Stomata closure allows plants to limit transpiration; however, it may also limit CO_2 absorption, which leads to decreased photosynthetic activity (Yang *et al*., 2006). Furthermore, partial closing of the stomata is a known plant tolerance strategy to water stress, because it decreases the transpiration rate, preserves leaf water content, and reduces the risk of dehydration, and eventual death by desiccation (Peak *et al*., 2004). In addition to stomata closure, plants can also reduce stomata size in response to prolonged water lack and can alter their number, length, and width (Pirasteh *et al*., 2016)

Table 11: Effect of Varieties on stomata number, stomata width and stomata length

Varieties	Stomata number /mm^2	Stomata width(µm)	Stomata length(µm)
Haromaya	8.72^a	7.86^a	12.03^a
Hirna	7.38^b	5.11^b	10.63^b
Awash Melka	5.11^c	4.29^c	9.39^c
LSD (0.05)	0.86	0.57	0.74
CV (%)	18.05	14.68	10.19

Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of varianc

4.2.3. Proline

Proline was significantly ($P< 0.001$) impacted by the main, two and three way interactions of varieties, moisture, and fertilizer levels. Stressed plants fed with NPSBZn and NPSBZn+K fertilizer had the highest proline concentration. The smallest record was from well-watered plants that had no fertilizer treatment. Proline concentration was noticeably higher in water-stressed plants than in control plants, particularly in Hirna and Haromaya varieties (Table 12). In times of drought, Hirna and Haromaya may accumulate more proline, which may be an adaptation for drought tolerance that enables the crop to endure and continue producing. Moreover, the synthesis of proline for all Variety is increased when NPSBZn alone or in combination with potassium is applied in drought-stressed conditions.

It is commonly recognized that proline accumulation can protect plants from drought stress by reducing ROS and preserving osmotic equilibrium (Yang et al., 2019). According to Anjum (2011), the concentration of proline has been observed to be higher in stress-tolerant plants than in stress-sensitive plants, and the building of proline under stress has been connected to stress tolerance in many plant species. Proline accumulation under drought stress may contributes a protective role as scavenges of reactive oxygen species (ROS), resulted in improved adaptation ability and growth of plants under drought conditions (Türkan and Demiral, 2009). Accumulation of proline is an important indicator of drought stress tolerance in higher plants (Ashraf and Iram, 2005). Proline has been suggested as one of the possible means for overcoming osmotic stress caused by the loss of water (Caballero *et al.,* 2005).

Thus proline can be used as a metabolic marker in relation to stress. Plant tolerance to unfavorable conditions, particularly water deficit, has been associated with proline (a non-protein amino acid formed in the leaf tissues of plants exposed to water stress) accumulation (Saha *et al*, 2019). In similar manner with this study different authors reported that drought stress increased the accumulation of proline in groundnut varieties (Ranganayakulu, 2015) and in chickpea (Mafakheri *et al*., 2010). The increase in proline level may help to maintain osmotic potential of cytoplasm of cells which is important for survival of plants under stress (Saha *et al*., 2016). Accumulation of proline has been advocated as a parameter of selection for stress tolerance (Jaleel *et al*., 2007).

Table 12. Three-way interactions effect of variety, moisture and fertilizer level on proline content of common bean

Proline(μg.gm1FW)		Varieties	
Fertilizer with moisture level	Hirna	Haromaya	Awash Melka
F2W1	0.397^{i}	0.440^{g}	0.307^{k}
F1W1	0.373^{j}	0.417^{h}	0.293^{k}
F0W1	0.300^{k}	0.297^{k}	0.193^{l}
F2W0	0.877^{c}	0.917^{a}	0.587^{f}
F1W0	0.817^{d}	0.897^{b}	0.597^{f}
F0W0	0.687^{e}	0.807^{d}	0.360^{j}
CV (%)		2.17	
LSD (0.05)		0.019	

Where; F0=zero fertilizer, F1=NPSZnB, F2=NPSZnB+K w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.2.4. Relative water content

Common bean leaves' relative water content was significantly ($P< 0.05$) influenced by main effect of variety, moisture and fertilizer level and the two way interaction of variety with moisture level. The relative water content of leaves was not significantly ($P > 0.05$) impacted by the interaction effects of variety with fertilizer, fertilizer with moisture levels, and the three-way interaction variety, moisture and fertilizer level. Hirna and Haromaya varieties treated with NPSZnB+K and NPSZnB and subjected to well water conditions had the highest mean value. Whereas, Awash Melka variety grown under drought stress and treated with no fertilizer had the lowest mean value of relative water content (Table 13). The outcome demonstrated that common bean varieties under both drought and well-watered conditions have considerably varied leaf relative water contents. Under drought stress, the relative water content of all varieties decreased significantly. This result indicated that the Hirna and Haromaya varieties could withstand drought stress better than Awash Melka. This may be due to genetic potential of variety which reflects the ability of a plant to tolerate water stress and the height of relative water content in water stress condition indicates the ability of varieties to maintain the metabolism process so that it can survive (Amiri *et al*., 2017).

The finding also agrees with Anjum *et al*. (2011) finding that under conditions of high water stress, RWC is reduced, leading to stomatal closure to prevent further water loss through leaves. Similarly, Hossain *et al*. (2016) showed shoot and root water contents decreased under water stress condition. Similar research by Kumar *et al*. (2006) indicated that under the stress of a water deficit, RWC in bean leaves was reduced. Lack of water causes the plant to lose water, which alters the plant's water status and lowers stomatal conductance and transpiration (Ribas-Carbo, 2005). Potassium has greater role in the maintenance of water economy of plant by increasing relative water contents under water stress condition (Aslam et al., 2013).

Table 13: Interaction effect of moisture level and common bean varieties on relative water content

	Varieties		
Moisture level	Haromaya	Hirna	Awash Melika
W0	80.444^{c}	81.778B^{c}	74.333^{d}
W1	86.222^{a}	87.000^{a}	82.333^{b}
LSD (0.05)	1.5774		
CV (%)	2.01		

Where; w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance.

4.2.5. Photosynthetic rate (A) and Transpiration rate

Photosynthetic rate (A**)** is significantly (*P* < 0.05) affected by main, two ways and three way interactions of variety, moisture level and fertilizer level (Appendix Table 5). The highest photosynthesis rate was obtained from Hirna and Haromya varieties treated by NPSBZn+K with well watered condition followed by Hirna and Haromaya varieties treated by NPSBZn under well watered condition while the lowest mean value of photosynthesis rate was measured from Awash Melka grown without fertilizer and subjected to drought stress (Figure 1). Plants exposed to drought stress experienced a considerable reduction in photosynthesis rates across all varieties.

