



**RESPONSE OF WHEAT (*Triticum Aestivum* L.) YIELD AND YIELD  
COMPONENTS UNDER DIFFERENT MOISTURE STRESS  
LEVELS AT GEWANE WOREDRA, AFAR REGION, ETHIOPIA**

**MSc THESIS**

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**HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA**

**OCTOBER, 2021**

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LEVELS AT GEWANE WOREDA, AFAR REGION, ETHIOPIA**

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A THESIS SUBMITTED TO THE  
SCHOOL OF BIOSYSTEM AND WATER RESOURCES  
ENGINEERING, DEPARTMENT OF WATER RESOURCES AND  
IRRIGATION ENGINEERING  
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## **DEDICATION**

I dedicate this thesis manuscript to all my family members for nurturing me with care and love and for their dedicated partnership in the success of my life.

## **STATEMENT OF AUTHOR**

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## ABBREVIATION AND ACRONYMS

AFAP	Afar Forestry Action Program
Bd	Bulk density
CSA	Central Statistical Agency
CV	Coefficient of variation
CIMMYT	International Maize and Wheat Improvement Center
DAP	Di-ammonium phosphate
DF	Degree of freedom
DI	Deficit Irrigation
EARO	Ethiopian Agricultural Research Organization
EGTE	Ethiopian grain trade enterprise
EIAR	Ethiopia Institute of Agricultural Research
EMA	Ethiopia Metrological Agency
ET <sub>a</sub>	Actual evapotranspiration
ET <sub>c</sub>	Crop evapotranspiration
ET <sub>m</sub>	Maximum evapotranspiration
ET <sub>o</sub>	Reference evapotranspiration
FAO	Food and Agricultural Organization
FC	Field capacity
GIR	Gross Irrigation Requirement
IWMI	International Water Management Institute
ISRIC	International soil reference and information center
K <sub>c</sub>	Crop coefficient
K <sub>y</sub>	Yield response factor
LSD	Least significant difference
m.a.s.l	Meter above sea level
MOA	Ministry of agriculture
MoWIE	Ministry of Water, Irrigation and Energy
NI	Net income
NIR	Net Irrigation Requirement
Pe	Effective Rain fall
PH	Power of Hydrogen

PWP	Permanent Wilting point
Q	Discharge (l/sec)
RAW	Readily available water
RCBD	Randomized complete block design
SAS	Statistical analysis system
TAW	Total Available Water
USDA	United State Department of Agriculture
WARC	Werer Agricultural Research Center
WP	Water Productivity
WUE	Water Use Efficiency
Ya	Actual Yield
Ym	Maximum Yield

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## ABSTRACT

*Enhancing water productivity of irrigated crops through Agricultural water management practices is a vital option in water scarce areas. Field experiment was conducted at demonstration site of Gewane Agricultural Technical Vocational and Educational Training College located in Gewane woreda, Afar region, Ethiopia. The objective of this research was aimed to identify optimum moisture stress levels for wheat under moisture stress area of Gewane woreda. Ten deficit irrigation levels namely (45, 50, 55, 60, 65, 70, 75, 80, 85 and 90 %ETc) and the control (100%ETc) irrigation water application were used in whole growing season of wheat (*Triticum aestivum* L.). Adopted wheat variety Fentale -2 was used as testing crop and laid out in randomized complete block design with three replications. The daily climatic parameters used to estimate ETo were collected from Gewane meteorological station. Daily crop water requirement (ETc) was estimated by multiplying reference evapotranspiration with crop coefficient. Yield and yield components were collected and analyzed using SAS 9.0 statistical software. The analysis of variance showed that, the reduction of water application (moisture stress levels) had a highly significant ( $p < 0.01$ ) effect on growth parameters, yield and yield components except on the number of tillers per square meter and harvesting index as compared to the full irrigation (100%ETc). The result also showed that, the grain yield reduced as the stress levels increased, whereas water use efficiency was increased as the stress levels increased. The highest grain yield of 4472.2 kg/ha was obtained from full irrigation( 100%ETc) which had no significant difference with irrigation water application up to 70%ETc. Whereas the lowest grain yield of 3475.7 kg/ha was recorded from 45%ETc. In terms of water use efficiency, the highest and lowest water use efficiency of 1.32 and 0.82 kg/m<sup>3</sup> was obtained from 45 and 100%ETc respectively. Therefore, wheat could be irrigated at 70%ETc to improve water use efficiency without a significant grain yield reduction. Moreover, it could be irrigated at 45%ETc in area where water use efficiency is top priority with compromise of grain yield reduction by 22.28% as result of saved water to irrigate other crops.*

**Keywords:** Deficit irrigation, ETc, Grain yield, Semi-arid, Wheat, WUE

# 1. INTRODUCTION

## 1.1. Background

Water is a critical natural resource upon which all economic and social activities and ecosystem functions depend. It is a finite resource used in different sectors (agriculture, domestic and industry). Among this, agriculture is the main water-consuming sector in the world, which accounts 70% of all water resources withdrawn from rivers, aquifers, streams and lakes (FAO, 2011 and Pimentel *et al.*, 2004). The competition for both quantity and quality of water is highly increasing from time to time (Biswas, 1997). This is due to ever-increasing world population and the demand for additional water supply by industrial, municipal, and agricultural sectors exert a lot of pressure on renewable water resources (Valipour, 2014).

Agricultural sector plays a major role in poverty reduction for sub-Saharan African countries; almost half of its population currently remains under poverty line (World Bank, 2016). In Ethiopia more than 85% of the national growth domestic product of the country is derived from the agricultural sector. The success of sustained agricultural production majorly depends on availability of water. It is evident that, irrigation water has increased food security and enhanced living standards in many parts of the world (FAO, 2002b).

However, the increasing world population and the demand for additional water supply exert a high pressure on renewable water resources forcing the agricultural sector to use the available irrigation water efficiently in order to produce more food to meet the increasing demand (Andarzian *et al.*, 2011). Irrigation is an application of water to the soil for the purpose of supplying the moisture needed in the plant root-zone to prevent stress that may cause yield reduction and poor quality of harvest of crops (Reddy, 2010). Irrigation development in Ethiopia can be considered as a cornerstone of food security and poverty reduction tool as it has a power to stimulate economic growth and rural developments. Therefore, it is useful to transform the rain-fed agricultural system which depends on rainfall into the joint rain-fed and irrigation agricultural system (Hagos *et al.*, 2009).

On the other hand, Crop failure due to moisture stress in Ethiopia is a common experience especially in the moisture stress area of the country which caused by low and erratic rainfall distribution. Accordingly, the need to meet the growing demand for food will require increased crop production from less and less water (Gobena *et al.*, 2017). Thus, improving crop productivity represents a major challenge for agricultural water management and consequently sustainable crop production. Recently, emphasis has been placed on the concept of water use efficiency (WUE). Concept of WUE in agricultural production systems is focused on producing more food with less water resources. While the Water productivity mainly refers to the ratio between outputs derived from water use and the water input (Clement *et al.*, 2011).

According to Zwart and Bastiaansen (2004 ) for many crops water productivity increases under Deficit irrigation (DI), relative to its value under full irrigation. Therefore, in the context of improving water productivity, there is a growing interest in deficit irrigation. Deficit irrigation is an irrigation practice whereby water supply reduced below full crop-water requirements without significant loss of crop yield (FAO, 2002a).

A certain level of water stress is applied to the crops in deficit irrigation strategy either during specific growth stages or throughout the growing season, without significant yield reduction compared with the benefits achieved by diverting saved water to irrigate other crops (Fererres and Soriano, 2007). Crops less sensitive to stress such as maize, groundnut, wheat, sunflower, and sugar beet can adapt well to deficit irrigation practices provided good management practices can be secured (FAO, 2002a).

The target crop wheat (*Triticum aestivum* L.) is one of the vital food crops cultivated in more than 221 million hectares of land producing 728.9 million tonnes of food grains with a productivity of 3.6 ton/ha in the world (FAO, 2014). The production of wheat in Africa lays under 10-20% of its potential. Ethiopia is the second-largest wheat producer in Sub-Saharan Africa. As revealed by Eyob *et al.* (2015), Ethiopia is the major producer of wheat in eastern Africa accounting for over 70% of the total wheat area in the region. Although most of the wheat grown in Ethiopia is bread wheat, both bread and durum wheat are widely grown in the country constituting about 60% of bread wheat and the remaining 40% of durum wheat out of the total wheat production (CIMMYT, 2014).

In Ethiopia, wheat is majorly produced under rain-fed conditions predominantly by smallholder farmers and the major wheat-growing areas are the highland parts. In arid and semi-arid areas, the moisture stress is the major limiting factors for cultivation of wheat. However, as stated by Shao *et al.*, (2011) wheat successfully grown with reduced irrigation in different part of the world where scarcity of water resources for irrigation is common. Now a day, the early maturing wheat varieties which able to perform better in lowland areas are available. Particularly in Afar region varieties likes, Gambo, Fentale and Lucy are well adopted by the Werer agricultural research center.

Increasing the production of such crops is important to feed the population through improved agricultural practice like improving agronomic practices, better yielding varieties and irrigation activities. In semi- arid with limited water resources and increasing demand for water combined with high evapotranspiration rates limits the production and productivity of the crop. Hence, alternatives need to be explored for effective and efficient use of the existing water resources (Enchalew *et al.*, 2016). There is a growing interest in irrigating with different stress levels to improve water use efficiency. Depending on crop sensitivity the different crops responses differently for water stress. Therefore, this study was intended to determine the response of wheat (*Triticum aestivum* L.) yield and yield components under different moisture stress levels.

## **1.2. Statement of the Problem**

Water is one of the major important factors for crop production provided that other essential requirements such as climate, soil and nutrient are adequate. Water stress is the most significant abiotic factor limiting plant and also crop growth and development (Khalili *et al.*, 2013). Most climate change methods have predicted an increase in the aridity in many areas of the globe due to change in environmental conditions. Hence, the interest in the research on plant responses to shortage of water is gaining considerable ground (Ashraf *et al.*, 2010). In Ethiopia, moisture stress is a frequently occurring phenomenon. Rainfall do not meets the timely required amount of water application for plant growth except in some highland parts. This is majorly due to spatial and temporal variation of rainfall.

Particularly in semi- arid with limited water resources and increasing demand for water combined with high evapotranspiration rates limits the production and productivity of the

crop. Hence, alternatives need to be explored for effective and efficient use of the existing water resources (Enchalew *et al.*, 2016).

In semi-arid of Ethiopia, including the Gewane woreda, traditional surface irrigation are widely used although there exist acute water shortage and drought is frequent, availability of rainfall do not meets the timely required amount of water for plant growth. In such areas where moisture stress is common in crop production, drought leads to major socioeconomic problems like food insecurity, poverty and low quality of life. No enough effort is being made to improve socioeconomic condition of farming community with locally available water resources. Therefore, there must be appropriate technologies for improving the socioeconomic condition of farming community with locally available water resources. In this regards, innovation targeted at optimizing the yield and water use efficiency have to be developed.

When water resources are scarce, deficit irrigation is one way of maximizing water use efficiency (Bekele and Tilahun, 2007). Deficit irrigation is an alternative way which save scarce water but, there has not been a study made to use surface irrigation in conjunction with moisture stress throughout growth stage of Wheat under moisture stress area of Gewane woreda. Therefore, considering the scarcity of irrigation water in the district and the sensitivity of wheat crop to less amount of moisture, this study was conducted to evaluate the response of wheat yield and yield components under different moisture stress levels with less amount of water application during the entire growing season using furrow irrigation.

### **1.3. Objective of the Study**

#### **1.3.1. General objective**

The general objective of this study was to identify optimum moisture stress levels for wheat under moisture stress area of Gewane.

#### **1.3.2. Specific objectives**

- To determine seasonal water demand of wheat under moisture stress and non-stressed condition

- To evaluate the effect of moisture stress levels on yield, yield components and water use efficiency
- To determine moisture stress threshold level of wheat crop

#### **1.4. Research Questions**

- What were the seasonal water demand of wheat under moisture stress and non-stressed condition?
- What were the effect of moisture stress levels on yield, yield components and water use efficiency?
- At what moisture stress level the threshold level of wheat crop could be obtained?

#### **1.5. Significance of the Study**

Understanding of deficit irrigation technologies was crucial in designing future research and development strategies. This study were helps policy makers to develop evidence based future research, extension, and development programs aimed at benefiting smallholder farmers. Policy makers were benefit from the research output, since they require micro-level information to formulate policies and strategies so that their effort would be appropriate in meeting smallholder farmers' need in particular and to bring change in agricultural sector, in general. Therefore, this study was generated information on diverse set of issues related to response of wheat yield and yield components under different moisture stress levels at Gewane district.

#### **1.6. Scope and Limitation of the Study**

This study was conducted at Gewane ATVET College demonstration site. The study was conceptually focused on response of wheat yield and yield components under different moisture stress levels. The emphasis was to identify optimum moisture stress levels for wheat under moisture stress area. Adapted variety Fentale-2 used as testing crop and the irrigation water application was carried out by lowering irrigation water application up to 45%ETc. Awash River was used as source of irrigation and furrow irrigation was used to irrigate the wheat. Due to financial and time constraint this study was limited to one cropping season and only one variety as testing crop.

## **2. LITERATURE REVIEW**

### **2.1. Importance of Irrigated Agriculture**

Irrigation has an important role to play in contributing to food security and poverty alleviation. Of the 1,500 million hectares of global cropland, only about 250 million hectares (17 %) are irrigated, despite this 17 percent irrigated agriculture provides about 40% of world food production (FAO, 2000). More than 40% of annual food production comes from irrigated land, and Agriculture is the largest consumer of water, around 70% of all freshwater withdrawals worldwide (FAO, 2007).

As water scarcity becomes more acute in many parts of the world, increasing the effectiveness with which agricultural water resources are used is a priority for increasing food security. FAO (2012) revealed that the world population is predicted to grow beyond 7.5 billion and food demand to increase by 50% by 2030. Beside this, climate change will impact the extent and productivity of both irrigated and rain-fed agriculture across the globe, increasing crop water demand and decreasing crop productivity in many regions.

A significant problem for agriculture is to provide the world's growing population with a sustainable and secure supply of sufficient, safe, nutritious food that meets dietary needs and food preferences for an active and healthy life. This will probably be done using less farmland and reduced quantities of water (FAO, 2002b). Agricultural water productivity must be improved unless otherwise increasing global food security will be impossible if agricultural water-resource utilization is not sustainable (Biswas, 2008).

Agriculture in Ethiopia is mainly rely on rain fed which is becoming risky practice due to highly erratic and uneven distribution of rainfall in most area of the country both temporarily and spatially. Failure of a given seasonal rain leads to severe drought and widespread food insecurity. Even in good years, Ethiopia cannot meet its large food deficit through rain fed production (USAID, 2009).

Therefore, rapidly declining of natural resource base, growing population pressure and rainfall variability have secured irrigated agriculture a prominent position on the country's development agenda (Sisay *et al.*, 2011).

## **2.2. Irrigation Agriculture in Ethiopia**

Water is the most vital and versatile natural resource, and has always played a role in Ethiopian society as it is an input to almost all production system (MoWR, 2006). It is also considered as an essential resource for irrigation. Irrigation is an application of water to the soil for the purpose of supplying the moisture needed in the plant root-zone to prevent stress that may cause yield reduction and poor quality of harvest of crops (Reddy, 2010). Irrigation agriculture is vital to the reliable and sustainable agricultural developments in Ethiopia. Subsistence dominated smallholder farmers' economy can be improved through the use of irrigation in the Ethiopian agriculture (MoA, 2011b).

According to Hagos *et al.* (2009) irrigation development in Ethiopia can be considered as a cornerstone of food security and poverty reduction tool as it has a power to stimulate economic growth and rural developments. Beside this the benefits of irrigation includes; increase food production in arid and semi-arid regions, enhances food production, promotes economic growth and sustainable development, create employment opportunities, and improve living conditions of small-scale farmers (Nata *et al.*, 2011).

However, as mentioned by MoA (2011a) the main challenges for the irrigation agriculture in Ethiopia are inadequate awareness of irrigation water management such as irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities, inadequate knowledge on improved and diversified irrigation agronomic practices. In Ethiopia irrigation efficiencies are generally low, of the order of 25 to 50%, and problems with rising water tables and soil salinization are now emerging (EARO, 2002). Therefore, increasing water use efficiency in irrigation may be the most appropriate way of preserving our valuable water resources.