This finding shows that under drought stress, stomatal restrictions reduced photosynthetic rate, whereas the application of NPSBZn+K increased photosynthetic rate through improving stomatal conductance, relative water content, and leaf area of plants. Adding NPSBZn+K supplementation increased photosynthetic rate in comparison to no nutrient supply and to NPSBZn alone. Similarly (Aslam et al., 2013) showed that the application of potassium enhanced photosynthesis significantly as per treatment of potassium. Photosynthesis was reduced under drought stress in Maize hybrid but when the level of potassium increased maximum rate of photosynthesis was observed in higher levels of potassium (Aslam, 2013). According to (Mathobo *et al*., 2017) the photosynthetic rates results in serious reduction at any growth stage of dry bean under drought stress conditions. A report by (Farooq et al., 2017) stated that rate of photosynthesis is diminished due to drought stress in grain legumes. (Guerfel et al., 2009) reported that strong reduction of photosynthesis gas exchange (A) was recorded when treating two olive cultivars under drought stress conditions and the reduction is (64%) and (73%) in Chemlali and Che´toui cultivar respectively.

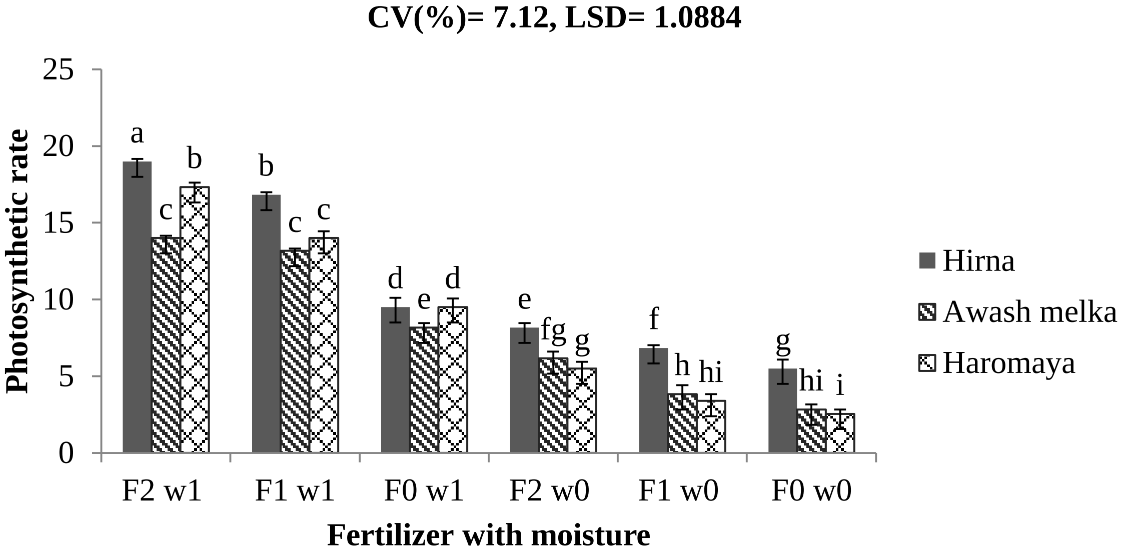

Figure 1 Mean value of photosynthesis rates of three common bean varieties as influenced by different blended fertilizer and soil moisture levels.

Transpiration rate was significantly ($P < 0.05$) affected by main, two way interaction effect of varieties and moisture, moisture with fertilizer, and three way interaction effect of variety, fertilizer and moisture levels. However, the interaction effect of variety and fertilizer didn't show significant effect on transpiration rate (Appendix Table 5). Among the tested varieties Hirna and Haromaya treated with NPSBZnK and NPSBZn, and subjected to well watered condition gave the highest transpiration rate, while the minimum was recorded from Awash Melka with NPSBZn and zero fertilizer level under drought stress (Figure 2). The varieties grown under water stress showed lower transpiration rates than those with an adequate water supply. This might be due to the varieties under drought stress conditions treated with NPSBZn and NPSBZn+K transpired more water than plants grown under moisture stress and no fertilizer.

In previous report by (Karim and Abdul, 2004) irrespective of the water stress levels, increasing potassium fertilizer rate from 75 kg K ha^{-1} to 112.5 kg K ha-1 increased transpiration. They also reported that under water stress conditions, the reduced transpiration rate of *Beta vulgaris* L. was due to the increase in the stomatal resistance as a result of the decrease in the water conductivity of roots. With the increase in the active uptake of K+ by the guard cells, the stomata might be opened due to the increase in cell turgor. Osmotic pressure in the guard cells increased due to the active influx of K+, which led to water uptake and to an increase in the turgidity of guard cells, and eventually to the opening of stomata. Another researcher also stated that under water-deficit conditions, K+ is pumped out from the guard cell, allowing the pores to close tightly. Thus, K controls the evapotranspiration (ET) of water through pores under a water deficit in the soil environment, and it protects the plant from water stress (Hasanuzzaman *et al.*, 2018).

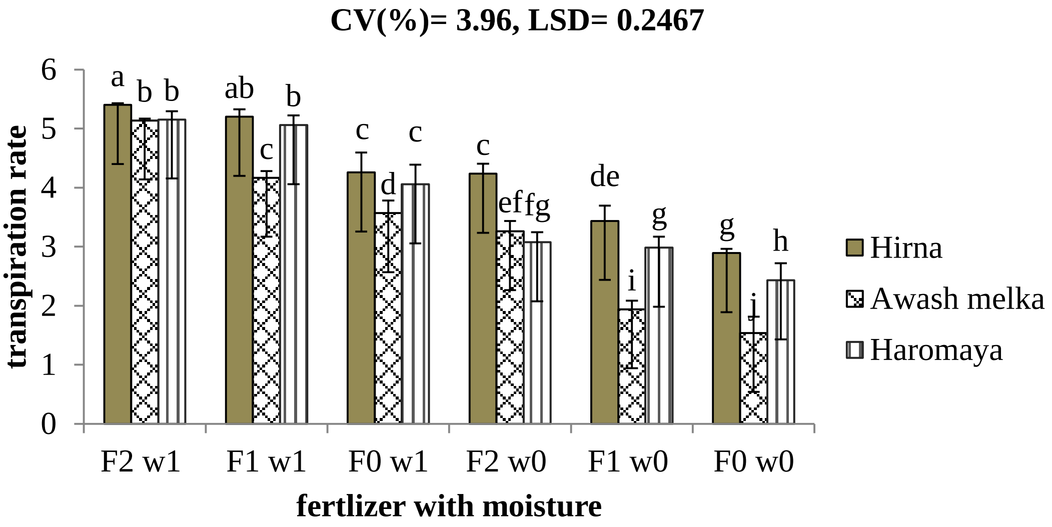

Figure 2: Mean value of transpiration rates of three common bean varieties as influenced by different blended fertilizer and soil moisture levels