The annual renewable fresh surface water resources of Ethiopia amount to some 125 billion m<sup>3</sup> in the twelve river basins (Seleshi, 2010). However, almost 97% of this is lost as runoff to lowlands of neighboring countries leaving the rest 3% in the country. Moreover, there is no surface water enters to the country from neighboring countries (FAO, 2013b). As reported by MoWIE (2014) the preliminary estimated amount of annual groundwater recharge of the country is about 28 billion m<sup>3</sup>.

Even though, Ethiopia is blessed with ample water resources in central, western and south western parts; most of north eastern and eastern parts of the country are relatively dry. In these parts of the country, the distribution and availability of water is erratic both in space and time. Therefore, optimizing water allocation in order to generate the maximum economic benefit from this limited resource becomes desirable (Seleshi *et al.*, 2005).

Particularly utilization of resource for the development of irrigation potential in pastoralist areas requires innovations, as it poses significant changes related to pastoralists' traditional lifestyles such as sedentary farming, voluntary settlement from degraded highlands, and small to largescale commercial agriculture (Seleshi, 2010). To improve the food security of the country, the government of Ethiopia gives more emphasis for small-scale irrigation development activities involving farmers in different phases (Seleshi *et al.*, 2007). This demonstrates that there are plans of ongoing irrigation-based development activities for accelerated and sustained development to end poverty in the country.

### **2.3. Wheat Production**

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops produced worldwide with larger area of cultivation than any other crop covering 221million hectares of land and producing 728.9 million tonnes of food grain with average productivity of 3.6 ton/ha in the world (FAO, 2014). It is also one of the major cereal crops grown in Ethiopia, which ranks the country in first place followed by Sudan and Kenya in East Africa and second place from sub-Saharan Africa after South Africa (FAO, 2015). Wheat is the largest deficit item in the developing country food basket. Between years 1970 to 2010, more than half of the increment in wheat consumption was met by increased wheat imports, and several countries became totally dependent on imports for wheat FAO (2013a). The wheat consumption in Sub-Saharan African countries has also become increased.

In Ethiopia, wheat is mainly grown in the highlands, which lie between 6 and 16° N latitude and 35 and 42° E longitude, at altitudes ranging from 1500 to 2800 m above sea level and with mean minimum temperatures of 6 to 11°C (MoA, 2012).

Among cereals, wheat is the fourth most important crop in area coverage following teff, maize and sorghum holding 13.25% out of the total grain crops cultivation area.

Moreover, in amount of production volume, next to maize, teff and sorghum, wheat is the higher production volume from cereals production in the country with total production of 3,434,706 tons, which accounts around 14.85% from the total grain production during 2012/2013 production season (CSA, 2013). There are two types of wheat grown in Ethiopia and both of them are produced under rain fed conditions: durum (pasta and macaroni) wheat, accounting for 40% of production, bread wheat, accounting for the remaining 60% and the yield and production of wheat is increasing from time to time (Eyob *et al.*, 2015).

In Ethiopia due to improvements in seed supply, greater fertilizer applications and increase in extension support, wheat production is slightly increasing. However, during 2012/13 marketing year, 984,000 metric tons of wheat imported from India, USA and Italy. On the other hand, during 2013/14 marketing year, the Ethiopia Grain Trade Enterprise (EGTE), the government owned enterprise that controls all commercial wheat imports, planned to import 400,000 metric tons of wheat (Abu and Teddy, 2014). According to Mihratu *et al.* (2017) about 1.0 million tons of wheat is being imported annually since 2008 in Ethiopia at the cost of 500 million US dollars. Lately, Ethiopia imported 1.7 million tonnes of wheat (EIAR, 2020).

According to CSA (2016) Wheat cultivated area and production during 2015/16 cropping season was about 1.66 million ha and 4.2 million tons, respectively, with productivity of 2.53 t ha<sup>-1</sup>. But, wheat yield in Ethiopia is low as compared to the attainable yield of 5 t ha<sup>-1</sup> (MoA, 2012).

Wheat production can be scaled up by developing short duration, heat and stress tolerant varieties under lowland areas (< 1500 m). Studies conducted at Werer Agricultural Research Centre of the Ethiopian Institute of Agricultural Research had indicated that wheat grain yield of above 40.0 q/ ha could be obtained in lowland irrigated areas (Jemal, 1994).

#### **2.4. Water Scarcity in Crop Production**

Water scarcity has a huge impact on food production. Without water people do not have a means of watering their crops. Water scarcity is among the major problems that are challenging many societies in different part of the world (Pereira *et al.*, 2009). In some places, water is abundant, but getting it to people is difficult because of lack of

infrastructure, restricted access, political and socio-cultural issues. On the other places, people's demands go beyond what the natural resource base can handle, and not everyone is assured access to water (IWMI, 2007).

Therefore, water scarcities are often classified as physical and economical water scarcity. The physical water scarcity occurs when there is not enough water resource is available to meet all the demand from all sectors where as economic water scarcity is caused due to a lacks of investment in water, human capacity, institutional, and financial capital limit, access to water even though water in nature is available locally to meet human demands (IWMI, 2007).

In Ethiopia, water scarcity is majorly associates with economic considerations. Hence, despite abundance in some parts, the country is highly water-scarce due to lack of water control infrastructure (Seleshi *et al.*, 2007). However, high population pressures drive the country to water scarcity. According to CSA (2014) the population of the country is estimated to 87,952,000 in 2014. This shows that the per capital share of annual renewable fresh water is 1,421 m<sup>3</sup> per capital per year. As revealed by Pereira *et al.* (2009) the country to be between the thresholds of 2,000m<sup>3</sup> and 1000m<sup>3</sup> per capita per year, which is classified water stressed and water scarce area.

The major water source for crop production in Ethiopia is rainfall. However, the trend of rainfall amount is decreasing and the distribution is erratic especially in arid and semi-arid areas of the country. Due to moisture stress during growing season, yield reduction is common in the country as the rainfall is erratic (Woldeamlak, 2009).

## **2.5. Effect of Moisture Stress and Tolerance Mechanism**

Water stress at any stage can reduce wheat yield. Crops are different in their response to water stress at a given growth stage. Different crops have different water requirements and respond differently to water stress. Crop sensitivity to water stress varies from one growth stage to another (Al-Kaisi and Broner, 2010). There is a large variation of the total growing period not only between crops but also within one crop type. In general, it can be assumed that the growing period for a certain crop is longer when the climate is cool and shorter when the climate is warm (FAO, 1998).

Precipitation and minimum temperature are key determinants for selection of wheat growing area with minimum rainfall of 350 mm and minimum temperature between 6 to 11°C during the wettest quarter (White *et al.*, 2001). The mechanisms of crop resistance to water stress are numerous and vary according to the nature of physiological and morphological processes and characteristics involved (Pereira *et al.*, 2009). Drought tolerance level varies based on types of crops. Crops like wheat, maize, cowpea and apple possess isohydric feature in which message is delivered from roots to leaves to lower their water vapor loss through stomata by their partial closure (Gupta, 2002).

Similarly, with tolerance level of different crops, different varieties of the same crops respond differently. There is a significant difference among wheat genotypes resistance for moisture stress in which some dwarf varieties are particularly developed for moisture stressed lowland areas. Moreover, moisture stress affect yield and yield component differently when the stress occur at different growth stages in which the reproductive stage is more sensitive for wheat (Sokoto and Singh, 2013).

In regions facing water shortage, deficit irrigation method can be on appropriate management option to enhance the productivity of water under irrigated wheat condition (Mohammad and Hossein, 2012). Genotypes not only performed differently but also responded variably to water stress conditions; hence, some being more tolerant than the others are at various growth stages. Therefore, Selection of appropriate genotypes is important for water-limited environments to enhance the yield and water productivity of wheat (Li *et al.*, 2011).

Drought is one of the most important phenomena, which limit crop production and yield. In response to drought, different crops demonstrate various morphological, physiological, biochemical, and molecular responses to tackle drought stress. Different vegetative and reproductive growth stages of crops are affected due to stress. Drought tolerance is a complicated trait, which is controlled by different genes, and their expressions are influenced by various environmental conditions. Several genes control moisture stress tolerance in wheat. These genes produce different types of enzymes and proteins like late embryogenesis abundant, responsive abscisic acid,

rubisco, helicase, proline, glutathione- S-transferase and carbohydrates (Nezhadahmadi *et al.*, 2013).

In response to moisture stress wheat physiological responses include closure of stomata, decrease in the activity of photosynthesis, development of oxidative stress, alteration in the integrity of cell wall, production of metabolites, which are toxic and cause plants' death. However, Different wheat genotypes responses differently to moisture stress classifying varieties in to tolerant, susceptible and semi-tolerant (Safoora *et al.*, 2013).

## **2.6. Deficit Irrigation**

The deficit irrigation is an irrigation practice where by water supply is reduced below maximum level and mild stress is allowed, during non-sensitive growth stage or throughout the growing season, without significant yield reduction (Geerts and Raes, 2009). As stated by Igbadun *et al.* (2008) deficit irrigation is a scheduling method where irrigation is purposefully supplied below fully crop water requirements and the plants are forced to extract soil moisture beyond the readily available water in the plant root zone. The main approach in deficit irrigation is to save water, labor and energy, by eliminating those irrigations with minimal effects on yield (Aguilar *et al.*, 2007).

In this method, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season without necessarily causing significant yield reduction compared with the benefits achieved by diverting saved water to irrigate other crops (Leskovar, 2010). As reported by Ali *et al.* (2007) any yield reduction will be compensated by increased production from the additional irrigated area with the water saved by deficit irrigation.

Experiments confirm that deficit irrigation can increase water use efficiency without severe yield reductions. For example for winter wheat in Turkey, planned DI increased yields by 65% as compared to winter wheat under rain fed cultivation, and had double the water use efficiency as compared to rain fed and fully irrigated winter wheat (Ilbeyi *et al.*, 2006). Therefore, deficit irrigation is beneficial for the farmers because it reduces the cost of water and prevents a loss of crop yield (for certain crops) later on in the growing season due to drought.

### **2.6.1. Deficit Irrigation Management**

Deficit irrigation practices differ from traditional water supplying methods. The manager needs to know the level of transpiration deficiency allowable without significant reduction in crop yields. The main goal of deficit irrigation is to increase the water use efficiency of a crop by eliminating irrigations that have little impact on yield. The resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional irrigation practices (Feres and Soriano, 2007).

In order to ensure successful deficit irrigation, it is necessary to consider the water retention capacity of the soil. In sandy soils, plants may undergo water stress quickly under deficit irrigation, whereas plants in deep soils of fine texture may have ample time to adjust to low soil water matric pressure, and may remain unaffected by low soil water content. Therefore, success with deficit irrigation is more probable in finely textured soils (FAO, 2002a).

Under deficit irrigation practices, agronomic practices may require modification, e.g. decrease plant population, apply less fertilizer, adopt flexible planting dates, and select shorter-season varieties. Therefore, before implementing a deficit irrigation program, it is necessary to know crop yield responses to water stress, either during defined growth stages or throughout the whole season (Kirda and Kanber, 1999).

### **2.6.2. Crop response to water deficit**

Stomata of plant leaf close when the leaf potential declines below a threshold value. This is a manifestation of the development of plant water deficit. Stomata closure can cause marked but indirect effects on cell metabolism; changes in CO<sub>2</sub> influx, water loss, leaf temperature, and solute transport within the plant (Zhang *et al.*, 1990).

Shreds of evidences demonstrate that the stomata regulation process works through a chemical signal; the increased concentration of Abscisic acid (ABA), in the xylem flow from roots to shoots controlling transpiration. The reduction of evapotranspiration to decrease crop water requirement or reducing irrigation requirement has been a long-standing goal in arid and semi-arid regions. In this regard, much of the research work has been directed toward modifying canopy resistance through the use of chemical, anti-transparent. Several of the suggested chemicals, however, are toxic to plants and animals.

In some cases, the reduction of transpiration is accompanied by a reduction in photosynthesis; the water use efficiency of the plant is, therefore, unaffected (Zhang *et al.*, 2002).

The early release of Abscisic acid (ABA) into the apoplast appears sufficient for rapid stomatal closure. Furthermore, there is evidence that ABA produced by roots in drying soil moves up through the stem and accumulates at or near guard cells with the concomitant decrease in leaf conductance (Davies and Zhang, 1987). Stomata control the opening of plant gas exchange and transpiration water loss. Recent investigations have shown that stomata may directly respond to the level of available water in the soil by regulating their size of openings (Davies, 1991).

### **2.6.3. Crop yield Response to Deficit Irrigation**

A deficiency in the full water requirement (or water stress) leads to lower crop yields. The effect of this deficiency on yield is estimated by relating the relative yield decrease to the relative evapotranspiration deficit through a yield response factor (Doorenbos and Kassam, 1979). When water deficit occurs during a specific crop development period, the yield response can vary depending on crop sensitivity at that growth stage. Therefore, timing the water deficit appropriately is a tool for scheduling irrigation where a limited supply of water is available (FAO, 2002a).

The approach and the calculation procedures for estimating yield response to water were published in the FAO Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979) which was considered one of FAO's milestone publications, and were used worldwide for a broad range of applications. Yield response is differ majorly depending on the stage the water stress occurs. Typically flowering and yield formation stages are sensitive to water stress, while stress occurring during the ripening phases has a limited impact, as in the vegetative phase, provided the crop is able to recover from stress in subsequent stages (FAO, 2012).

According to FAO (2002a), yield response factor of different crops and different stress condition varies from 0.20 for tolerant crops to 1.15 for sensitive crops. For example Crops such as cotton, maize, wheat, sunflower, sugar beet and potato are well suited for deficit irrigation applied either throughout the growing season or at pre-determined growth stages. As reported by FAO (2002a) reducing irrigation water

during practicing deficit irrigation in wheat at flowering and grain filling resulted a yield response factor of 0.39 and 0.76, respectively. On the other hands any significant decrease in soil water storage has an impact on water availability for a crop and, subsequently, on actual yield and actual evapotranspiration. As revealed by Elias *et al.* (2017) yield response factor for wheat crop during the whole growing season varies from 0.23 to 0.58, which indicates lower yield response factor associated with lower stressed treatments and higher values associated with highly stressed treatments.

#### **2.6.4. Wheat response to deficit irrigation**

The sensitivity of plant growth stage to water deficit can be affected by many factors, such as climatic conditions, crop species and cultivars, and agronomic management practices. For example, under a Mediterranean climate, the most sensitive growth stage of wheat (*Triticum aestivum*) is at stem elongation and booting, followed by anthesis and grain filling (Garcia Del Moral *et al.*, 2003). In North China Plains, wheat plants respond to water deficit more sensitively post-tillering than in the early stage. With a plant species, genotypes differ in photosynthesis rate, stomatal conductance, and transpiration rate, thus, expressing different degrees of responses to water stress (Hongbo *et al.*, 2005).

The increase in plant height due to increase in irrigation water level might be due to better availability of soil moisture that may enhance the vegetative growth of plants by increasing cell division and elongation. On the other hands, when plants respond to water stress by closing their stomata to slow down water loss by transpiration, gas exchange within the leaf is limited, as a result, photosynthesis and growth will slow down (Curah and Proctor, 1990).

The study conducted on response of wheat water stress under different growth stage in Amibara woreda, Afar, Ethiopia revealed that, growth, yield and yield components of wheat had significance difference as reported by (Jemal *et al.*, 2019). While the study conducted at Melkassa, indicated practicing deficit irrigation on wheat under whole growing season of wheat showed that, effective tillers and harvesting index had no significance difference under different stress levels. Whereas on plant height, spike length, number of kernel per spike, above ground biomass and grain yield highly significant difference were observed among the treatments (Elias *et al.*, 2017). Moreover, water use efficiency improved as moisture stress level increased.

## 2.7. Crop Water Requirement

The term crop water requirement is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field. As reported by (Allen *et al.*, 1998) the crop water requirements refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ET<sub>o</sub>) and the effect of crop characteristics (K<sub>c</sub>) are important (Doorenbos and Pruitt, 1977).

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

Based on the comparative studies of the reference evapotranspiration methods and recommendations of a panel of experts and researchers organized in FAO, Rome, in 1990, the Penman Monteith equation has been adopted as the globally best performing method of estimating evapotranspiration (Smith *et al.*, 1991). On the other hand, the calculation can be done using CROPWAT model and the reference evapotranspiration (ET<sub>o</sub>) is calculated based on the FAO Penman-Monteith method (Allen *et al.*, 1998). This equation uses standard climatologically records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water.

As stated by Doorenbos and Pruitt (1977) when reference evapotranspiration is adopted, transforming ET<sub>o</sub> into the crop evapotranspiration (ET<sub>c</sub>) requires the use of crop coefficients (k<sub>c</sub>). Various crop growth stages and their respective lengths are identified for the locations of interest, and then K<sub>c</sub> for the various stages of the crop is determined. K<sub>c</sub> values are then adjusted for frequency of wetting condition for rain or irrigation. For spring wheat crop coefficient (k<sub>c</sub>) ranges: 0.3- 0.4, during the initial stage, 0.7-0.8 at development stage, 1.05-1.2 at mid-season stage, 0.65-0.75 at late-season stage and 0.2-0.25 at harvest as reported on FAO 33 irrigation and drainage paper by (Doorenbos and

Kassam, 1979). The first number indicates area under high humidity and low wind. While the second number is indicated low humidity and strong wind. Crop water requirement is then calculated for well-watered conditions for each period of interest as the product of  $ET_o$  and  $K_c$ .

Having  $ET_c$  and all necessary meteorological data, crop water requirement can compete with the aid of CROPWAT program. The gross water requirement will be then computed assuming 60% of application efficiency as suggested by FAO (1989). For high yield, Wheat water requirement ( $ET_m$ ) are 450 to 650mm depending on climate and length of growing period as reported by (Doorenbos and Kassam, 1979).

## **2.8. Irrigation Scheduling**

The irrigation scheduling is the process of determining how much water to apply per irrigation, when to irrigate, how often and how long to irrigate the crop (Aslam *et al.*, 2014). It is also the process involved in deciding on the right time and the right amount of water a crop needs in order to maximize yield, quality and minimize water and nutrient leaching (Sammis *et al.*, 2012; Carr and Knox, 2011). As stated by Waskom (1994) proper irrigation scheduling is based on timely measurements or estimations of soil moisture content and crop water needs, is one of the most important best management practices for irrigation management.

Irrigation scheduling involves making a decision on how much and when to apply water. However, as reported by Mohamed and Makki (2005) water needs by the crop evapotranspiration, water availability, and water holding capacity of the soil are influence the decision.

The accurate determination of an irrigation schedule is a time-consuming and complicated process. The introduction of computer programs, however, has made it easier and it is possible to schedule the irrigation water supply exactly according to the water needs of the crops. Ideally, at the beginning of the growing season, the amount of water given per irrigation application, also called the irrigation depth, is small and given frequently because of the low evapotranspiration of the young plants and their shallow root depth. During the mid-season, the irrigation depth should be larger and given less

frequently because of high evapotranspiration and maximum root depth (Brouwer and Prins 1989).

Under conditions when maximum evapotranspiration is about 5 to 6 mm per day water uptake of the crop is little affected at soil water depletion of less than 50% of the total available soil water ( $p = 0.5$ ). Moderate water stress to the crop occurs at depletion levels of 70 to 80 % and severe stress occurs at levels exceeding 80 % (Doorenbos and Kassam, 1979).

## **2.9. Water Use Efficiency**

Water Use Efficiency is expressed as the crop dry matter or yield production per unit of water used by the plant (Gregory, 1988). In simplest terms water use efficiency is defined as the crop yield per unit of water use, while at a more biological level it is the amount of carbohydrate formed through photosynthesis per unit of transpiration (Howell, 2001). Approaches to dealing with water scarcity include efforts to improve crop water use efficiency (WUE) by changing irrigation methods (furrow, drip, and sprinkler), applied amounts (deficit irrigation), crops variety, tillage practices, and other management methods (Nazirbay *et al.*, 2007).

Increasing the amount of water used by the plant or increasing the growth and yield of the plant can change water use efficiency. Soil management practices like, tillage and residue management, and plant nutrient practices like, addition of nitrogen and phosphorous have a positive impact on water use efficiency (Stewart *et al.*, 1981; Jones, 1980).

On the other hands, the agronomic definition of water use efficiency involves two major terms: a biological component also called transpiration efficiency, which specifies the amount of dry matter produced per unit of water transpired, and a management component, which specifies the fraction of the total water supply used for transpiration. Hence, water use efficiency is usually a seasonal value defined as yield in an area per water used to produce the yield. The yield is frequently expressed as grain yield. However, in many dry land areas, the straw has an economic value that of the grain because it is used to sustain livestock. In dry land agriculture, yield is expressed as the total shoot mass (Gregory, 1988; Gregory *et al.*, 1984).

## **2.10. Experimental Design**

Experiment is the study of the effect of changes in the treatment on the response variable controlling other factors constant. Response variable is the variable whose change we wish to study. Whereas independent variable (factor) is the variable whose effect on the response variable we wish to study. In agriculture the most commonly used designs are RCBD, CRD, split plot, strip plot and lattice designs.

### **2.10.1. Randomized Complete Block Design**

Randomized complete block design is the standard design for agricultural experiment where similar experimental units are grouped into blocks or replicates. It is one of the most widely used experimental design in agricultural research. The design is especially suited for field experiment where the number of treatment is not large and the experimental area has a predictable productivity gradient. The primary distinguishing feature of the randomized complete block design is the presence of blocks of equal size, each of which contains all the treatments. The field or space is divided into uniform units to account for any variation so that observed differences are largely due to true differences between treatments (Gomez and Gomez, 1984).

### **2.10.2. Blocking Technique**

The primary purpose of blocking is to reduce experimental error by eliminating the contribution of known sources of variation among experimental units. This done by grouping the experimental units into blocks such that variability within each block is minimized and variability among blocks is maximized. Because only the variation within a block becomes part of the experimental error, blocking is most effective when the experimental area has a predictable pattern of variability. There are three sources of variability in RCBD. Those are treatment, replication and experimental error (Gomez and Gomez, 1984). The advantages of RCBD are more precise than the completely randomized design (CRD), no restriction on the number of treatments or replicates, some treatments may be replicated more times than others and missing plots are easily estimated (Clewley and Scarisbrick, 2001).

### 3. MATERIALS AND METHODS

#### 3.1. Description of the Study Area

##### 3.1.1. Location

The experiment was conducted at demonstration site of Gewane Agricultural Technical Vocational and Educational Training College. The demonstration site is located in Gewane woreda, Afar region. The experiment was undertaken from December 2019 to March 2020. The area is located at about 350 km and 135km Northeast from Addis Ababa and Awash 7 kilo respectively. As indicated in Fig.3.1, geographically the site is located between 9°59'0"N to 10°2'0" N latitude and 40°33'30"E to 40°38'0" E longitude at mean altitude of 572 m.a.s.l.

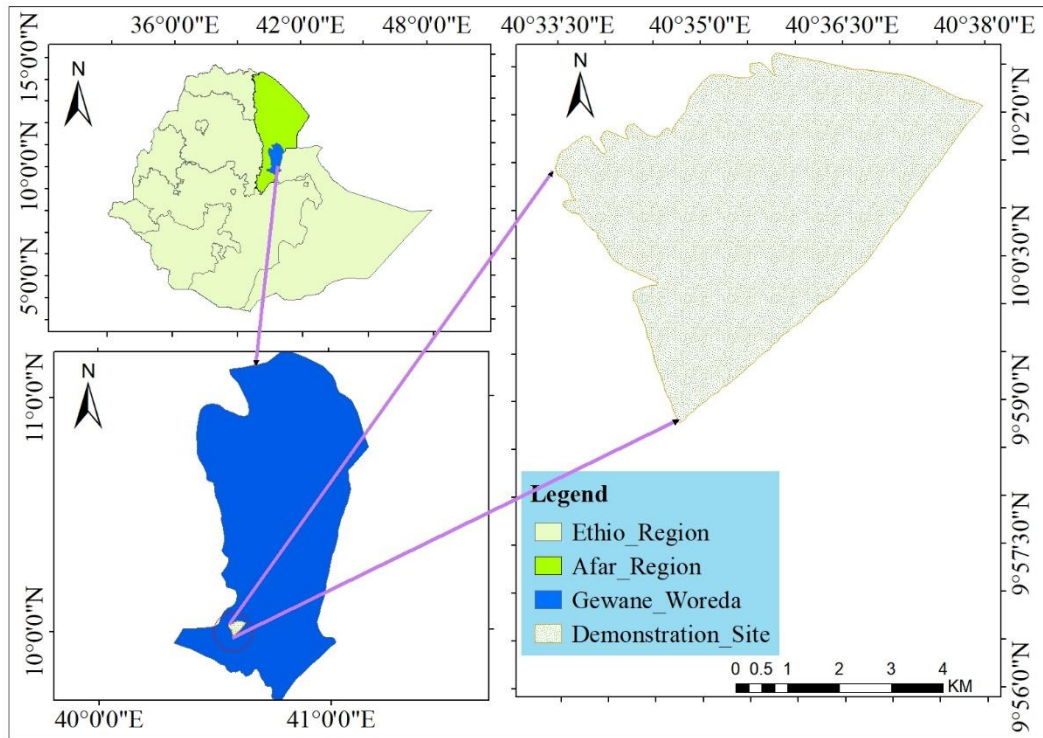


Figure 3.1. Map of study area

##### 3.1.2. Climate condition

The EMA (2015) reported that, the average annual rain fall of the area is 400mm. According to the long term (1995-2018) climatic data record of Gewane meteorological station, the average annual rainfall recorded for 24 years was around 409mm. The rainfall pattern is characterized by inter- and intra-annual variations. The mean maximum and minimum monthly rainfall values are 95.5 mm and 8.5 mm occurs in the month of August

and December, respectively. More than 56.7% of the rain occurs from July to September, with July and August are the main rainy season followed by March and April as shown in (Figure 3.2). The mean annual temperature is 29.56 °C with mean minimum and maximum temperature of 21.93 °C and 37.19 °C respectively. For more information the long term climate data presented in (Appendix Table 1).

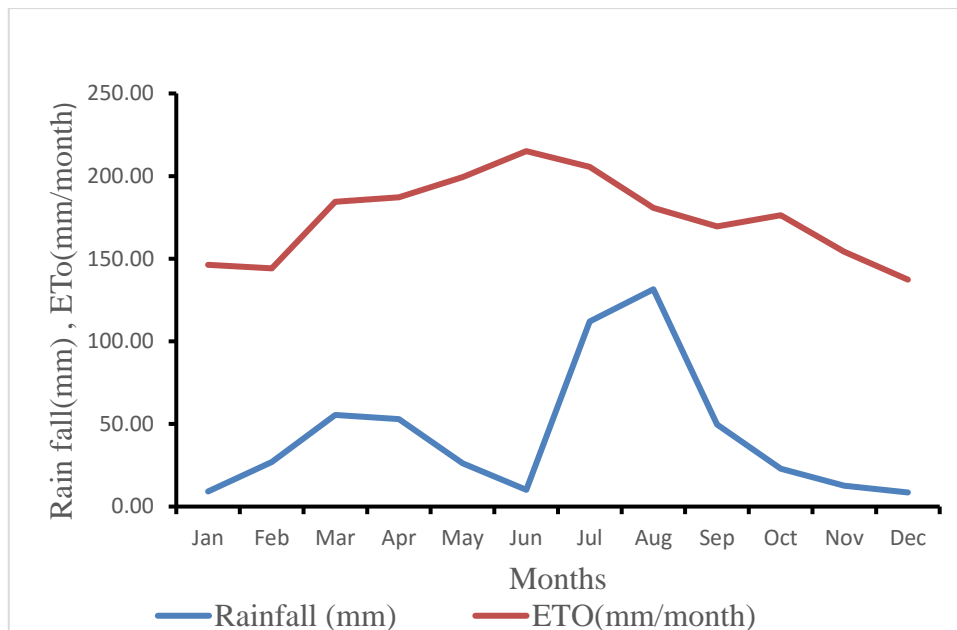


Figure 3.2. Long term rainfall and ETo of the study area (1995-2018)

### 3.1.3. Farming System

The major land uses of the area were pastoral and agro-pastoral farming system. The land use and land cover of the study area includes invaded land by prosopis juliflora, range land, bare land and cultivated land. Agricultural crops such as: - cotton, sesame maize, onion, tomato and watermelon are mainly characterizing the land use pattern of the study area (Fantahun, 2019). Currently wheat production also becomes apparent and crop production is mainly dependent on irrigation.

### 3.1.4. Soil condition

The area is found in the flood plain of the Awash River and the main geo-morphological unit of the experimental area is alluvial which resulted from the Awash River basin (Yirgalem, 2001). The soil of experimental site is mainly Fluvisols followed by Vertisols occupying about 30% of the total area (Wondimu, 2009). The Fluvisols are coarser in

texture than Vertisols and their textural classes range between clay and silt loams. The soils are brown in color and turn to dark brown when moist. Mostly, the wide-spread occurrence of salinity and sodicity problem in irrigated area of Gewane woreda is mainly due to weathering of Na, Ca, Mg and K rich igneous rocks and poor irrigation water management. The recent study indicated that the salt affected soils were mostly clayey to silt clay loam in both soil types, slightly alkaline to moderately alkaline (7.53 to 8.45) and low in organic matter with high soluble salt. According to Wondimu (2009) there is deficiency of micronutrient like Fe, Zn and Mn which needs neutralizing of the soil reaction (pH) and for minimizing toxicity effect of B and Mo.

### **3.2. Soil Sampling and Analysis**

Before sowing the wheat, composite soil samples was taken randomly along the diagonal of the experimental site at depths of 0 -30cm, 30-60cm and 60-90 cm. The soil was taken in regular depth because of soil in experimental field has uniform profile. The soil samples was collected, air-dried on the ground, mixed, and passed through 2 mm sieve and was analyzed for different physical and chemical properties according to international soil reference and information center guidelines (ISRIC, 2002). The collected samples were taken to Werer Agricultural Research Center for determination of soil texture, bulk density, initial soil moisture contents, pH and organic matter. While moisture contents at field capacity (FC) and permanent wilting point (PWP) was determined at Oromia Water Works Enterprise Soil laboratory.

**Soil texture** was determined by the Boycouos hydrometer method for analyzing soil particle size distribution (Bouyoucos, 1962) and the textural class was determined using USDA textural triangle following the procedure indicated by Day (1965).

**Bulk density:** Undisturbed soil sample of known volume was taken using core-sampler from three representative places in the trial plot at three different depths. The sampled soil was oven dried at 105<sup>0C</sup> for 24 hours to a constant weight and weighed to determine the dry weight of the soil. Then, the bulk density was calculated as provided in Eq. 3.1 (Hillel, 2004).

$$Bd = \frac{Ms}{Vs} \quad (3.1)$$

Where,  $B_d$  is bulk density ( $\text{g/cm}^3$ ),  $M_s$  is dry weight of the soil (g) and  $V_s$  is volume of the soil in the core ( $\text{cm}^3$ ).

**Field capacity and permanent wilting point:** The collected samples were taken to Oromia Water Works Enterprise Soil laboratory. The moisture content at field capacity and permanent wilting point were determined after sample are saturated for one day and extracting water from the saturated soil using the pressure plate and pressure membrane apparatus at 1/3 and 15 bars, respectively. Then, the total available water (TAW) in mm of the experimental field was determined following Eq. (3.2) and as given in Allen *et al.* (1998).

$$\text{TAW} = \left( \frac{(\text{FC} - \text{PWP}) * B_d * \text{RD}}{100} \right) * \frac{1}{p_w} \quad (3.2)$$

Where: TAW is total available water (mm per RD), FC is field capacity (% wt) , PWP is permanent wilting point (% wt.),  $B_d$  is Bulk density ( $\text{g/cm}^3$ ), RD is effective root depth of crop (mm) and  $p_w$  density of water ( $\text{g/cm}^3$ ).

**pH measurement:** The soil pH was determined by measuring soil solution of 1:2.5 ratios (soil to water) using a standard glass electrode pH meter (Rhoades, 1982) and Electrical conductivity of the soil (ECe) was determined using electrical conductivity meter (EC meter).

**Organic matter:** Titration method, which is oxidation under standardized condition with potassium dichromate in sulphuric acid, was followed for organic carbon determination. Then, conversion of organic carbon to organic matter was done by multiplying the percentage of organic carbon by 1.724 as described by (Nelson and Sommers, 1996).

**Water sampling and analysis:** The sample of one litter of water was taken from the water source at a representative sampling point using sampling bottle and taken to Werer soil Laboratory for electrical conductivity of water (ECw), pH and sodium absorption ratio (SAR) determination. The sodium absorption ratio was determined from the relative concentrations of sodium, magnesium, and calcium.