4.2.6. Water use efficiency

Water use efficiency was significantly ($P < 0.05$) influenced by the main, two and three-way interaction effects of cultivar, fertilizer, and water level but not two way interactions of variety and fertilizer (Appendix Table 5). The highest water use efficiency was observed for all NPSBZnK and NPSZnB-treated cultivars under well-irrigated conditions, whereas the lowest average water use efficiency was observed for the Awash Melka cultivar with no fertilizer treatment and under drought stress conditions (figure 3). This indicates that the Hirna and Haromaya cultivars have higher water use efficiencies than Awash Melka variety, showing the highest under drought stress by reducing water loss from plant cells through transpiration of dry bean. Under drought stress condition application of NPSBZn and NPSBZn+K increased the water use efficiency for the varieties, but the value was much lower than the well watered plants. This shows that supplementation of NPSBZn and potassium to drought-stressed plants will increase the tolerance of common bean varieties by improving water use efficiency. This result is in agreement with

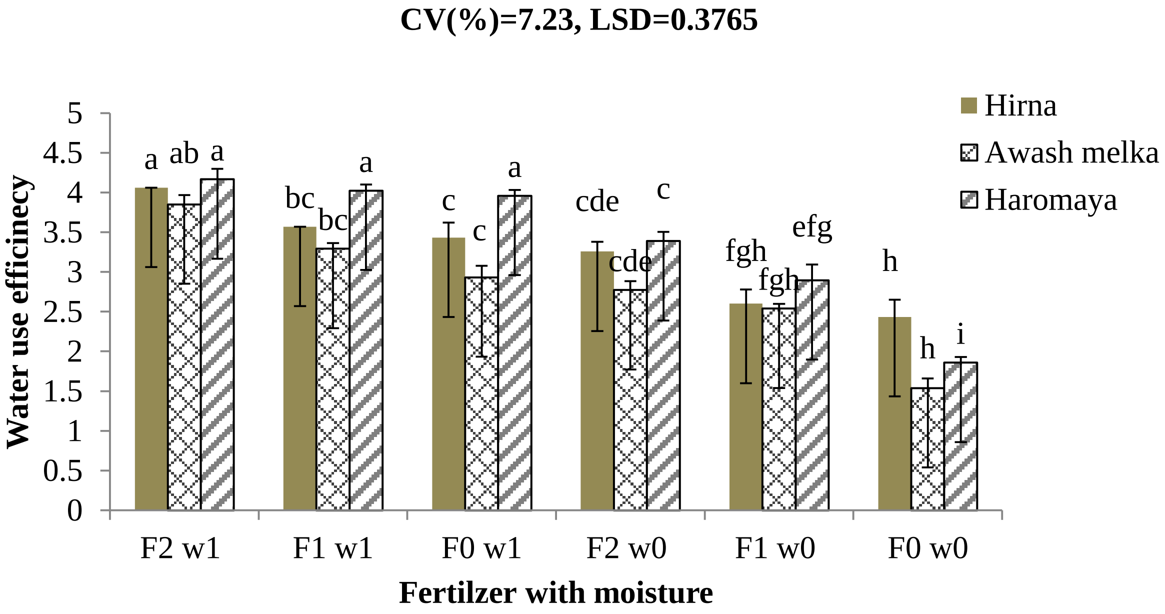

Figure 3: Mean value of water use efficiency of three common bean varieties as influenced by different blended fertilizer and soil moisture levels

4.2.7. *Stomatal conductance*

The analysis of variance showed that there is significant ($p<0.001$) difference in main, two and three way interactions of variety, fertilizer and moisture level (Appendix Table 5). The highest was recorded from Hirna variety under well watered conditions and treated in NPSBZnK but the minimum record was from Awash Melka under drought stress and treated with no fertilizer (Figure 4). This may be due to a reduction in the amount of moisture in the cell, which leads to turgor loss and stomatal closure. The function of Stomatal guard cells was regulated by the presence of K. When there is a water stress K^+ is pushed out of the guard cell, to close the pore and limit stomatal conductance(Loha et al., 2023). According to Mulatu (2023) stomatal conductance was affected by variety irrigated treatment water stress limit root hydraulic conductivity and finally reduce stomatal conductance by clothing stomata to save water.

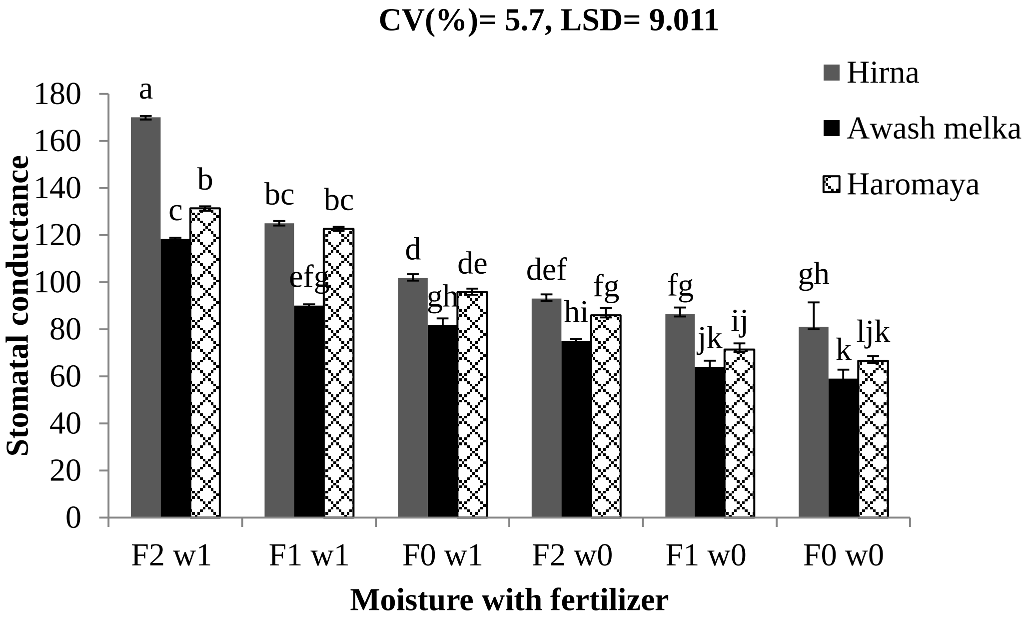

Figure 4: Mean value of stomata conductance of three common bean varities as influenced by different blended fertilizer and soil moisture levels