### 3.3. Experimental Treatment and Design

The treatment comprised of ten irrigation levels namely 45, 50, 55,60,65,70,75,80,85 and 90%ETc and the control (100%ETc). The treatments were assigned in each plot and laid out in randomized complete block design with three replications following the design procedure for RCBD by Gomez and Gomez (1984). The treatment description is given in Table 3.1 and the lay-out of experimental field is provided in Fig. 3.3.

Table 3.1. Treatment and Treatment Designation

Treatment numbers	Irrigation levels	Moisture stress levels
T1	100%ETc	No stress
T2	90%ETc	10 % moisture stress
T3	85%ETc	15 % moisture stress
T4	80%ETc	20 % moisture stress
T5	75%ETc	25 % moisture stress
T6	70%ETc	30 % moisture stress
T7	65%ETc	35 % moisture stress
T8	60%ETc	40 % moisture stress
T9	55%ETc	45 % moisture stress
T10	50%ETc	50 % moisture stress
T11	45%ETc	55 % moisture stress

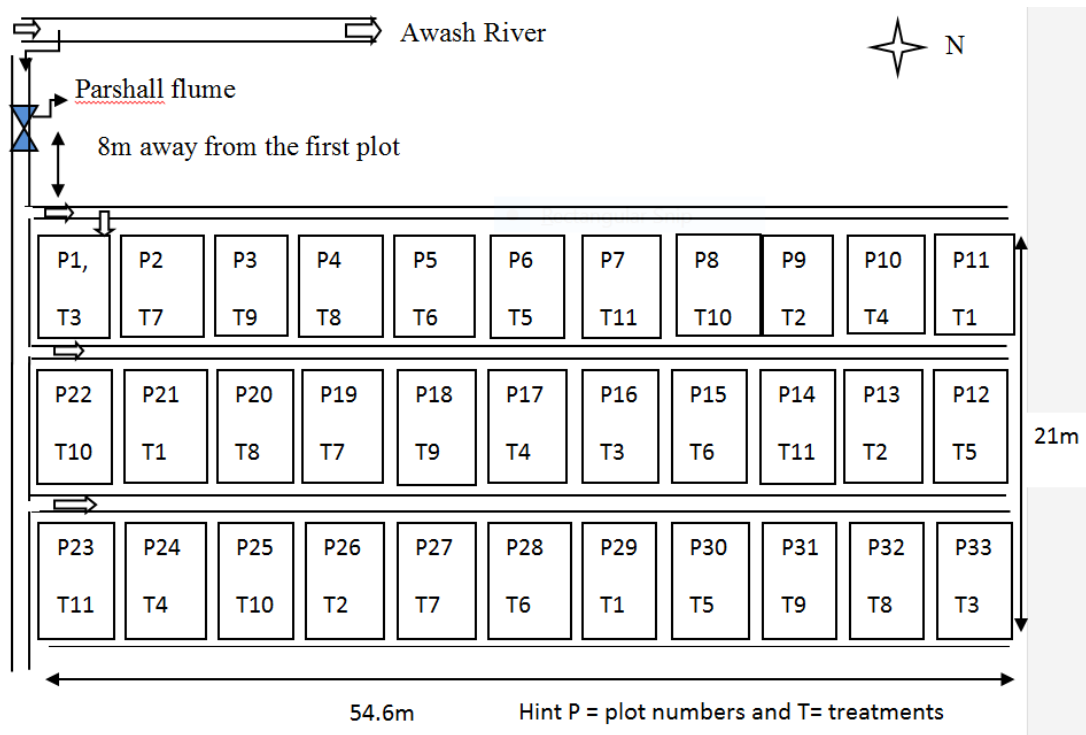


Figure 3.3. Lay-out of experimental field

### **3.4. Experimental Procedure**

The experimental field layout was made by dividing the field in to 33 plots including free space between blocks and field channels (Fig. 3.3). Each experimental plot had plot size of 5 m by 3.6 m to contain five furrows of 5 m length with spacing of 60 cm between ridges. Each replication was then subdivided in to eleven experimental units and free space between each plot, maintaining the desired spacing. The space between plots and replication had a buffer zone of 1.5m and 3m, respectively. The total area used for this experiment was 1146.6 m<sup>2</sup> (54.6 m x 21 m). The bunds around each plot were made stable to control water movement between plots. Once the layout was prepared, main canal outside the experimental field and field channels were constructed for the conveyance of irrigation water.

After the land well prepared and pre irrigated, wheat cultivar fentale-2 was sown on the experimental field by drilling in rows. Prior to sowing seeds, each plot was irrigated as pre-irrigation to create favorable condition for seed germination. Irrigation treatment was performed after crop establishment and 100% ETC (control) irrigation water was applied in accordance with the computed crop water requirement with the aid of CROPWAT Model 8.0. The irrigation scheduling was done based on the optimum irrigation level for wheat ( $p=0.50$ ). The stressed treatments received the percentage proportion of the control treatment (full irrigation).

Based on the irrigation scheduling the irrigation amount and irrigation interval was calculated for the control treatment (100% ETC). The ten treatments received the proportion of depth of irrigation water than the control treatment based on their moisture stress levels. In this experiment, the same irrigation interval was used as that of control treatment.

### **3.5. Wheat Agronomy**

Fentale-2 early maturing cultivar released by WARC during 2017 was selected for this study. The variety is preferable for moisture stressed area like the study area with day to

maturity of 82-85 days and yield potential ranges from 5 - 5.7 t/ha on station and from 4-4.5 t/ha on farmer field (Mihratu *et al.*, 2017).

Wheat seed was weighted and packed for all rows of each plot with seeding rate of 80-100 kg/ha as recommended by Werer Agricultural Research center (Mihratu *et al.*, 2017). For this particular study 80kg/ha was used. Based on plot area and spacing used, the number of rows in each plots were ten. Therefore, 14.4 g of seed was sown per row. Totally, 4,752 gram of seed was used for the whole experimental plots. Wheat cultivar Fentale-2 seed was sown on December 13, 2019. Furrow irrigation with the spacing of 60 cm between ridges and 20 cm between rows of crops was used to grow the plant. Each plot had five ridges in which seed was sown in double row with spacing of 20 cm.

The seed were planted on both sides of a ridge and for sowing the seeds in rows; 2-3cm deep furrow was made manually using wooden peg keeping row spacing of 20 cm between rows (EIAR, 2007). At the center of the seed row, at the peak of the ridge, similar furrows were made for fertilizer application.

Each plots were fertilized with DAP and Urea fertilizer with the rate of 100 kg/ha each (Abebe *et al.*, 2014). Urea fertilizer was applied in split manner. Half of the dose was applied during seed sowing with DAP and the rest half was applied at tillering (EIAR, 2007) as topdressing after weeding and it was combined with soil while hoeing immediately. The fertilizers dose applied per one plot was 180 gram for both DAP and Urea. During seed sowing since the fertilizer was applied per ridge, 18 gram of Urea and 36 gram of DAP was applied for five ridges of each plots. Both the seed and fertilizer covered with soil as soon after sowing. Weeding was performed uniformly depending on its occurrence.

### **3.6. Irrigation Water Management**

The source of water which was used for irrigation was from Awash River. The water was pumped from Awash River and reach the filed by gravity. Three-inch Parshall flume was used to deliver measured water. A 3 inch standard Parshall flume was installed at 8m distance from the head of first plot to measure irrigation water to be applied in to each plot. Leveling in all direction of converging section was checked. Leveling for the diverging section was checked only across the waterway. The entrance section was set at

4 cm above the canal bed to avoid submergence flow and apron was put in the downstream side on canal bed to minimize down streams curing.

When the flow reached a constant head in the Parshall flume, the water was allowed to flow into the experimental plot. This discharge was allowed to flow into one plot for the calculated time period. The irrigation depth was converted to volume of water by multiplying it with area of the plot. Based on the volume of water and the discharge capacity of Parshall flume at different head, the time required to irrigate each treatment was calculated.

### **3.7. Determination of Crop Water and Irrigation Water Requirement**

#### **3.7.1. Determination of Crop Water Requirement**

**Reference Evapotranspiration (ET<sub>o</sub>):-** The daily reference evapotranspiration (ET<sub>o</sub>) was calculated by CROPWAT 8.0 software using the daily FAO Penman-Monteith method (Allen et al., 1998). The daily climatic parameters used to estimate ET<sub>o</sub> such as maximum temperature, minimum temperature, relative humidity, wind speed (at two meter) and sunshine hour was collected from Gewane meteorological station adjacent to the experimental site.

Crop coefficient was collected from FAO 33 for spring wheat and adjusted to the climatic condition of the area. Accordingly, the crop coefficient values used for respective growth stages were 0.37, 1.15 and 0.72 for initial, mid and late stage, respectively. Whereas the length of growth stages of wheat were taken from FAO irrigation and drainage paper 56 and adjusted to climatic condition based of growth stage of wheat (Allen *et al.*, 1998). Accordingly, growth stage of 15, 25, 45, and 25 days were considered for initial, development, mid-season and late season respectively. For more information based on the K<sub>c</sub> values of the crop and length of each growth stages, daily crop coefficient was interpolated for development and late season stage (Appendix Table 2). Then the daily crop water requirement (ET<sub>c</sub>) was performed following Eq. 3.3.

$$ET_c = k_c \times ET_o \quad (3.3)$$

Where, ET<sub>c</sub> is the daily crop water requirement (mm/day), ET<sub>o</sub> is daily reference evapotranspiration (mm/day) and k<sub>c</sub> is the crop coefficient (Fraction).

The daily crop evapotranspiration was subtracted from the net irrigation depth for the control treatment (100% ETc) until the cumulative subtraction from the net irrigation depth applied approached to nil. On the other hand the next irrigation was applied when the cumulative ETc approach to net irrigation depth applied for the control treatment. The effective root depth of the crop taken as 0.3m at germination, 1m at mid-season and the daily effective root depth value was interpolated for the duration between germination to the first day of mid-season.

**Net irrigation water requirement (NIR):-** Net irrigation water requirement was done based on the water holding capacity of the soil from critical depletion level to field capacity in the effective root depth for 100% ETc as Eq.3.4.

$$\text{NIR} = \text{ETc} - \text{Pe} \quad (3.4)$$

Where, NIR is net irrigation requirement (mm), ETc is the crop water requirement (mm) and Pe is the effective rainfall (mm). However, since there was no rain fall during study period, net irrigation requirement is equivalent to crop water requirement (NIR=ETc).

### 3.7.2. Soil moisture determination

The soil moisture content was measured for experimental field before and after irrigation gravimetrically at the laboratory. The soil samples were taken with augers from three depths: 0-30 cm, 30-60 cm and 60- 90 cm at three locations from different plots randomly. The samples were weighed and oven dried for 24 hours at a temperature of 105<sup>0</sup>C. Then, the oven-dried sample was weighed again and finally the water content in the soil is determined in volume base as given in Eq. 3.5 (Jaiswal, 2003).

$$\theta_v = \left( \frac{W_w - W_d}{W_d} \right) * \rho_b * 100 \quad (3.5)$$

Where,  $\theta_v$  is volumetric moisture content in (%),  $W_d$  is weight of dry soil (g),  $W_w$  is weight of wet soil (g),  $\rho_b$  is soil bulk density (g/cm<sup>3</sup>).

### 3.7.3. Irrigation efficiency and gross irrigation water requirement

Field irrigation application efficiency is the ratio of water directly available to the crop to water received at the field inlet. To estimate the gross irrigation requirement, application efficiency of 60% was used which is common for surface irrigation method in furrow irrigation (FAO, 2002b).

Based on the net irrigation requirement depth and irrigation application efficiency, the gross irrigation requirement was calculated based on Eq. 3.6.

$$\text{GIR} = \frac{\text{NIR}}{e_a} \quad (3.6)$$

Where, GIR is gross irrigation requirement (mm), NIR is net depth of irrigation water requirement (mm) and  $e_a$  is irrigation application efficiency.

The gross irrigation was finally applied to each experimental plot based on the stress levels. Volume of water applied for every treatment was determined by multiplying plot area with the depth of gross irrigation requirement. Finally, the time required to deliver the desired depth of water into each plot was determined using the Eq. 3.7 (Michael, 2008).

$$t = \frac{d \cdot w \cdot l}{6 \cdot Q} \quad (3.7)$$

Where,  $d$  is gross depth of water applied (cm),  $t$  is application time (min),  $l$  is furrow length (m),  $w$  is furrow spacing (m), and  $Q$  is flow rate of discharge (l/s).

The irrigation scheduling was done based on RAW for 100%ETc and irrigation interval is obtained from RAW divided by the average ETc and the same irrigation interval was used for all treatments.

### **3.8. Data Collection**

The crop was harvested when the spikes were completely ripened and all the wheat color turns to yellow. Data on crop growth performance yield and yield components at different stages of the crop growth stage were collected. For grain yield, above-ground biomass and straw yield, all the wheat excluding the outside rows and the end 50 cm of the plot both sides (7.2 m<sup>2</sup> area) were harvested as recommended by (Bell and Fischer, 1994). Five randomly pre-tagged plants were collected for growth and yield component data. Harvesting was done manually and the harvested sample of each plot was collected in sack separately. The harvested samples were dried in sun for a week before the data collected for above-ground biomass and threshing. Furthermore, sampling, data collection and recording for each yield and yield components were determined as follow.

### **3.8.1. Phenological and growth data**

Days to 50% booting and 50% heading were recorded by observation based on the number of days from the day of planting to the day on which 50% of the plants in a plot reached the respective phenological stages. Data on growth parameters like plant height, spike length and number of tiller per meter square were recorded at physiological maturity. On the other hand days to maturity was recorded based on the number of the days from the date of planting to the date when 90% of the plants in each plot turned their leaves yellow and grain hardened (Sikder, 2009).

**Plant height** (cm): It was measured from ground surface to tip of the spike from five location in the central three ridges, systematically in crisscross manner from each plot at maturity stage using metal hand tape.

**Spike length** (cm): The length of spike was measured from peduncle end to peak of spike at maturity stage. Metal hand tape was also used to measure the spike length. The mean plant height and spike length of each experimental unit were determined from the five samples by calculating the average of the collected five samples (Bell and Fischer, 1994).

### **3.8.2. Yield and yield components**

**Number of effective tillers per meter square:** The tillers whose spikes had grains were considered as productive tillers. Such kinds of tillers were counted to get effective tillers per meter square after physiological maturity stage. The sample area was taken from selective five locations in the central three ridges. Number of tillers within a single row from double row ridge was taken from 50 cm length row. As mentioned in experimental design each ridge contains double row of crop with ridge spacing of 60 cm. Therefore, each sample area represents 0.15 m<sup>2</sup> area of land (Bell and Fischer, 1994). Then, the mean number of tillers per square meter of each sample was converted to per square meter.

**Number of kernel per spike:** Number of kernels per spike of wheat in each trial unit was collected from five pre tagged mother plants. The collected five spikes were threshed in hand and the number of kernels in each spike was counted manually. The number of kernels per spike of each trial unit was determined from the five samples by calculating the mean of the counted five spikes kernel number.

**Aboveground biomass:** The aboveground biomass of each plot was determined from sample harvested from net plot area of 7.2 m<sup>2</sup> (three double row ridges of 0.6 m spacing and 4 m length). Wheat was harvested from the ground surface just above the soil and sun-dried in container sack for one week before the data on aboveground biomass collected. After sun drying to a constant weight, the aboveground biomass obtained from the sampled area was converted to yield in kilo gram per hectare (kg/ha) using Eq. 3.8.

$$\text{Aboveground biomass kg/ha} = \frac{\text{Sample above ground biomass (kg)}}{\text{Harvested sample area (m}^2\text{)}} * 10^4 \text{m}^2 \quad (3.8)$$

**Grain yield:** The data on grain yield was obtained by weighing the grain yield after sun drying, threshing and cleaning. Threshing was done manually using wooden stick after the wheat was sundried for a week. Then the grains was separated, cleaned and weighed using sensitive balance to determine the grain yield per plot. Finally, the grain yield achieved from the sampled area was converted to per hectare using Eq. 3.9.

$$\text{Grain yield (kg/ha)} = \frac{\text{Grain weight of sample (kg)}}{\text{Harvested sample area (m}^2\text{)}} * 10^4 \text{m}^2 \quad (3.9)$$

The moisture content of the grain was determined by grain moisture meter and finally the yield was adjusted based on 12.5% moisture content.