4.3. Yield and yield components

4.3.1. Pod and seed numbers per plant

Analysis of variance depicted that pod number per plant and seeds number per plant were highly significantly ($P < 0.01$) affected by the main factors and two ways interactions of variety and moisture level, but there is no significant difference in two-way interactions of variety with fertilizer and fertilizer with moisture and three way interaction of varieties, fertilizer and moisture levels (Appendix Table 2). The highest and minimum pod numbers per plant were recorded from Haromaya and Hirna varieties, respectively both under well watered and stressed condition. The minimum pod number per plant may be due to the variety response to water stress (Table 14). According to Darkwa (2016) genotype vary in stress tolerance. Water stress enhances flower abortion and may be this also the reason for minimum number of pod per plant in Hirna variety. This result also in line with (Parameters et al., 2022) who reported that variety and moisture level significantly influence on pod formation, pod development and seed yield of common bean.

In case of seed number per plant Awash Melka was showed the highest seed number under well watered condition; the variety also showed that higher seed number per plant under water stress condition with significant reduction. This result indicated that water stress reduce seed number which may be due to flower abortion and poor pod development during flowering stage or it might be caused by a decrease in photosynthetic assimilation and poor carbohydrate partitioning to the developing grain This result agree with Darkwa ., (2016), The reduction in seed yield and 100 seed weight associated with drought is thought to be caused by a decrease in photosynthetic assimilation and poor carbohydrate partitioning to the developing grain because of drought stress and there is strong association between photosynthetic assimilation and better remobilization of carbohydrates by drought-tolerant genotypes.

Table 14: Interaction effect of Moisture level and common bean varieties on pod number per plant and seed number per pod

Moisture Level	Varieties	Pod Number Per Plant(Count)	Seed Number Per Plant(Count)
W0	Haromayya	7.0211^{b}	8.89^{d}
	Hirna	3.5511^{d}	5.36^{e}
	Awash Melka	5.7122^{c}	9.80^{d}
W1	Haromayya	8.3667^{a}	17.06^{b}
	Hirna	6.0722^{c}	12.31^{c}
	Awash Melka	7.1267^{b}	23.04^{a}
LSD		0.5911	1.14
CV(%)		9.8	9.32

Where; w1=well watered W0=drought stressed Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.3.2. Grain yield

The analysis of variance showed that grain yield very highly significantly ($p<0.001$) affected by main and two way interactions of variety, moisture and fertilizer level but not three way interactions (Appendix Table 2). The highest yield was recorded from the variety Hirna followed by Haromaya variety treated with and without fertilizer whereas, the lowest yield was recorded from Awash Melka variety without fertilizer (Table 15). Hirna variety have large seed size but showed little number of pods and the greatest yield of these varieties could be due to their inherent genetic potential**.** Based on this experiment fertilizer increase grain yield in all variety. Blended fertilizer which contain K potentially improve grain yield than blended fertilizer alone. This may be due to the role of K in plant physiology especially in relation to stomatal conductance and photosynthesis.

Water stress also potentially reduced grain yield however the degree of reduction was varying among Varieties. The control growing condition had a positive effect on yield because control treatment showed that grater yield than stressed treatment (Table 15). Among the tested varieties, the lowest grain yield was recorded from Haromaya variety treated with water stress condition. In contrast, the highest grain yield was recorded from Hirna variety treated with well watered condition. Yield reduction under water stress condition could be due to reduction in photosynthesis efficiency. This result agreed with (Ohashi, 2006) who reported that water stress limit net photosynthesis , transpiration and other physiological process and resulted in grain yield reduction. According to Mideksa (2016) water stress reduced pod formation, seed setting and seed filling by affecting the source-sink relationships.

Moisture stress also responsible for flower abscission and embryo abortion (Bernier et al., 2007) limited and poor pod development especially water stress at flowering and pod filling periods reduced seed yield and seed weight (Szilagyi, 2003). Interaction effect of moisture level and fertilizer also affected grain yield. The Greatest grain yield was recorded from treatment which received blended fertilizer with K at both well watered and stress conditions. The minimum mean value was observed from zero fertilizer under water stress condition. This result indicated that fertilizer improved yield under stress condition which may be due to the role of minerals present in the fertilizer in the plant physiology. Our result indicated that blended fertilizer with K give greater yield than blended fertilizer without K and the control condition this may be due to the role of K in photosynthetic activity and translocation of photosynthetic product to sink part. According to (Loha et al., 2023) Potassium plays a vital role to control the transport of nutrients, sugars, and water in the plant tissue, and it controls a number of physiological activities, including the maintenance of turgor under stressful conditions, transpiration, the creation of high-energy molecules, and the translocation of assimilates. In addition Potassium is required for the activation of more than 80 plant enzymes. Based on this data the mean value of grain yield reduced from 6.5526 kg/ha to 2.9007 kg/ha under well-watered and water stressed condition, respectively in treatment which received NPSZn B + k this result indicated that the efficiency of fertilizer highly limited by moisture stress which may be due to poor nutrient uptake by root. the result confirmed the finding of (Do and Akinci, 2017) that nutrient uptake from the soil solution is closely linked to the plant root and soil water status.

Table15. Interaction effect of fertilizer and common bean varieties on grain yield

	Varieties		
fertilizer level	Hirna	Awash Melka	Haromaya
F2	5.3555^{a}	3.9100^{d}	4.9143^{b}
F1	4.780^{b}	3.7323^{de}	4.3350^{c}
F0	3.9333^{d}	3.2983^{f}	3.5967^{e}
LSD (0.05)	0.2901		
CV (%)	5.89		

Where; F0=zero fertilizer, F1=NPSZnB, F2=NPSZnB+K LSD (Least significance difference) comparison method CV=coefficient of variance

Table 16. Interaction effect of Varieties and moisture on grain yield of common bean

	Varieties		
Moisture level	Hirna	Awash Melka	Haromaya
W1	6.7370^{a}	5.2349^{c}	6.0878^{b}
W0	2.6422^{d}	2.4762^{d}	2.0589^{e}
LSD (0.05)	0.2369		
CV (%)	5.89		

Table 17. Interaction effect of moisture and fertilizer level on grain yield of common bean varities

	Fertilizer level		
moisture level	F2	F1	F0
W1	6.5526^{a}	6.3182^{a}	5.1889^{b}
W0	2.9007^{c}	2.2467^{d}	2.0300^{d}
LSD (0.05)	0.2369		
CV (%)	5.89		

Where; F0=zero fertilizer, F1=NPSZnB, F2=NPSZnB+K w1=well watered W0=drought LSD (Least significance difference) comparison method CV=coefficient of variance

4.3.3. Harvest index

The analysis of variance showed that harvest index was significantly (p<0.01) affected by main, two way and three way interactions of variety, moisture and fertilizer level (Appendix Table 2). The maximum mean value of harvest index was recorded from Hirna and Haromaya variety treated with NPSZnB+K and NPSZnB fertilizer under well watered conditions whereas, the minimum value was recorded from Awash Melka variety treated with no fertilizer and subjected to water stress (Table 18). Reduction in harvest index was observed because of moderate moisture stress in common beans (Kellman, 2008). Thus, traits of possible interest for improving crop tolerance to drought would include a high harvest index (Turner *et al*., 2003; Richards, 2006).

Table 17: Interaction effect of moisture levels, fertilizer levels and varieties on harvest index of common bean

HI	Varieties		
Fertilizer with moisture levels	Hirna	Awash Melka	Haromaya
F2 w1	71.333^{a}	66.333^{b}	70.000^{a}
F1 w1	70.333^{a}	65.667^{bc}	70.000^{a}
F0 w1	67.000^{b}	64.497^{cd}	65.667^{bc}
F2 w0	64.667^{cd}	60.220^{f}	63.667^{de}
F1 w0	62.433^{e}	56.833^{g}	60.000^{f}
F0 w0	62.333^{e}	51.667^{h}	56.000^{g}
CV (%)	1.57		
LSD (0.05)	1.6368		

Where; F0=zero fertilizer, F1=NPSZnB, F2=NPSZnB+K w1=well watered W0=drought Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

4.4. Correlation analysis

Correlation result of morphological, physiological and yield components of common bean varieties under different blended fertilizer and soil moisture level

There was significant and strong positive correlation with physiological and yield parameters except proline which had negative correlation with all parameters (Table 19). Leaf area showed a positive and strong correlation with leaf dry weight (r=0.93), leaf fresh weight (r=0.93), stomatal conductance (r=0.87). There was a positive and high magnitude correlation of photosynthetic rate with leaf area (r=0.94), chlorophyll content (r=0.93), leaf fresh weight (r=0.77), leaf dry weight (r=0.77).

The significant decrease in yield and yield components were associated with a significant decrease in photosynthetic rate. There was also observed that a positive and high strong correlation of photosynthetic rate with chla (r=0.87) .Transpiration rate also positively and significantly correlated with grain yield (r=0.87). The correlation analysis indicating that a significant decrease in yield and yield components were associated with decrease in transpiration rate, photosynthesis and water use efficiency. The correlations obtained indicated that the optimum yield is very much dependent on growth, morphology and physiological parameters, like leaf area, stomata conductance, water use efficiency, chlorophyll fluorescence and proline accumulation, those parameters are related well to yield and can therefore be used as drought screening tools.

Table19. Pearson Correlation coefficient(r) among physiological traits and yield components of common bean varieties influenced by different blended fertilizer and soil moisture levels.

	proline	RWC	gs	A	E	WUE	Chlb	Chla	Tchl	GY
proline	1									
RWC	-0.59	1.00								
gs	-0.51	0.85	1.00							
A	-0.72	0.78	0.77	1.00						
E	-0.57	0.66	0.79	0.76	1.00					
WUE	-0.35	0.22	0.03	0.34	-0.26	1.00				
Chlbb	-0.72	0.82	0.85	0.94	0.83	0.19	1.00			
Chlaa	-0.67	0.83	0.81	0.86	0.81	0.18	0.94	1.00		
Tchll	-0.71	0.84	0.85	0.93	0.84	0.19	0.99	0.97	1.00	
GY	-0.73	0.80	0.87	0.86	0.87	0.03	0.96	0.89	0.95	1.00

Where, Chl-a= Chlorophyll-a, Ch-b=Chlorophyll-b, Tchl = Chl (a+b), RWC=Leaf Relative water content, gs=Stomata conductance, A=Photosynthetic rate, E=Transpiration rate, WUE=Water use efficiency, GY= grain yield

Table 20. Pearson Correlation coefficient(r) among physiological traits and morphological parameters of common bean varieties influenced by different blended fertilizer and soil moisture levels.

	LN	LA	PH	LFW	LDW	BN	gs	A	E	WUE	Chlbb	Chlaa	Tchll
LN	1												
LA	0.34	1.00											
PH	0.85	0.33	1.00										
LFW	0.36	0.93	0.38	1.00									
LDW	0.36	0.93	0.37	0.99	1.00								
BN	0.83	0.55	0.89	0.63	0.62	1.00							
gs	0.28	0.87	0.30	0.90	0.89	0.50	1.00						
A	0.62	0.80	0.56	0.77	0.77	0.67	0.77	1.00					
E	0.15	0.81	0.05	0.78	0.77	0.23	0.79	0.76	1.00				
WUE	0.69	0.08	0.72	0.13	0.13	0.72	0.03	0.34	-0.26	1.00			
Chlbb	0.49	0.91	0.46	0.89	0.88	0.60	0.85	0.94	0.83	0.19	1.00		
Chlaa	0.43	0.91	0.41	0.91	0.90	0.63	0.81	0.86	0.81	0.18	0.94	1.00	
Tchll	0.48	0.92	0.45	0.91	0.90	0.62	0.85	0.93	0.84	0.19	0.99	0.97	1.00

Where, LN= Leaf number, La= Leaf area, PH= Plant height, LFW= Leaf fresh weight, LDW=Leaf dry weight, N= Branch umber, Chl-a= Chlorophyll-a, Ch-b=Chlorophyll-b, Tchl = Chl (a+b), RWC=Leaf Relative water content, gs=Stomata conductance, A=Photosynthetic rate, E=Transpiration rate, WUE=Water use efficiency, GY= grain yield.