**Thousand kernels Weight (g):** The 1000 kernels weight was measured from randomly picked grain yield for each plot. The weight of 1000 seeds was determined by careful counting of the grains manually and weighing them using a sensitive balance. Then the weight was adjusted to 12.5% moisture content.

**Straw yield:** The straw yield was obtained by subtracting the grain yield from aboveground dry biomass yield per hectare of each plot. The grain yield subtracted was the value before converting to the standard 12.5 % moisture content since the aboveground biomass is only sun dried.

**Harvest Index (%):** Harvesting index was determined as the ratio of grain yield per hectare to aboveground biomass per hectare after sun dried and expressed as percentage using Eq. 3.10 (Chandrasekaran *et al.*, 2010).

$$\text{Harvest Index \%} = \frac{\text{Grain yield} \left( \frac{\text{kg}}{\text{ha}} \right)}{\text{Aboveground biomass} \left( \frac{\text{kg}}{\text{ha}} \right)} \times 100 \% \quad (3.10)$$

### 3.9. Water Use Efficiency (WUE)

The WUE was determined as the ratio of yield of wheat (grain yield per hectare) to the net irrigation depth used from germination to harvest and expressed as kg of grain yield per m<sup>3</sup> following Eq.3.11 (Chandrasekaran *et al.*, 2010).

$$\text{WUE (kg/m}^3\text{)} = \frac{\text{Grain yield}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Seasonal net amount of water}\left(\frac{\text{m}^3}{\text{ha}}\right)} \quad (3.11)$$

### 3.10. Yield Response Factor

Crop yield response factor ( $k_y$ ) is relates to relative yield decrease to relative evapotranspiration deficit from the optimum irrigation (Stewart *et al.*, (1977). The relative yield decrease values are the reduction of grain yield obtained from each treatment after the grain yield was analyzed from the full irrigation treatment. While, the decrease in evapotranspiration was the reduction in irrigation amount due to stress level from the 100%ET<sub>C</sub> application. Finally yield response factors was determined based on the ratio of relative yield decrease to relative evapotranspiration deficit expressed in decimal and computed using Eq. 3.12 (FAO 2002a).

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y \left(1 - \frac{ET_a}{ET_m}\right) \quad (3.12)$$

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

### 3.11. Determination of moisture stress threshold level of wheat

Moisture stress threshold value of wheat was determined by observing the obtained grain yield result at different stress levels. Then, the maximum stress levels at which the SAS output results had no significant difference with control treatment was considered as moisture stress threshold value of wheat crop (Chai *et al.*, 2013).

### **3.12. Methods of Data Analysis**

The collected data were subjected to analysis of variance (ANOVA) appropriate to RCBD and analyzed using statistical analysis system (SAS) version 9.0 statistical package (SAS, 2002). Whenever the treatment effects were found significant, least significant difference (LSD) was performed to assess any significant difference among treatments means.

## 4. RESULTS AND DISCUSSION

### 4.1. Soil and Water Properties

Selected physicochemical properties of the soil of the experimental site such as soil texture, bulk density, field capacity, permanent wilting point, pH, EC and organic matter content were analyzed and summarized in Table 4.1 and 4.2, respectively.

#### 4.1.1. Soil physical properties

The laboratory analysis showed that the average composition of sand, silt and clay percentages were 22%, 28% and 50%, respectively as shown in Table 4.1. Hence, according to the USDA soil textural classification, the particle size distribution for experimental field was classified as clay.

The bulk density of the soil of the experimental field has shown a variation with depth from 1.07 to 1.14 g/cm<sup>3</sup>. Generally, the top soil surface had slightly lower bulk density (0-30 cm) than the subsurface soil. This might be due to high organic matter contents in the top soil surface reduces bulk density and the higher compaction level in the lower part increased bulk density.

Table 4.1. Some of soil physical properties of the experimental field

Soil property	Soil depth in(cm)			Average	
	(0-30)	(30-60)	(60-90)		
Particle size distribution	Sand (%)	22.4	22.1	21.5	22.0
	Silt (%)	29.8	27.2	27.0	28.0
	Clay (%)	48.7	50.3	51.0	50.0
Textural class	Clay	Clay	Clay	Clay	
Bulk density (g/cm <sup>3</sup> )	1.07	1.10	1.14	1.10	
FC (%)	40.4	38.4	37.2	38.7	
PWP (%)	21.6	20.2	19.6	20.5	
TAW(mm/m)	201.5	200.2	200.6	200.3	

While, the moisture content at field capacity varied with the soil depth from 40.4% to 37.2% on a weight basis (Table 4.1). In line with this, the FC of clay soil ranges from 31.89 to 45% on weight basis as reported by (Hillel, 2004). Therefore, the values achieved in the present trial were agreed within the range of expected for the clay soil. On the other hand, the PWP values range from 21.6% to 19.6% on a weight basis, respectively.

Whereas the TAW obtained was also related with the clay available water content of the soil which ranges from 200 to 250 mm/m as reported by Euro consult (1989).

#### 4.1.2. Soil chemical properties

The result of soil chemical analysis has shown that the pH value of the soil ranged from 7.25 to 7.85 with mean soil pH value of 7.57 (Table 4.2) which is within the optimum range for wheat production (6-8) according to FAO 33 paper (Doorenbos and Kassam 1979). According to EthioSIS (2014) soil pH classification, the soil with the range of 7.4 to 8.4 are moderately alkaline. Therefore, the soil of the experimental area was classified as moderately alkaline. On the other hand, the result of soil electrical conductivity of the experimental field varied from 1.09 dS/m to 1.32 dS/m (Table 4.2).

As reported by Hazelton and Murphy (2007) soil with electrical conductivity of less than 4ds/m considered as non-saline. This revealed that, the soil of the experimental area was non saline. Wheat is a moderately salt-tolerant crop (Maas and Hoffman, 1977). In the field, where the salinity rises to about 10 dS /m), rice will die before maturity, while wheat will produce a reduced yield. Whereas the maximum and minimum total organic carbon varied from 1.02 to 0.55, respectively. The minimum and maximum values were obtained from lower and top soil profile, respectively. The soil with total organic carbon of (0.5 to 1.5 %) considered as low organic carbon and it need continuous improvement with the organic fertilizers (Tekalign, 1991).

Table 4.2. Soil chemical properties of the experimental field

soil depth (cm)	pH	ECe (ds/m)	TOC (%)	TN (%)	P (mg/kg)	OM (%)
0-30	7.85	1.32	1.02	0.07	4.72	1.76
30-60	7.63	1.25	0.73	0.06	4.50	1.26
60-90	7.25	1.09	0.55	0.05	4.36	0.95
Average	7.57	1.22	0.77	0.06	4.53	1.32

OM =Organic matter, TN= total nitrogen, TOC = Total organic carbon ,p = phosphorus

The analysis result also revealed that, total nitrogen varies from 0.05 to 0.07%. As suggested by Tekalign (1991) soil with total nitrogen availability of < 0.05% considered as very low, 0.05- 0.12% as low, 0.12-0.25% as moderate and > 0.25% as high.

On the other hands, the P of soil was varied from 4.36 to 4.72 mg/kg. According to the rating of EthioSIS (2014) soil with P less than 15mg/kg was very low. Therefore, the soil of experimental field has very low available P.

Whereas, the organic matter (OM) varied from 0.95 to 1.76 % with average organic matter of 1.32% as presented in Table 4.2. This was considered as low according to findings of Tekalign (1991) who reported that soils having OM value in the range of 0.86-2.59% are considered as low.

#### **4.1.3. Analysis of irrigation water**

The laboratory result of irrigation water quality analysis has indicated pH value of 8.2. While the EC<sub>w</sub> was 0.73 ds/m (Table 4.3). According to FAO (1999) water salinity classification, the EC<sub>w</sub> of applied water was medium to salinity effect; low (0.1-0.25 dS/m), medium (0.25-0.75 dS/m) and high (0.75-2.25 dS/m).

Moreover, the SAR was calculated to determine the sodicity or alkalinity effect of irrigation water. The result shown that, the SAR of irrigation water was 5.09 (Table 4.3). As reported by Brady and Weil (2002) the SAR of <13 is considered as safe. This implied that, SAR value of irrigation water of the experimental site was safe.

Table 4.3. Chemical properties of irrigation water

Sample	pH	EC <sub>w</sub> (ds/m)	Na (Meq/L)	Ca+Mg (Meq/L)	SAR
Water	8.2	0.73	5.91	2.7	5.09

#### **4.2. Crop Water Requirement of Wheat**

The seasonal crop water requirement determined based on the seasonal water application depth from germination to harvest varied based on the treatment application (Table 4.4). The common irrigation depth of 30.2 mm was applied for all treatments after sowing.

As indicated in Table 4.4, the highest net irrigation water application of 547.5 mm was applied for the control treatment (100% ET<sub>c</sub>) and the minimum net irrigation of 263.0 mm was applied for the highly stressed treatment (45% ET<sub>c</sub>). For this particular study only irrigation water was considered, because of no rainfall has occurred during the crop growing period in the study site and hence there was no effective rainfall considered to

be deducted from the net irrigation required. Therefore, net irrigation requirement was equivalent to crop water requirement ( $NIR = ET_c$ ).

Table 4.4. Seasonal depth of net irrigation water application

Irrigation level (%ET <sub>c</sub> )	Common irrigation (mm)	Irrigation during treatment application (mm)	Net Irrig (mm)	Gross Irrig(mm)
100	30.2	517.3	547.5	912.5
90	30.2	465.6	495.8	826.3
85	30.2	439.7	469.9	783.2
80	30.2	413.8	444.0	740.0
75	30.2	388.0	418.2	697.0
70	30.2	362.1	392.3	653.8
65	30.2	336.2	366.4	610.7
60	30.2	310.4	340.6	567.7
55	30.2	284.5	314.7	524.5
50	30.2	258.7	288.9	481.5
45	30.2	232.8	263.0	438.3

### 4.3. Effect of Moisture Stress Levels on Phenology of Wheat

The analysis of variance showed that, the different moisture stress levels has created highly significant ( $P < 0.01$ ) influence on the number of days to booting and heading. Days to booting varied from 42 days to 46 days (Table 4.5). The maximum day to booting of 46 was recorded from control, 90 and 85% ET<sub>c</sub>. While the minimum day to booting was 42 days and this was recorded from 50 and 45 % ET<sub>c</sub> irrigation water applications.

Table 4.5. Effect of moisture stress levels on phenology of wheat

Irrigation level	Days to booting (Days)	Days to heading (Days)	Days to Maturity (Days)
100%ET <sub>c</sub>	46 <sup>a</sup>	50 <sup>a</sup>	83 <sup>a</sup>
90%ET <sub>c</sub>	46 <sup>a</sup>	50 <sup>a</sup>	83 <sup>a</sup>
85%ET <sub>c</sub>	46 <sup>a</sup>	50 <sup>a</sup>	83 <sup>a</sup>
80%ET <sub>c</sub>	45 <sup>b</sup>	49 <sup>b</sup>	82 <sup>ab</sup>
75%ET <sub>c</sub>	45 <sup>b</sup>	49 <sup>b</sup>	82 <sup>ab</sup>
70%ET <sub>c</sub>	44 <sup>c</sup>	48 <sup>c</sup>	80 <sup>bc</sup>
65%ET <sub>c</sub>	44 <sup>c</sup>	48 <sup>c</sup>	80 <sup>bc</sup>
60%ET <sub>c</sub>	43 <sup>d</sup>	47 <sup>d</sup>	79 <sup>cd</sup>
55%ET <sub>c</sub>	43 <sup>d</sup>	47 <sup>d</sup>	79 <sup>cd</sup>
50%ET <sub>c</sub>	42 <sup>e</sup>	46 <sup>e</sup>	78 <sup>cd</sup>
45%ET <sub>c</sub>	42 <sup>e</sup>	46 <sup>e</sup>	77 <sup>d</sup>
Cv	1.31	1.20	1.65
LSD0.05	0.98	0.99	2.27

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different according to LSD test at  $p < 0.05$  level of significance.

Whereas day to heading was varied from 46 to 50 days. The earlier day to heading was recorded from 45 and 50%ETc irrigation water applications and the later day of heading was recorded from the control treatment (100%ETc), 90 and 85% ETc irrigation water applications (Table 4.5).

On the other hand, the analysis of variance has also shown a highly significant ( $p < 0.01$ ) effect on days to maturity of wheat due to different moisture stress levels. The highest days to maturity of 83 day was obtained from the 100, 90 and 85%ETc irrigation water application and has no significant differences with irrigation application of 80 and 75%ETc.

The minimum days to maturity of 77 days was recorded from plot that received 45%ETc application and has shown no significant differences with 50, 55 and 60%ETc applications. Similar finding reported that, stressed treatments in wheat leads to early maturity (Elias *et al.*, 2017; Kilic and Yagbasanlar, 2010). This shows that the higher the deficit level, the earlier was the day to maturity.

#### **4.4. Effect of Moisture Stress Levels on Growth and Yield Components of Wheat**

The effect of different moisture stress levels had shown no significant effect on number of tillers, while plant height, spike length and number of kernels per plant had shown a highly significant ( $p < 0.01$ ) difference among treatments under different irrigation water applications.

##### **4.4.1. Number of tillers**

Number of tillers per square meter shows the plant population in the experimental field at harvest. The average number of tillers per square meter of experimental field was in the range of 557.2 to 581.7 (Table 4.6). The highest and lowest number of tillers per square meter was obtained from 75%ETc and 55%ETc water applications respectively and shows no significant difference with all other treatments.

This indicates that, the moisture stress levels effect is not prominent before the completion of tillering. That means pre-irrigation and common irrigation provided

equally to all treatments for the establishment of good wheat crop stand may be a reason for avoiding the moisture stress level to the level that affects the tillering capacity. That might be the reason for the number of tillers per square meter was not significantly affected as tillering of wheat generated at earlier stages. Similar finding also have reported on wheat by Elias *et al.* (2017), El Hwary and Yagoub (2011).

#### 4.4.2. Plant height

The highest plant height of 84.6cm was recorded from control treatment (100%ET<sub>c</sub>) and has no significant differences with an irrigation water application of 90, 85 and 80%ET<sub>c</sub> treatments. Whereas the minimum plant height of 68.5cm was obtained at 45%ET<sub>c</sub> and has no significant difference with irrigation water application of 50%ET<sub>c</sub>. This shows that, as the stress levels increased from optimum irrigation of 100%ET<sub>c</sub> to irrigation of only 45%ET<sub>c</sub>, the plant height reduced (Table 4.6).

Table 4.6. Effect of moisture stress levels on number of tillers, plant height, spike length and number of kernels per spike

Treatments	Number of Tillers	Plant height (cm)	Spike length (cm)	Number of kernels per spike
100%ET <sub>c</sub>	577.2 <sup>a</sup>	84.6 <sup>a</sup>	8.4 <sup>a</sup>	42.7 <sup>a</sup>
90%ET <sub>c</sub>	575.0 <sup>a</sup>	83.8 <sup>ab</sup>	8.4 <sup>a</sup>	42.4 <sup>a</sup>
85%ET <sub>c</sub>	568.3 <sup>a</sup>	82.6 <sup>abc</sup>	8.4 <sup>a</sup>	41.8 <sup>ab</sup>
80%ET <sub>c</sub>	561.7 <sup>a</sup>	82.4 <sup>abc</sup>	8.3 <sup>ab</sup>	40.8 <sup>ab</sup>
75%ET <sub>c</sub>	581.7 <sup>a</sup>	81.4 <sup>bc</sup>	8.2 <sup>ab</sup>	39.6 <sup>bc</sup>
70%ET <sub>c</sub>	568.3 <sup>a</sup>	80.2 <sup>cd</sup>	8.1 <sup>abc</sup>	38.4 <sup>cd</sup>
65%ET <sub>c</sub>	559.4 <sup>a</sup>	77.7 <sup>de</sup>	7.9 <sup>bc</sup>	38.3 <sup>cde</sup>
60%ET <sub>c</sub>	566.1 <sup>a</sup>	75.5 <sup>ef</sup>	7.8 <sup>c</sup>	36.9 <sup>de</sup>
55%ET <sub>c</sub>	557.2 <sup>a</sup>	73.4 <sup>f</sup>	7.8 <sup>cd</sup>	35.9 <sup>ef</sup>
50%ET <sub>c</sub>	563.9 <sup>a</sup>	70.4 <sup>g</sup>	7.5 <sup>de</sup>	34.2 <sup>gf</sup>
45%ET <sub>c</sub>	559.4 <sup>a</sup>	68.5 <sup>g</sup>	7.3 <sup>e</sup>	33.6 <sup>g</sup>
CV (%)	2.59	2.17	2.51	3.46
LSD (0.05)	NS	2.89	0.34	2.27

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at  $p < 0.05$  level of significance. NS: non-significant ( $P > 0.05$ ).