Table 21. Pearson Correlation coefficient(r) among physiological traits of common bean varieties influenced by different blended fertilizer and soil moisture levels.

	proline	Fv/Fm	RWC	gs	A	E	WUE	Chlbb	Chlaa	Tchll
proline	1.00									
Fv	-0.60	1.00								
RWC	-0.59	0.65	1.00							
gs	-0.51	0.54	0.85	1.00						
A	-0.72	0.87	0.78	0.77	1.00					
E	-0.57	0.49	0.66	0.79	0.76	1.00				
WUE	-0.35	0.58	0.22	0.03	0.34	-0.26	1.00			
Chlbb	-0.72	0.74	0.82	0.85	0.94	0.83	0.19	1.00		
Chlaa	-0.67	0.73	0.83	0.81	0.86	0.81	0.18	0.94	1.00	
Tchll	-0.71	0.75	0.84	0.85	0.93	0.84	0.19	0.99	0.97	1.00

Where, Fv/Fm=Chlorophyll fluorescence, *Chl-a= Chlorophyll-a, Ch-b=Chlorophyll-b, Tchl = Chl (a+b), RWC=Leaf Relative water content, gs=Stomata conductance, A=Photosynthetic rate, E=Transpiration rate, WUE=Water use efficiency*

5. CONCLUSION AND RECOMMENDATIONS

Common bean *(Phaseolus vulgaris L.)* is the most important food legume crop for direct consumption in the world and is the most popular legume of the Americas and of Eastern and Southern Africa. It is growing in the tropics and subtropical region and has large coverage due to its low input agricultural systems, and as an export crops. There are biotic and abiotic stresses which cause a decrease in crop yield, being the water deficit and low soil nutrient are the most limiting factor in the world agricultural production. Therefore the study was conducted to investigate the effect of blended fertilizer on morpho physiology and yield of common bean varieties under different moisture level. Accordingly Hirna and Haromaya varieties were considered as tolerant as they were able to maintain their phenotypic plasticity and performed better yield compared to Awash Melka. Moreover Hirna and Haromaya varieties treated with NPSBZn+K produced the highest values for most physiological parameters under well-watered condition. In contrast, the lowest values were observed from Awash Melka variety with zero fertilizer application under drought stress conditions. In the drought stress conditions all the growth, physiological and yield parameters were significantly reduced as compared to the well-watered treatment in all varieties, however the reduction was high in Awash Melka variety compared with Hirna and Haromaya. The result revealed that Hirna and Haromaya have good performance under drought conditions than Awash Melka variety. Supplementation of K fertilizer to NPSZnB showed increment on yield than zero and NPSZnB alone.

The application of NPSBZn with K could reduce the oxidative damage in plants by increasing relative water content, stomata conductance, water use efficiency, proline, and carbohydrate content, and improve the drought tolerance abilities of common bean plants compared to plants grown with NPSBZn alone or without fertilizer. Compared to plants treated with NPSBZn fertilizer alone or without fertilizer, common bean cultivars treated with NPSBZn and potassium fertilizer demonstrated a higher capacity for drought tolerance.

It should be remembered that this study was limited to one season and was done in greenhouse. Therefore, more field-based research is required to ascertain the effects of moisture stress and blended fertilizer level on numerous common bean varieties before a broad conclusion can be made.

6. REFERENCE

Acosta-Gallegos, J.A., and J.W. White. 1995. Phenological plasticity as an adaptation by common bean to rainfed environments. Crop Sci. 35(1): 199–204. doi: 10.2135/cropsci1995.0011183X003500010037x.

Amiri, H., A. Ismaili, and S.R. Hosseinzadeh. 2017. Influence of Vermicompost Fertilizer and Water Deficit Stress on Morpho-Physiological Features of Chickpea (Cicer arietinum L. cv. karaj). Compost Sci. Util. 25(3): 152–165. doi: 10.1080/1065657X.2016.1249313.

Anjum, S.A., M. Farooq, L.C. Wang, L.L. Xue, S.G. Wang, et al. 2011. Gas exchange and chlorophyll synthesis of maize cultivars are enhanced by exogenously-applied glycinebetaine under drought conditions. Plant, Soil Environ. 57(7): 326–331. doi: 10.17221/41/2011-pse.

Ashraf, M., and A. Iram. 2005. Drought stress induced changes in some organic substances in nodules and other plant parts of two potential legumes differing in salt tolerance. Flora Morphol. Distrib. Funct. Ecol. Plants 200(6): 535–546. doi: 10.1016/j.flora.2005.06.005.

Aslam, M., M. Shahid, I. Zamir, I. Afzal, and M. Yaseen. 2013. Response of maize hybrids to K application under drought MORPHOLOGICAL AND PHYSIOLOGICAL RESPONSE OF MAIZE HYBRIDS TO POTASSIUM APPLICATION UNDER DROUGHT STRESS. J. Agric. Res 51(4): 51.

Bekele, Z.T. 2021. Response of Common Bean (Phaseolus Vulgaris L.) to Deficit Irrigation Under Alternative, Fixed and Conventional Furrow Irrigation Methods at Malkasa, Central Rift Valley of Ethiopia.

Bernier, J., A. Kumar, V. Ramaiah, D. Spaner, and G. Atlin. 2007. A Large-Eff ect QTL for Grain Yield under Reproductive-Stage Drought Stress in Upland Rice. Crop Sci. 47: 507–518. doi: 10.2135/cropsci2006.07.0495.

Broughton, W.J., G. Hernández, M. Blair, S. Beebe, P. Gepts, et al. 2003. Beans (Phaseolus spp.) – model food legumes. Plant Soil 252(1): 55–128. doi: 10.1023/A:1024146710611.

Chaves, M.M., J.S. Pereira, J. Maroco, M.L. Rodrigues, C.P.P. Ricardo, et al. 2002. How plants cope with water stress in the field. Photosynthesis and growth. Ann. Bot. 89(SPEC. ISS.): 907–916. doi: 10.1093/aob/mcf105.

Darkwa, K., D. Ambachew, H. Mohammed, A. Asfaw, and M.W. Blair. 2016. ScienceDirect Evaluation of common bean (Phaseolus vulgaris L .) genotypes for drought stress adaptation in Ethiopia. CJ 4(5): 367–376. doi: 10.1016/j.cj.2016.06.007.

Do, N., and Ş. Akinci. 2017. Effects of water stress on the uptake of nutrients by bean seedlings (phaseolus Effects of Water Stress on the Uptake of Nutrients by Bean Seedlings (Phaseolus vulgaris L .). 20.

Emam, Y., A. Shekoofa, F. Salehi, and A.H. Jalali. 2010. Water Stress Effects on Two Common Bean Cultivars with Contrasting Growth Habits. 9(5): 495–499.

Farooq, M., N. Gogoi, S. Barthakur, B. Baroowa, N. Bharadwaj, et al. 2017. Drought Stress in Grain Legumes during Reproduction and Grain Filling. J. Agron. Crop Sci. 203(2): 81–102. doi: 10.1111/jac.12169.

Ghanbari, A.A., M.R. Shakiba, and M. Toorchi. 2019. Morpho-physiological responses of common bean leaf to water deficit stress. 3(1): 487–492.

Gibberson, D.I., O. Joshua, B. Ato, O. Justice, and A.A. Paul. 2016. The Effect of Deficit Irrigation and Manure on Soil Properties , Growth and Yield of Orange Fleshed Sweet Potato [Ipomea Batatas Lam]. 3(7): 463–473. doi: 10.21276/sjavs.2016.3.7.4.

Guerfel, M., O. Baccouri, D. Boujnah, W. Chaïbi, and M. Zarrouk. 2009. Impacts of water stress on gas exchange, water relations, chlorophyll content and leaf structure in the two main Tunisian olive (Olea europaea L.) cultivars. Sci. Hortic. (Amsterdam). 119(3): 257–263. doi: 10.1016/j.scienta.2008.08.006.

Hasanuzzaman, M., M.H.M.B. Bhuyan, K. Nahar, A. Awal, C. Masud, et al. Potassium : A Vital Regulator of Plant Responses and Tolerance to Abiotic Stresses. doi: 10.3390/agronomy8030031.

Karim, A., and E. Abdul. 2004. Effect of Fertilizer Potassium on Growth , Yield and Water Relations of Bushbean (Phaseolus vulgaris L .) under Water Stress Conditions. 48(1): 1–9.

Kıymaz, S., and R. Beyaz. 2019. Morpho-physiological responses of common bean (Phaseolus vulgaris L.) cultivars to drought stress. Legum. Res. 42(4): 505–511. doi: 10.18805/LR-429.

Loha, G., M. Silas, and G. Gidago. 2023. Effect of Common Bean (Phaseolus vulgaris L .) Varieties and Variable Rates of Potassium Fertilizer on Yield and Yield-Related Traits at Areka , Southern Ethiopia.

M, L. 2012. Response of photosynthesis and chlorophyll fluorescence to drought stress in two maize cultivars. African J. Agric. Reseearch 7(34): 4751–4760. doi: 10.5897/ajar12.082.

Makbul, S., N. Saruhan Güler, N. Durmuş, and S. Güven. 2011. Changes in anatomical and physiological parameters of soybean under drought stress. Turk. J. Botany 35(4): 369–377.

doi: 10.3906/bot-1002-7.

Manivannan, P., C.A. Jaleel, B. Sankar, A. Kishorekumar, R. Somasundaram, et al. 2007. Growth, biochemical modifications and proline metabolism in Helianthus annuus L. as induced by drought stress. Colloids Surfaces B Biointerfaces 59(2): 141–149. doi: 10.1016/j.colsurfb.2007.05.002.

Mathobo, R., D. Marais, and J.M. Steyn. 2017. The effect of drought stress on yield, leaf gaseous exchange and chlorophyll fluorescence of dry beans (Phaseolus vulgaris L.). Agric. Water Manag. 180: 118–125. doi: 10.1016/j.agwat.2016.11.005.

Mekonnen, L., and J. Saliha. 2018. The Response of Common Bean (Phaseoluse Vulgaris L .) to Various Levels of Blended Fertilizer. 5(7): 15–20.

Merga, J.T. 2020. Evaluation of common bean varieties (Phaseolus vulgaris L .) to different row-spacing in Jimma , South Western Ethiopia. Heliyon 6(April). doi: 10.1016/j.heliyon.2020.e04822.

Mideksa, A. 2016. Evaluation of morphological aspects of common bean (Phaseolus vulgaris L .) genotypes for post-flowering drought resistance in Rift Valley of Ethiopia. African J. Agric. Res. 11(32): 3020–3026. doi: 10.5897/AJAR2015.10467.

Miklas, P.N., J.D. Kelly, S.E. Beebe, and M.W. Blair. 2006. Common bean breeding for resistance against biotic and abiotic stresses : From classical to MAS breeding. : 105–131. doi: 10.1007/s10681-006-4600-5.

Mohd Zain, N.A., M.R. Ismail, A. Puteh, M. Mahmood, and M.R. Islam. 2014. Drought Tolerance and Ion Accumulation of Rice Following Application of Additional Potassium

Fertilizer. Commun. Soil Sci. Plant Anal. 45(19): 2502–2514. doi: 10.1080/00103624.2014.932374.

Mulatu, M., A. Gedebo, A.G. Roro, and T.T. Geletu. 2023. Effect of Moisture Stress on Physiological and Yield Responses of Common Bean Varieties at Lath House Condition , Hawassa University , Southern Ethiopia. Int. J. Agron. 2023(9).

Ohashi, Y., N. Nakayama, H. Saneoka, and K. Fujita. 2006. Effects of drought stress on photosynthetic gas exchange , chlorophyll fluorescence and stem diameter of soybean plants. 50(1): 138–141.

Parameters, A., F. Papathanasiou, E. Ninou, I. Mylonas, D. Baxevanos, et al. 2022. The Evaluation of Common Bean (Phaseolus vulgaris L .) Genotypes under Water Stress Based on Physiological and.

Prasad, P.V. V, and S.A. Staggenborg. 2008. Impacts of Drought and/or Heat Stress on Physiological, Developmental, Growth, and Yield Processes of Crop Plants. Response Crop. to Ltd. Water Underst. Model. Water Stress Eff. Plant Growth Process. Adv. Agric. Syst. Model.: 301–355.

Ribas-Carbo, M., N.L. Taylor, L. Giles, S. Busquets, P.M. Finnegan, et al. 2005. Effects of water stress on respiration in soybean leaves. Plant Physiol. 139(1): 466–473. doi: 10.1104/pp.105.065565.

Saha, S., H.H. Begum, and S. Nasrin. 2019. Effects of Drought Stress on Growth and Accumulation of Proline in Five Rice Varieties (Oryza Sativa L.). J. Asiat. Soc. Bangladesh, Sci. 45(2): 241–247. doi: 10.3329/jasbs.v45i2.46597.

Shumi, D. 2018. Response of common bean (Phaseolus vulgaris L.) varieties to rates of blended NPS fertilizer in Adola district, Southern Ethiopia. African J. Plant Sci. 12(8): 164–179. doi: 10.5897/ajps2018.1671.

Szilagyi, L. 2003. Influence of drought on seed yield components in common bean. : 320–330.

Türkan, I., and T. Demiral. 2009. Recent developments in understanding salinity tolerance. Environ. Exp. Bot. 67(1): 2–9. doi: 10.1016/j.envexpbot.2009.05.008.