This implies that, the higher plant height was related with higher water application and the shorter plant height was related to the lower application of irrigation water. The reduction in irrigation water application from 100 to 45% ET<sub>c</sub> leads to a reduction of 19 % in plant height. This result showed that, plant height is associated with the amount of irrigation water applied and reverse with stress levels. That means plant height is decrease as moisture stress level increased.

Similar finding reported by different researcher on wheat by (Jemal *et al.*, 2019; Elias *et al.*, 2017; Maqbool *et al.*, 2015; Guo *et al.*, 2013; El Hwary and Yagoub, 2011) reveal that plant height is affected due to various stress levels.

#### **4.4.3. Spike length**

The highest spike length of 8.4cm was recorded from optimum treatment (100% ET<sub>c</sub>), 90 and 85%ET<sub>c</sub> and has no significant differences with 80, 75 and 70% ET<sub>c</sub> irrigation water application (Table 4.6). Whereas, the minimum spike length of 7.3cm was recorded from 45%ET<sub>c</sub> and this has no significant difference with irrigation water application of 50%ET<sub>c</sub>. The result showed that, the application of higher amount of water leads to wheat of longer spike and as moisture stress levels increased, the spike length was reduced.

As the irrigation water application reduced from 100 to 45%ET<sub>c</sub>, the spike length was reduced by 13.09 % (Table 4.6). Similar studies reported by Jemal *et al.* (2019), Elias *et al.* (2017), Maqbool *et al.* (2015) and, El Hwary and Yagoub (2011) have also reveal that spike length of wheat is affected by moisture stress levels. The longer spike length has a capacity to contain higher numbers of kernels and this may be contributes to increase the grain yield per hectare as it has a positive impact on grain yield.

#### **4.4.4. Number of kernels per spike**

The highest number of kernels per spike of 42.7 was recorded from control treatment (100% ET<sub>c</sub>) and has no significant differences with irrigation water application of 90, 85 and 80%ET<sub>c</sub>. The minimum number of kernels per spike of 33.6 was recorded from 45%ET<sub>c</sub> and has no significant difference with 50%ET<sub>c</sub> irrigation water application (Table 4.6).

As the irrigation water application reduced from optimum irrigation of 100% ET<sub>c</sub> to irrigation of 45% ET<sub>c</sub> the number of kernels contained in wheat spike was reduced. This revealed that, the higher number of kernels per spike was related with the higher amount of irrigation water application and the lower kernels per spike was related with lower amount of irrigation water application.

The reduction of irrigation water application from 100% ET<sub>c</sub> to 45% ET<sub>c</sub> reduced the number of kernels per spike by 21.31%. This reveals that number of kernels per spike of wheat is directly related with the amount of irrigation water applied and reverse with the

moisture stress levels. This has direct impact on grain yield production per hectare as the number of grains has a great influence on grain yield production. The different research done on wheat has shown that number of kernels per spike affected by different stress levels during the whole or part of the growth stages (Jemal *et al.*, 2019 and Elias *et al.*, 2017). Similar finding have also reported by Tolessa *et al.* (2015) and Assefa *et al.* (2014).

#### **4.5. Effect of different Moisture Stress Levels on Yield of Wheat**

Analysis of variance revealed that the application of different moisture stress levels on wheat created a highly significant ( $p < 0.01$ ) effect on aboveground biomass, grain yield, straw yield and thousand seed weight.

##### **4.5.1. Aboveground biomass**

The finding conducted on wheat shows that reduction in irrigation water application affects total aboveground biomass. The highest aboveground biomass of 12541.7kg/ha was obtained due to a control treatment (100% ET<sub>c</sub>) and this has no significant differences with irrigation water application of 90, 85 and 80% ET<sub>c</sub> (Table 4.7). Whereas, the minimum aboveground biomass of 9615.7kg/ha was recorded from 45% ET<sub>c</sub> application and this has no significant difference with 50% ET<sub>c</sub> water application. This show that, the higher amount of irrigation water application related with larger amount of biomass production and reverse. As moisture stress levels increased, the aboveground biomass production become lower gradually.

The reduction of irrigation water amount from 100 to 45% ET<sub>c</sub> reduced the biomass production by 23.33% (Table 4.7). This may be due to the increase in physical growth contributes to the total aboveground biomass production need larger water depth. Similar result reported by different researchers (Elias *et al.*, 2017; Maqbool *et al.*, 2015; Guo *et al.*, 2013; Tavakoli and Moghadam, 2012).

As reported by Guo *et al.*, (2013) the moisture stress affects photosynthesis capacity through reduction of chlorophyll content and damage of the reaction center of photosystem. This results with lower aboveground biomass as 90% of crop biomass is derived from photosynthetic products (Amane, 2011). As the stress level increase, the amount of water applied is not enough for the production of higher biomass. However,

the amount of water stress in moderate stress treatments is not pronounced as that of highly stress treatment due to the reason that crops tolerate some level of drought and utilize available water effectively by different mechanisms to minimize the effect of biomass reduction (Farooq *et al.*, 2009).

#### 4.5.2. Grain yield

The highest grain yield of 4472.2kg/ha was recorded from a control treatment (100% ET<sub>c</sub>) and has no significant differences with irrigation water applications of 90, 85, 80, 75 and 70% ET<sub>c</sub> (Table 4.7). Whereas, the minimum grain yield of 3475.7g/ha was observed from 45%ET<sub>c</sub> irrigation water application and this has no significant difference with irrigation application of 50%ET<sub>c</sub>.

This showed that, the higher amount of irrigation water application related with larger amount of grain yield production and lower amount of irrigation water application leads to less amount of grain yield production per hectare. The reduction of irrigation water from the 100 to 45%ET<sub>c</sub> leads to reduction of grain yield by 22.28%.

Table 4.7. Effect of moisture stress levels on aboveground biomass, grain yield, straw yield and thousand seed weight of wheat

Treatment	Biomass (kg/ha)	Grain yield (kg/ha)	Straw yield (kg/ha)	Thousand seed weight (g)
100%ET <sub>c</sub>	12541.7 <sup>a</sup>	4472.2 <sup>a</sup>	7430.6 <sup>a</sup>	33.4 <sup>a</sup>
90%ET <sub>c</sub>	12398.1 <sup>ab</sup>	4456.0 <sup>a</sup>	7305.6 <sup>ab</sup>	33.4 <sup>a</sup>
85%ET <sub>c</sub>	12217.6 <sup>abc</sup>	4419.6 <sup>a</sup>	7166.7 <sup>ab</sup>	33.3 <sup>a</sup>
80%ET <sub>c</sub>	12162.0 <sup>abc</sup>	4379.1 <sup>a</sup>	7157.4 <sup>ab</sup>	33.1 <sup>ab</sup>
75%ET <sub>c</sub>	12074.1 <sup>bcd</sup>	4334.5 <sup>ab</sup>	7120.4 <sup>ab</sup>	32.7 <sup>abc</sup>
70%ET <sub>c</sub>	11916.7 <sup>cd</sup>	4314.2 <sup>ab</sup>	6986.1 <sup>bc</sup>	32.4 <sup>abc</sup>
65%ET <sub>c</sub>	11689.8 <sup>d</sup>	4176.5 <sup>b</sup>	6916.7 <sup>bc</sup>	32.3 <sup>abc</sup>
60%ET <sub>c</sub>	10986.1 <sup>e</sup>	3852.4 <sup>c</sup>	6583.3 <sup>c</sup>	32.1 <sup>bc</sup>
55%ET <sub>c</sub>	10222.2 <sup>f</sup>	3694.4 <sup>cd</sup>	6000.0 <sup>d</sup>	31.7 <sup>cd</sup>
50%ET <sub>c</sub>	10023.1 <sup>fg</sup>	3597.2 <sup>de</sup>	5912.0 <sup>d</sup>	30.6 <sup>de</sup>
45%ET <sub>c</sub>	9615.7 <sup>g</sup>	3475.7 <sup>e</sup>	5643.5 <sup>d</sup>	29.6 <sup>e</sup>
CV (%)	2.13	2.37	3.65	2.09
LSD (0.05)	414.87	166.01	420.41	1.15

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at  $p < 0.05$  level of significance.

On the other hands, the reduction of irrigation water application to 65, 60, 55 and 50%ET<sub>c</sub> from the optimum irrigation treatment reduced grain yield production per hectare by 6.61, 13.86, 17.39 and 19.57%, respectively (Table 4.7).

The different research conducted on wheat reported that moisture stress level affects grain yield production (Elias *et al.*, 2017; Maqbool *et al.*, 2015; Guo *et al.*, 2013; Tavakoli and Moghadam, 2012). Among the stress level 90%ETc showed the least reduction of grain yield. Whereas 45%ETc showed the highest yield reduction.

As reported by Farooq *et al.*, (2009) the reason for this reduction could be as the soil dries, the rate of absorption by roots falls, short of transpiration rate by the plant, thus creating an internal water stress, which affects photosynthesis and reduce food production. The finding conducted on wheat showed that wheat could tolerate water stress to some level either in its full growth season or in some particular growth stages. For instance the study conducted by Tavakoli and Moghadam (2012) reported wheat output could be substantially and consistently increased in semi-arid climate zone when 66% of full irrigation with appropriate management practiced.

#### **4.5.3. Straw yield**

The highest straw yield of 7430.6 kg/ha was observed from a control treatment (100% ETc) and this has no significant differences with irrigation water application of 90, 85, 80 and 75%ETc. While the minimum straw yield of 5643.5 kg/ha was obtained from 45%ETc application and this has no significant differences with an irrigation water application of 50 and 55%ETc (Table 4.7). This showed that, as the amount of water applied reduced, straw yield reduced similarly. Reduction of irrigation water amount from 100%ETc to 45%ETc reduced the straw yield production by 24.05%.

The result also revealed that straw yield productions have a direct relationship with the amount of water applied. That means the higher amount of irrigation water application related with larger amount of straw production and lesser amounts of irrigation water application leads to less amount of straw yield. Similar result reported on wheat by Tavakoli and Moghadam (2012). This may be due to the increase in physiological growth contributes to the total above ground biomass production for full irrigation treatment which has a direct relation with evapotranspiration and photosynthesis.

The straw yield decreased in stressed treatments might be due to reduction in photosynthesis in which chlorophyll is important. This may be because of the higher photosynthesis rate performed due to large biomass production, which most part of the

biomass is straw. As reported by Shamsi *et al.* (2010), the effect of moisture stress reduces chlorophyll content, which resulted with the reduction of biomass production.

#### **4.5.4. Thousand seed weight**

The highest thousand seed weight of 33.4g was observed from control and 90%ETc and this had no significant differences with irrigation water applications of 85,80, 75, 70 and 65%ETc. Whereas the minimum thousand seed weight of 29.6g was recorded due to irrigation water application of 45%ETc and this has no significant difference with irrigation water applications of 50%ETc (Table 4.7). This reveals that, the higher thousand seed weight was related with higher amount of irrigation water application and the lower thousand seed weight was related with lower amount of irrigation water applied.

The reduction of irrigation water application from 100%ETc to 45%ETc reduced thousand seed weight by 11.37%. The result showed that wheat thousand seed weight directly related with the amount of irrigation water applied and inversely with the moisture stress levels. Different research conducted on wheat showed that moisture stress levels affect thousand seed weight both during the whole and part of the growth stages (Maqbool *et al.*, 2015; Jazy *et al.*, 2012; El Hwary and Yagoub, 2011).

### **4.6. Response of Moisture Stress Levels on Harvesting Index, Water Use Efficiency and Yield Response Factor**

The response of stress levels to harvest index has shown no significant difference among treatments. While application of different moisture stress levels on wheat created a highly significant ( $p < 0.01$ ) effect on water use efficiency.

#### **4.6.1. Harvesting index**

As moisture stress levels increased harvesting index remained within the narrow range of 40.11% and 41.37% (Table 4.8). This shows that, there is no relation between moisture stress level and harvesting index. This may be due to the reason that, as the moisture stress levels increased, both grain yield and aboveground biomass production reduced similarly. Since harvesting index is the ratio of grain yield to aboveground biomass, the similar decrease or increase due to stress levels of both parameters might lead to the statistical similarity among the treatments.

As reported by Atikullah *et al.* (2014), different irrigation water amount applied at different date affect harvesting index in which the value ranges from 34.3% to 37.2%. On the other hand, Sokoto and Singh (2013) also reported water stress at flowering and grain filling significantly reduce harvesting index.

However, in this finding, moisture stress level happened to the completely growing season and harvesting index was not influenced due to different moisture stress levels. This finding also in line with finding of Elias *et al.* (2017) which reported similar findings in wheat, which the value ranges from 39.1% to 42.5% at different moisture stress levels.

#### 4.6.2. Water use efficiency

The highest water use efficiency of 1.32 kg/m<sup>3</sup> was recorded from 45%ETc treatment and this was significantly higher than all other treatments. Whereas the minimum water use efficiency of 0.82 kg/m<sup>3</sup> was obtained from 100%ETc application and this was significantly lower than all other treatments (Table 4.8). This showed that, the control treatment (100%ETc) was the least in water use efficiency based on grain yield production obtained.

Table 4.8. Effect of moisture stress levels on harvesting index and water use efficiency of wheat

Treatments	Harvest index (%)	Water use efficiency (kg/m <sup>3</sup> )
100 %ETc	40.75 <sup>a</sup>	0.82 <sup>h</sup>
90 %ETc	41.08 <sup>a</sup>	0.90 <sup>g</sup>
85 %ETc	41.34 <sup>a</sup>	0.94 <sup>fg</sup>
80 %ETc	41.15 <sup>a</sup>	0.99 <sup>ef</sup>
75 %ETc	41.03 <sup>a</sup>	1.04 <sup>e</sup>
70 %ETc	41.37 <sup>a</sup>	1.10 <sup>d</sup>
65 %ETc	40.83 <sup>a</sup>	1.13 <sup>cd</sup>
60 %ETc	40.11 <sup>a</sup>	1.14 <sup>cd</sup>
55 %ETc	41.36 <sup>a</sup>	1.17 <sup>c</sup>
50 %ETc	41.00 <sup>a</sup>	1.25 <sup>b</sup>
45 %ETc	41.32 <sup>a</sup>	1.32 <sup>a</sup>
CV (%)	3.11	2.88
LSD0.05	NS	0.05

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at p<0.05 level of significance. NS: non-significant (P>0.05).

The lower water use efficiency at 100%ETc might be due to higher irrigation water depth applied, much of it was lost through soil evaporation and deep percolation. On the other hands, reducing the amount of irrigation water applied leads to improve the water use

efficiency. This revealed that, the reduction of irrigation water amount used is higher than the reduction in yield because of lower evapotranspiration reduction relative to yield reduction.

In this finding the reduction of irrigation water application from 100 to 45%ETc leads to improve water use efficiency of wheat by 61.79%. The data reveals that water use efficiency is directly related with the moisture stress level, whereas inversely associated with irrigation amount. As reported by Shamsi *et al.* (2010) water use efficiency of wheat varied from 0.66 to 1.34 kg/m<sup>3</sup> between different irrigation regimes. On other hands, on study conducted by Elias *et al.* (2017) water use efficiency of wheat varied from 1.08kg/m<sup>3</sup> to 1.86 kg/m<sup>3</sup>.

However, increasing the irrigated areas with the saved water could compensate for any yield loss due to deficit irrigation. For instance, as presented under 4.2 (Table 4.4) the full irrigation water application (100% ETc) was about 547.5 mm; and that under 45% ETc was about 263.0 mm. The water saved which was about 284.5 mm could be used to irrigate 0.52 ha additional wheat cropped land or similar crop and 2324.0kg /ha additional yield that might be produced as a result of saved water.

In addition to this, the grain yield production per hectare due to full irrigation (100%ETc) was statistically similar up to 70% ETc (Table 4.7). Even though there was no significant difference in grain yield between irrigation water application from 100%ETc to 70%ETc irrigation water applications, the water use efficiency of 70%ETc was significantly higher than 100% ETc treatment. Therefore, for this particular wheat variety Fentale -2 at the district and similar agro-ecology, it could be irrigated to 70% ETc without significantly affecting the grain yield production per hectare with improving water use efficiency by 34.63% than the full irrigation.