Yadav, S., P. Modi, A. Dave, A. Vijapura, D. Patel, et al. 2020. Effect of Abiotic Stress on Crops. Sustain. Crop Prod.: 1–21. doi: 10.5772/intechopen.88434.

Yang, J., G. Duan, C. Li, L. Liu, G. Han, et al. 2019. The Crosstalks Between Jasmonic Acid and Other Plant Hormone Signaling Highlight the Involvement of Jasmonic Acid as a Core Component in Plant Response to Biotic and Abiotic Stresses. Front. Plant Sci. 10(October): 1–12. doi: 10.3389/fpls.2019.01349.

7. APPENDICES

Appendix Table 1: Analysis of variance of branch number, leaf number, leaf area, leaf fresh weight and leaf dry weight of common beans varieties.

Source	**DF**	BN	LA	LFW	**LDW**	**LN**
variety	2	115.1***	552145.0***	230.1***	13.5***	173.3***
fertilize	2	8.2***	142416.0***	158.9***	10.8***	0.6ns
moisture	1	47.2**	4152795.0***	1038.4***	62.3***	80.5***
variety*fertilize	4	0.023ns	2199.0*	0.5ns	0.1ns	1.5ns
variety*moisture	2	0.7**	16668.0***	14.6***	0.6**	3.2ns
fertilize*moisture	2	0.8**	4365.0**	28.3***	1.7***	1.1ns
variety*fertilize*moisture	4	0.1ns	3283.0**	2.0ns	0.2ns	2.1ns
Error	36	0.1	689.0	0.9	0.1	1.2

*The sign ns, ** and *** indicates; non-significance different at (P>0.05), highly significant Difference at (p<0.01) and very highly significant difference at (P<0.001) respectively, DF=degree of freedom and CV= coefficient of variation*

Appendix Table 2: Analysis of variance plant height, pod number, seed number, harvest index and grain yield of common beans varieties.

Source	DF	PH	PN	SEN	HI	GY
variety	2	70179.2***	37.5***	259.8***	267.4***	5.0**
fertilize	2	236.2ns	8.6***	35.5***	100.3***	5.7**
moisture	1	20408.5***	41.8***	1205.9***	696.5***	177.6**
variety*fertilize	4	291.0ns	0.3ns	0.4ns	0.9ns	0.3**
variety*moisture	2	3856.0***	2.0**	50.1***	13.8***	1.0**
fertilize*moisture	2	235.0ns	1.2ns	1.3ns	19.4***	0.9**
variety*fertilize*moisture	4	153.9ns	0.6ns	1.4ns	1.2ns	0.1ns
Error	36	307.0	0.4	1.4	0.7	0.1

*The sign ns, ** and *** indicates; non-significance different at (P>0.05), highly significant Difference at (p<0.01) and very highly significant difference at (P<0.001) respectively, DF=degree of freedom and CV= coefficient of variation*

Appendix Table 3 Analysis of variance for chlorophyll a, chlorophyll b, total chlorophyll concentration, chlorophyll fluorescence of common bean varieties.

Source	**DF**	Chl A	Chl B	Tchl	FV/fv
variety	2	0.593**	82.102***	95.436***	0.039***
fertilize	2	6.417***	10.026***	32.054***	0.046***
moisture	1	52.087***	45.469***	195.282***	0.303***
variety*fertilize	4	0.437**	0.910***	1.826***	0.003***
variety*moisture	2	2.529***	3.126***	11.059***	0.011***
fertilize*moisture	2	0.577**	0.342***	0.059ns	0.007***
variety*fertilize*moisture	4	0.275*	0.107***	0.382**	0.002**
Error	36	0.099	0.005	0.086	0.000

*The sign ns, ** and *** indicates; non-significance different at (P>0.05), highly significant Difference at (p<0.01) and very highly significant difference at (P<0.001) respectively, DF=degree of freedom and CV= coefficient of variation*

Appendix table 4: Analysis of variance for, stomata number, stomata length and stomata width of common bean varieties.

Source	**DF**	SL	SW	**SN**
variety	2	31.2279***	62.6413***	60.0185***
fertilize	2	0.0552ns	0.0545ns	0.1296ns
moisture	1	0.0824ns	0.0313ns	1.1852ns
variety*fertilize	4	0.3608ns	0.0657ns	0.8519ns
variety*moisture	2	0.7426ns	0.2969ns	4.0185ns
fertilize*moisture	2	0.064ns	0.3889ns	0.3519ns
variety*fertilize*moisture	4	0.0763ns	0.0502ns	0.3519ns
Error	36	1.1865	0.713	1.6296

*The sign ns, ** and *** indicates; non-significance different at (P>0.05), highly significant Difference at (p<0.01) and very highly significant difference at (P<0.001) respectively, DF=degree of freedom and CV= coefficient of variation*

Appendix table 5 Analysis of variance of photosynthetic rate, transpiration rate, stomatal conductance, water use efficiency and relative leaf water content of common bean varieties.

Source	**DF**	Gs	WUE	A	E
variety	2	3570.4***	1.4634***	42.753***	4.2196***
fertilize	2	4486.9***	3.4989***	131.553***	7.0883***
moisture	1	20886***	16.5115***	981.419***	43.758***
variety*fertilize	4	133.5**	0.1148ns	1.721**	0.4551***
variety*moisture	2	267.7***	0.1966*	6.165***	0.4755***
fertilize*moisture	2	1090.4***	0.4826***	32.417***	0.1671**
variety*fertilize*moisture	4	268.2***	0.186*	2.117**	0.0604*
Error	36	29.6	0.0517	0.432	0.0222

*The sign ns, ** and *** indicates; non-significance different at (P>0.05), highly significant Difference at (p<0.01) and very highly significant difference at (P<0.001) respectively, DF=degree of freedom and CV= coefficient of variation*

SKETCH OF BIOGRAPHY

The author, Alem Sisay Sahile was born on May 08, 1995 G.C at North Shewa. He attended his primary (1-8), Yolat secondary (9-10) and preparatory (11-12) school at Bulga, secondary and preparatory school, respectively. After the completion of Ethiopian Higher Education Entrance Examination (EHEEE), he joined Addis Ababa University in 2015 to pursue his first Degree and graduated with BSc Degree in Horticulture in July 2017 G.C. After his graduation, he had been employed as a Graduate assistant at Wachemo University. After serving two year at Wachemo University, he has got a chance to attend his Master's program. In 2019, he joined the Graduate program in Horticulture at Hawassa University