#### **4.6.3. Yield response factor**

The yield response factor is one of the important parameters that show whether deficit levels are advantageous or not in terms of improving the water productivity. Any significant decrease in soil water storage has an impact on water availability for a crop and subsequently on actual evapotranspiration and actual yield. The result showed that yield response factor ranged from 0.04 to 0.43 (Table 4.9).

The result also reveal that, the lower yield response factor was due to lower moisture stress level and higher values related with highly moisture stressed treatments. This might be due to sensitivity of yield increased as the amount of applied water reduced. The irrigation water application of 90, 85, 80, 75, 70, 65, 60, 55, 50 and 45%ETc showed a yield reduction of 0.36, 1.18, 2.08, 3.08, 3.53, 6.61, 13.86, 17.39, 19.57 and 22.28%, respectively compared with control treatment (Table 4.9).

Table 4.9. Yield response to irrigation levels

Treatments	$a = \frac{(1 - Y_a)}{Y_m}$	$b = \frac{(1 - ET_a)}{ET_m}$	$K_y = \frac{a}{B}$
100 %ETc	0.000	0.000	-
90 %ETc	0.004	0.093	0.04
85 %ETc	0.012	0.140	0.08
80 %ETc	0.021	0.187	0.11
75 %ETc	0.031	0.233	0.13
70 %ETc	0.035	0.280	0.12
65 %ETc	0.066	0.327	0.20
60 %ETc	0.139	0.373	0.37
55 %ETc	0.174	0.420	0.41
50 %ETc	0.196	0.467	0.42
45 %ETc	0.223	0.513	0.43

The yield response factor varies for different crop type and moisture stress levels. As reported by FAO (2002a), yield response factor of different crops and different moisture stress condition varies from 0.20 for tolerant crops to 1.15 for sensitive crops. In line with this, the study conducted by Elias *et al.* (2017) reported that, the reduction of irrigation water application in the whole season of wheat result with variation of yield response factor from 0.23 to 0.58.

#### 4.7. Moisture stress threshold level of wheat

As presented under 4.5 sub section 4.5.2 in (Table 4.7) the analysis of variance showed that, grain yield obtained had no significant difference up to 70%ETc. This showed that, 70%ETc irrigation water application is an optimum point at which the yield reduction had no significant difference with the control treatment. Whereas, the moisture stress levels below this point was resulted with highly significant difference in grain yield as compared to 100%ETc.

Beside this, result also revealed that, the relationship between moisture stress levels and grain yield obtained showed that there was a polynomial relation with quadratic

mathematical equation (Fig.4.1). Similar finding also reported on wheat by (Elias *et al.*, 2017) revealed 70%ETc as optimum moisture stress level. In similar manner Kebede (2019) and Fikadu (2020) reported similar result on onion and maize respectively at Amibara woreda, middle awash valley. The graph showed that, as moistures stress levels increased the grain yield obtained was also reduced similarly.

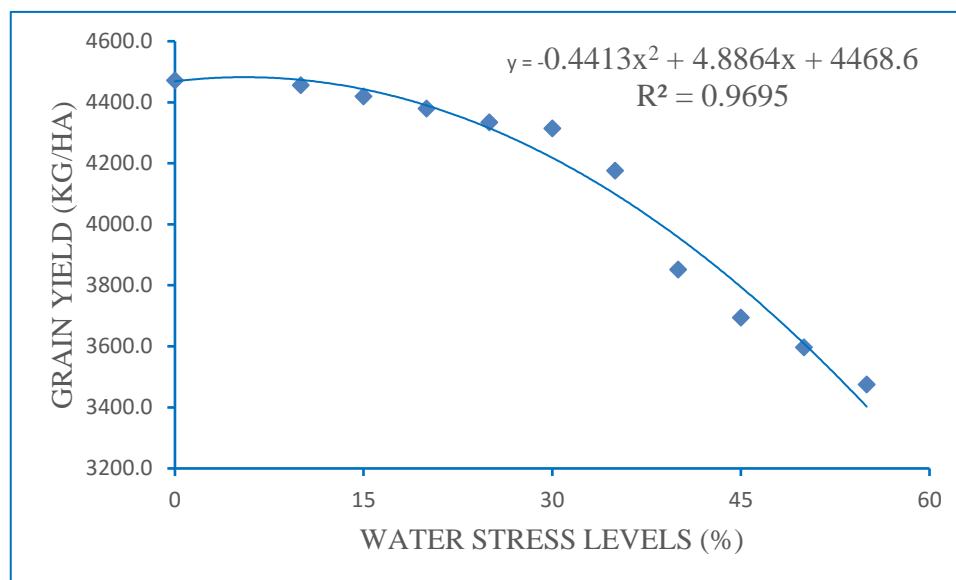


Figure 4.1. Effect of moisture stress levels on grain yield production.

#### 4.8. Correlation between Growth, Yield and Yield Components

The calculated values of Pearson's correlations coefficient (r) between growths, yield, yield components and water use efficiency were presented in (Table 4.10). The result shows that grain yield was highly correlated ( $p < 0.001$ ) with all parameters considered except number of tillers per square meter and harvesting index. Among the parameters considered, the water productivity was negatively correlated with grain yield. This might be due to the increase in water use efficiency lead to a decrease in grain yield.

The correlation analysis showed that there is a strong association between grain yield with yield components with the Pearson coefficient of 0.942, 0.920, 0.903, 0.964, 0.901 and 0.815 for plant height, spike length, number of kernels per spike, above ground biomass, straw yield, and thousand seed weight, respectively. As reported by Rameez *et al.* (2012), grain yield had a positive correlation with thousand seed weight and spike length. This reveals that, the increase in these parameters might lead to enhancement of grain yield. Among these parameters, above ground biomass had the highest positive

direct effect on grain yield followed by plant height, spike length and number of kernel per spike. Moreover grain yield and water use efficiency were negatively associated with strong Pearson correlation coefficient ( $r = -0.830$ ) at  $p < 0.001$ .

Water use efficiency had a negative effect on yield in which improving water use efficiency could not be achieved without compromise by a reduction in grain yield. This might be due to the reduction of irrigation water depth for the deficit treatments enhances the water use efficiency and reduce grain yield as the moisture stress level increased.

On the other hands, the straw yield was significantly ( $p < 0.001$ ) correlated positively with plant height, spike length, number of kernels per spike, above ground biomass, grain yield and thousand seed weight with a Pearson correlation coefficient of 0.941 ,0.786, 0.836 ,0.984, 901 and 0.776, respectively (Table 4.10). The data shows that as the parameter like plant height, spike length, number of kernels per spike, aboveground biomass, grain yield and thousand seed weight increased, the straw yield production was improved. But, straw yield was significantly ( $p < 0.001$ ) correlated negatively with water use efficiency and harvesting index.

Furthermore, water use efficiency was correlated negatively with all the parameters except harvesting index. This might be due to the enhancement of water productivity was with a compromise with reducing the yield and yield components due to the reduction of irrigation water amount. Blum (2009) reviewed different research works and explains plant water deficit results in high water use efficiency. However, this is not an all-time event and water use efficiency may vary due to different factors like environment, crop type and variety, water stress condition and crop growth stage in which moisture stress happen. The result of this study was in line with the result reported by Elias *et al.* (2017).

Table 4.10. Pearson's correlation coefficient of yield and yield components of wheat as affected by under different moisture stress levels

	Ph	SL	NTM	ABM	Gy	Sy	NKS	TSW	HI	WUE
PH	1	0.904***	0.473**	0.965***	0.942***	0.941***	0.901 ***	0.819***	-0.081ns	-0.898***
SI		1	0.272 <sup>ns</sup>	0.861***	0.920***	0.786***	0.932***	0.772***	0.218ns	-0.818***
NTM			1	0.409*	0.317 <sup>ns</sup>	0.455**	0.307 <sup>ns</sup>	0.223 <sup>ns</sup>	-0.345*	-0.376*
ABM				1	0.964***	0.984***	0.884***	0.812 ***	-0.129 <sup>ns</sup>	-0.869***
Gy					1	0.901***	0.903***	0.815***	0.137 <sup>ns</sup>	-0.830***
Sy						1	0.836***	0.776 ***	-0.305 <sup>ns</sup>	-0.862***
NKS							1	0.793***	0.065 <sup>ns</sup>	-0.893***
TSW								1	0.032 <sup>ns</sup>	-0.830***
Hi									1	0.139ns
WP										1

\*\*\*= very highly significant (p<0.001), \*\*= highly significant (p<0.01),\*= statistically significant (p<0.05) and ns= not significant (p>0.05). Ph: Plant height, SL: Spike length, NTM: Number of tillers per square per meter, ABM Aboveground biomass, GY: Grain yield, SY straw yield, NKS: Number of kernels per spike, TSW: Thousand seed weight, HI: Harvesting index, and WUE: Water use efficiency.

## **5. SUMMARY, CONCLUSION AND RECOMMENDATION**

### **5.1. Summary of Finding**

In semi- arid of Ethiopia, with limited water resources and increasing demand for water combined with high evapotranspiration rates limits the production and productivity of the crop. Hence, improving water productivity represents a major issue for agricultural water management and subsequently sustainable crop production. Therefore, adaptation of economically sound and scientifically recognized techniques is required to improve water productivity. Deficit irrigation could be one of the most desired management practices to meet water scarcity and its consequences. In view of this the experiment was conducted to examine the response of wheat yield and yield components under moisture stress area of Gewane woreda. The aim was to identify optimum moisture stress level for wheat in the area.

The treatment comprised of one control (100%ETc) and ten deficit levels namely (90, 85, 80, 75, 70, 65, 60, 55, 50 and 45%ETc). The 100% ETc irrigation indicated the amount of irrigation water applied in accordance with the estimated crop reference evapotranspiration with the aid of CROPWAT (8.0 Version) software on daily basis. While the rest treatments received lower percentage of the full irrigation depending on their stress levels. Wheat variety Fentale-2 was used as testing crop. The treatments were assigned in each plot and laid out in randomized complete block design with three replication.

Crop growth, yield and yield components such as days to booting, days to heading, day to maturity, plant height, spike length, number of kernel per spike, aboveground biomass, grain yield, straw yield, thousand seed weight, harvesting index and yield response factor were tested. Beside this the water productivity associated with irrigation treatments were also evaluated considering crop water use efficiency.

Analysis of variance showed that, moisture stress levels affect the phenology of wheat in which days to physiology maturity were varied. The result reveals that, reducing the application of irrigation water from 100% ETc to 45% ETc leads to earlier physiological maturity of wheat by six days.

Moreover, crop growth parameters like plant height and spike length were significantly reduced. Plant height and spike length were reduced from 84.6 cm to 68.5cm and from 8.4 cm to 7.3 cm respectively, due to the reduction of irrigation water from 100 to 45% ETc. Whereas, the yield components like number of kernels per spike and thousand seed weight were reduced from 42.7 to 33.6 and 33.4g to 29.6g as the irrigation water reduced from 100 to 45% ETc respectively.

Maximum aboveground biomass of 12541.7 kg/ha was obtained from 100%ETc (no stress) resulted in statistically similar average aboveground biomass with irrigation water application of 90, 85 and 80%ETc. The minimum aboveground biomass of 9615 kg/ha was recorded from the highly stressed treatment (45%ETc). The reduction of irrigation water amount by 55% leads to reduction of aboveground biomass by 23.33%. Maximum grain yield of 4472.2 kg/ha was obtained from 100%ETc, resulted in statistically similar average grain yield up to 70%ETc. While the minimum grain yield of 3475.7 kg/ha was recorded from 45% ETc treatment.

In addition to the effect on yield and yield components, reducing irrigation water application or increasing moisture stress levels leads to improve the water use efficiency. The minimum and maximum water use efficiency of 0.82 kg/m<sup>3</sup> and 1.32 kg/m<sup>3</sup> was observed from 100 and 45% ETc respectively. This showed that, reduction of irrigation water amount by 55% improve water use efficiency by 61.67%. But, the improvement of water use efficiency to this level was associated with grain yield reduction by 22.28%.

However, increasing the irrigated areas with the saved water could compensate for any yield loss due to different moisture stress levels. For instance, the water saved which was about 284.5 mm could be used to irrigate 0.52 ha wheat cropped land or similar crop and 2324.0 kg/ha additional yield that might be produced as a result of saved water.

The minimum and maximum yield response factor of 0.04 and 0.43 was observed at 90% ETc and 45% ETc treatments respectively. This showed that, as the moisture stress levels increased yield response factor was increased gradually. Whereas, the results of correlation analysis showed that all growth, yield and yield components of wheat were positively correlated with grain yield, except water use efficiency.

## **5.2. Conclusion**

Based on climatic data observed from the meteorological station, crop growth stage and kc of the crops the present study showed seasonal water demand of 547.5 mm net irrigation depth used for non-stressed condition (100%ETc). Whereas, for highly stress treatment (45%ETc) 263.0 mm of net irrigation water depth was used.

On the other hands, the present investigation also confirmed that, as moisture stress levels increased the growth parameters, yield and yield components of wheat were decreased except number of tiller per square meter and harvesting index. From the result of ANOVA we have concluded that, the stress levels exerted significant positive effect on growth, yield, yield components and negative with crop water use efficiency of wheat.

Moreover, considering the highest water saving and maximum grain yield obtained, among moisture stress levels irrigation water application at 70% ETc (30% stress) leads to improve the water use efficiency without significantly reducing the grain yield of wheat. Therefore, the moisture stress threshold level of wheat could be at 70%ETc irrigation water application.

## **5.3. Recommendation**

Since, this experiment was conducted in one location for one season using one wheat variety, conducting similar research in over locations and seasons under similar agro-ecological condition involving different varieties would be important to get conclusive result for best recommendation.

However, based on the result obtained from one cropping season the following recommendation can be made

- For non-stressed condition, wheat variety Fentale-2 could be irrigated with net seasonal irrigation depth of 547.5 mm for optimum irrigation (100% ETc) to attain maximum grain yield and aboveground biomass.
- For moisture stressed condition irrigating at 70%ETc of full wheat water requirement could be recommended for conserving water without significant grain yield reduction and improving water use efficiency by 34.63%.

- However, for highly stressed area to improve the water productivity, it could be irrigated to 45%ETc of the full irrigation amount to improve the water use efficiency with a compromise of yield reduction by 22.28% and produce 2324.0kg/ha additional yield by irrigation other crop as a result of saved water.

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## APPENDICES

### List of Tables in the Appendix

Table 1. Long term climatic data of study area from (1995-2018)

Month	Max. Temp. (°C)	Min. Temp (°C)	Rainfall (mm/month )	RH (%)	Sunshine hour (hr)	Wind Speed (m/s)	ETo (mm/day)
Jan	33.9	18.7	9.22	45	8.08	1.4	4.72
Feb	35.9	19.6	12.90	57	8.38	1.5	5.15
Mar	36.2	21.5	35.42	46	8.59	1.6	5.95
Apr	38.5	23.3	42.93	42	8.54	1.6	6.24
May	40.9	24.0	22.21	51	8.76	1.7	6.43
Jun	41.3	26.3	10.05	38	6.60	2.4	7.17
Jul	38.8	24.1	86.06	52	5.87	3.1	6.85
Aug	36.2	23.0	95.51	64	6.63	2.6	5.83
Sept	37.7	23.4	50.54	58	6.99	1.8	5.65
Oct	37.3	21.3	23.00	45	8.41	1.5	5.69
Nov	35.0	19.5	12.64	47	8.72	1.5	5.14
Dec	33.9	18.6	8.53	56	7.72	1.4	4.43

Source: Gewane Meteorological station located at (Latitude 10.08°N, Longitude 40.63°E and 568 masl).

Table 2. The Kc values for wheat during the growing season

Date	Kc	Date	Kc	Date	Kc	Date	Kc
1	0.37	29	0.81	57	1.15	85	1.15
2	0.37	30	0.84	58	1.15	86	1.13
3	0.37	31	0.87	59	1.15	87	1.12
4	0.37	32	0.90	60	1.15	88	1.10
5	0.37	33	0.93	61	1.15	89	1.08
6	0.37	34	0.96	62	1.15	90	1.06
7	0.37	35	0.99	63	1.15	91	1.05
8	0.37	36	1.03	64	1.15	92	1.03
9	0.37	37	1.06	65	1.15	93	1.01
10	0.37	38	1.09	66	1.15	94	1.00
11	0.37	39	1.12	67	1.15	95	0.98
12	0.37	40	1.15	68	1.15	96	0.96
13	0.37	41	1.15	69	1.15	97	0.94
14	0.37	42	1.15	70	1.15	98	0.93
15	0.37	43	1.15	71	1.15	99	0.91
16	0.40	44	1.15	72	1.15	100	0.89
17	0.43	45	1.15	73	1.15	101	0.87
18	0.46	46	1.15	74	1.15	102	0.86
19	0.49	47	1.15	75	1.15	103	0.84
20	0.53	48	1.15	76	1.15	104	0.82
21	0.56	49	1.15	77	1.15	105	0.81
22	0.59	50	1.15	78	1.15	106	0.79
23	0.62	51	1.15	79	1.15	107	0.77
24	0.65	52	1.15	80	1.15	108	0.75
25	0.68	53	1.15	81	1.15	109	0.74
26	0.71	54	1.15	82	1.15	110	0.72
27	0.74	55	1.15	83	1.15		
28	0.78	56	1.15	84	1.15		

Table 3. Root depth of wheat within growing season

Date	Root Depth (m)	Date	Root Depth (m)	Date	Root Depth (m)	Date	Root Depth (m)
1	0.30	29	0.79	57	1.00	85	1.00
2	0.32	30	0.81	58	1.00	86	1.00
3	0.34	31	0.83	59	1.00	87	1.00
4	0.35	32	0.84	60	1.00	88	1.00
5	0.37	33	0.86	61	1.00	89	1.00
6	0.39	34	0.88	62	1.00	90	1.00
7	0.41	35	0.90	63	1.00	91	1.00
8	0.42	36	0.91	64	1.00	92	1.00
9	0.44	37	0.93	65	1.00	93	1.00
10	0.46	38	0.95	66	1.00	94	1.00
11	0.48	39	0.97	67	1.00	95	1.00
12	0.49	40	0.98	68	1.00	96	1.00
13	0.51	41	1.00	69	1.00	97	1.00
14	0.53	42	1.00	70	1.00	98	1.00
15	0.55	43	1.00	71	1.00	99	1.00
16	0.56	44	1.00	72	1.00	100	1.00
17	0.58	45	1.00	73	1.00	101	1.00
18	0.60	46	1.00	74	1.00	102	1.00
19	0.62	47	1.00	75	1.00	103	1.00
20	0.63	48	1.00	76	1.00	104	1.00
21	0.65	49	1.00	77	1.00	105	1.00
22	0.67	50	1.00	78	1.00	106	1.00
23	0.69	51	1.00	79	1.00	107	1.00
24	0.70	52	1.00	80	1.00	108	1.00
25	0.72	53	1.00	81	1.00	109	1.00
26	0.74	54	1.00	82	1.00	110	1.00
27	0.76	55	1.00	83	1.00		
28	0.77	56	1.00	84	1.00		

Table 4. Climatic data and calculated ETo of December 2019

Ethiopian Agrometeorological Service							
Station Gewane		Month December			Year 2020		
Date	Temp (°C)		RH (%)	RF (mm)	Wind speed (m/s)	Sunshine (hr /day)	ETo (mm/day)
	Min	Max					
13	18.0	35.0	53	0.0	2.3	10.4	5.72
14	22.7	35.5	47	0.0	1.8	8.9	5.54
15	22.5	34.0	50	0.0	2.1	10.7	5.69
16	21.6	35.0	45	0.0	1.8	10.2	5.52
17	22.5	35.6	44	0.0	2.1	10.4	5.95
18	21.8	36.3	55	0.0	2.2	10.8	5.89
19	19.0	35.0	46	0.0	2.4	10.6	6.05
20	19.6	35.6	50	0.0	1.9	10.2	5.52
21	19.6	34.7	51	0.0	2.3	10.3	5.75
22	23.5	35.0	42	0.0	2.4	10.3	6.25
23	20.0	36.6	44	0.0	1.9	9.5	5.65
24	22.5	34.0	42	0.0	1.8	9.8	5.45
25	22.5	35.5	45	0.0	1.9	9.8	5.63
26	22.4	35.0	51	0.0	1.7	10.5	5.40
27	22.6	36.0	51	0.0	1.6	9.3	5.21
28	23.0	36.4	50	0.0	1.8	10.3	5.64
29	22.0	34.6	48	0.0	1.7	8.7	5.12
30	23.5	37.0	43	0.0	1.5	10.2	5.49
31	22.0	35.5	50	0.0	1.9	10.6	5.67
Average	21.6	35.4	47.7	0.0	2.0	10.1	5.6

Table 5. Climatic data and calculated ETo of Jan 2020

Ethiopian Agrometeorological Service							
Station Gewane		Month January			Year 2020		
Date	Temp (°C)		RH (%)	RF (mm)	Wind speed (m/s)	Sunshine (hr/day)	ETo (mm/day)
	Min	Max					
1	22.0	35.5	53	0.0	2.2	10.1	5.76
2	23.0	35.8	50	0.0	1.8	9.8	5.51
3	24.0	36.0	47	0.0	2.0	9.8	5.82
4	22.6	36.0	46	0.0	1.8	10.6	5.74
5	23.2	35.6	43	0.0	1.7	10.5	5.60
6	22.5	35.6	54	0.0	2.1	9.8	5.66
7	24.0	35.0	48	0.0	1.9	10.2	5.70
8	22.3	35.4	45	0.0	1.8	9.8	5.58
9	21.0	35.6	48	0.0	1.5	10.6	5.37
10	22.0	35.6	42	0.0	1.7	10.4	5.67
11	23.6	34.0	52	0.0	2.4	9.6	5.83
12	20.0	32.0	61	TR	1.8	8.4	4.65
13	20.6	33.3	50	0.0	1.5	8.9	4.87
14	20.0	32.0	58	0.0	1.7	10.2	4.98
15	19.5	34.0	47	0.0	1.8	9.3	5.31
16	20.5	33.6	42	0.0	1.5	10.5	5.29
17	14.6	32.8	45	0.0	1.4	10.8	5.19
18	15.0	33.0	41	0.0	1.8	10.9	5.49
19	17.6	34.0	45	0.0	2.2	10.2	5.85
20	19.5	33.0	46	0.0	1.7	9.8	5.27
21	22.6	33.5	44	0.0	1.6	10.6	5.58
22	20.0	33.5	47	0.0	1.6	9.7	5.23
23	22.0	32.5	53	0.0	1.8	9.8	5.35
24	22.4	33.4	57	0.0	2.1	9.4	5.43
25	23.0	34.2	48	0.0	1.7	8.8	5.33
26	22.2	34.2	45	0.0	1.4	7.6	4.86
27	22.5	28.5	65	0.0	1.5	0.3	2.81
28	23.0	32.6	59	0.0	1.6	1.4	3.49
29	20.5	33.4	46	0.0	1.6	7.6	4.97
30	20.0	34.0	52	0.0	1.6	7.3	4.84
31	20.5	33.5	45	0.0	1.5	8.2	5.12
Average	21.2	33.9	49.2	0.0	1.8	9.1	5.2

Table 6. Climatic data and calculated ETO of Feb 2020

Ethiopian Agrometeorological Service							
Station Gewane		Month February				Year 2020	
Date	Temp (°C)		RH (%)	RF (mm)	Wind speed (m/s)	Sunshine (hr/day)	ETo (mm/day)
	Min	Max					
1	21.2	34.0	51	0.0	1.5	6.2	4.62
2	23.2	34.2	59	0.0	2.1	7.4	5.18
3	23.5	33.0	45	0.0	1.9	9.8	5.76
4	23.0	34.4	46	0.0	2.0	7.6	5.56
5	21.6	35.5	52	0.0	1.8	10.2	5.81
6	21.5	35.5	52	0.0	1.7	6.2	4.95
7	21.5	35.5	51	0.0	1.5	5.6	4.69
8	21.2	36.0	48	0.0	1.7	8.6	5.56
9	20.0	35.4	39	0.0	1.4	8.4	5.28
10	21.0	35.0	51	0.0	1.3	10.5	5.45
11	22.4	35.0	57	0.0	2.2	6.4	5.27
12	21.5	33.5	69	TR	1.0	0.1	2.66
13	21.0	31.0	70	0.0	1.6	2.8	3.43
14	20.5	33.0	49	0.0	1.7	6.6	4.95
15	17.3	35.2	48	0.0	1.5	10.2	5.60
16	19.0	37.0	44	0.0	1.5	10.4	5.91
17	22.5	38.0	48	0.0	2.0	10.4	6.56
18	23.0	37.0	54	0.0	1.9	9.8	6.13
19	23.5	38.0	50	0.0	1.5	10.5	6.13
20	23.0	36.5	50	0.0	1.6	10.7	6.11
21	22.5	36.6	55	0.0	1.7	9.8	5.93
22	24.4	35.6	54	0.0	2.1	8.4	5.93
23	23.0	36.0	48	0.0	2.4	10.2	6.73
24	22.0	37.0	42	0.0	2.0	8.4	6.26
25	21.5	38.8	39	0.0	2.4	10.3	7.34
26	24.6	36.5	39	0.0	1.8	10.2	6.51
27	23.6	35.0	53	0.0	1.7	3.4	4.53
28	22.6	37.5	37	0.0	1.4	8.2	5.72
Average	22.0	35.6	50.0	0.0	1.7	8.1	5.5

Table 7. Climatic data and calculated ETO of March 2020

Ethiopian Agrometeorological Service							
Station Gewane		Month March			Year 2020		
Date	Temp (°C)		RH (%)	RF (mm)	Wind speed (m/s)	Sunshine (hr /day)	ETo (mm/day)
	Min	Max					
1	23.6	38.5	32	0.0	1.5	5.8	5.58
2	22.4	38.0	36	0.0	1.2	9.8	5.84
3	23.0	38.4	42	0.0	1.9	8.8	6.48
4	24.2	38.4	39	0.0	1.7	9.3	6.45
5	24.4	39.0	31	0.0	1.6	8.7	6.38
6	25.0	39.5	35	0.0	1.4	9.2	6.24
7	25.2	39.2	40	0.0	1.9	10.0	6.96
8	24.2	38.0	37	0.0	1.9	10.2	6.90
9	24.6	36.6	45	0.0	2.2	8.4	6.54
10	25.0	37.5	41	0.0	2.5	8.2	7.05
11	24.5	37.0	36	0.0	2.4	6.2	6.66
12	23.0	38.5	34	0.0	2.2	9.8	7.30
13	22.0	38.5	42	0.0	2.5	9.8	7.40
14	24.0	38.0	51	0.0	2.8	8.5	7.06
15	25.0	38.0	47	0.0	2.1	3.8	5.56
16	25.8	37.5	50	0.0	2.2	2.2	5.15
17	23.5	38.5	46	0.0	2.2	4.7	5.94
18	26.0	38.0	55	TR	1.6	4.8	5.11
19	20.0	37.0	58	0.0	1.2	8.8	5.49
20	25.0	37.0	55	0.0	1.2	5.2	4.77
21	23.6	37.0	61	0.0	2.0	8.2	5.97
22	22.0	35.2	58	0.0	1.4	2.3	4.01
23	21.0	34.5	70	0.0	1.4	4.8	4.27
24	23.0	35.6	50	0.0	1.2	9.3	5.67
25	21.0	34.0	48	0.0	1.3	5.4	4.75
Average	22.8	36.1	43.6	0.0	1.8	7.1	5.8

Table 8. Mean squares of ANOVA for phenological and growth parameter of bread wheat as affected by moisture stress levels

source of variation	degree of freedom	MS			
		Db	Dh	DM	PH
Replication	2	0.64 <sup>ns</sup>	0.64 <sup>ns</sup>	0.27 <sup>ns</sup>	0.57 <sup>ns</sup>
Treatment	10	7.09 <sup>**</sup>	7.09 <sup>**</sup>	14.02 <sup>**</sup>	92.75 <sup>**</sup>
Error	20	0.34	0.34	1.77	2.88

\*\*= highly significant at p<0.01 level of probability, and \*= significant at p<0.05 level of probability and ns= not significant. MS mean square, Db days of booting, Dh, days of heading, DM days to maturity and PH, plant height.

Table 9. Mean squares of ANOVA for growth and yield parameter of bread wheat as affected by moisture stress levels

source of variation	degree of freedom	MS				
		SL	NTM	NKPS	AGBM	GY
Replication	2	0.01 <sup>ns</sup>	52.53 <sup>ns</sup>	1.07 <sup>ns</sup>	5488.92 <sup>ns</sup>	5278.498 <sup>ns</sup>
Treatment	10	0.44 <sup>**</sup>	190.71	31.31 <sup>**</sup>	3292127.29 <sup>**</sup>	556354.05 <sup>**</sup>
Error	20	0.04	216.97	1.78	59334.08	12409.39

\*\*= highly significant at p<0.01 level of probability and \*= significant at p<0.05 level of probability and ns= not significant at p<0.05 level of probability. MS mean square, SL Spike length, NTM number of Tiller per meter square and NKPS number of kernels per spike, AGBM Above ground biomass and GY grain yield

Table 10. Mean squares of ANOVA for growth and yield parameter of bread wheat as affected by moisture stress levels

source of variation	degree of freedom	MS				
		SL	NTM	NKPS	AGBM	GY
Replication	2	0.01 <sup>ns</sup>	52.53 <sup>ns</sup>	1.07 <sup>ns</sup>	5488.92 <sup>ns</sup>	5278.498 <sup>ns</sup>
Treatment	10	0.44 <sup>**</sup>	190.71	31.31 <sup>**</sup>	3292127.29 <sup>**</sup>	556354.05 <sup>**</sup>
Error	20	0.04	216.97	1.78	59334.08	12409.39

\*\*= highly significant at p<0.01 level of probability and \*= significant at p<0.05 level of probability and ns= not significant at p<0.05 level of probability. MS mean square, SL Spike length, NTM number of Tiller per meter square and NKPS number of kernels per spike, AGBM Above ground biomass and GY grain yield

Table 11. Mean squares of ANOVA for yields and yield components of bread wheat as affected by moisture stress levels

source of variation	degree of freedom	MS			
		STY	TSW	HI	WP
Replication	2	543.163 <sup>ns</sup>	0.45 <sup>ns</sup>	0.14 <sup>ns</sup>	0.00 <sup>ns</sup>
Treatment	10	1154634.31 <sup>**</sup>	5.67 <sup>**</sup>	0.42 <sup>ns</sup>	0.12 <sup>**</sup>
Error	20	60928.15	0.6	1.63	0

\*\*= highly significant at p<0.01 level of probability and \*= significant at p<0.05 level of probability and ns= not significant at p<0.05 level of probability. STY Straw yield, TSW thousand seed weight, HI harvest index and WP water productivity

Table 12. Additional area and yield obtained as result of saved water

Treatment	Seasonal irrigation requirement (mm)	Yield obtained (kg/ha)	saved water (mm)	Additional area (ha)	Yield obtained (kg/ha)
100%ETc	547.5	4472.2	0	0	
90%ETc	495.8	4456.0	51.7	0.01	51.7
85%ETc	469.9	4419.6	77.6	0.14	633.8
80%ETc	444.0	4379.1	103.5	0.19	845.1
75%ETc	418.2	4334.5	129.3	0.24	1056.4
70%ETc	392.3	4314.2	155.2	0.28	1267.7
65%ETc	366.4	4176.5	181.1	0.33	1478.9
60%ETc	340.6	3852.4	206.9	0.38	1690.2
55%ETc	314.7	3694.4	232.8	0.42	1901.5
50%ETc	288.9	3597.2	258.7	0.47	2112.8
45%ETc	263.0	3475.7	284.5	0.52	2324.0

## APPENDIX FIGURES



Figure 1. During soil sample taken for moisture content test.



Figure 2. During land preparation and Parshall flume installation in the main canal



Figure 3. After land preparation and during sowing



Figure 4. During common and after 1st irrigation



Figure 5. Image taken during weeding



Figure 6. Image taken during head formation and supervision



Figure 7. Image taken during irrigation



Figure 8. Image taken during it start physiological maturity



Figure 9. Image taken after phonological maturity



Figure 10. Image taken during threshing and cleaning



Figure 11. Image taken during counting and weighting thousand seed weight

## **BIOGRAPHICAL SKETCH**

The author was born in Oromia region, Arsi zone, Hamda Diksis woreda in 1988 from his father Rube Hamid and his mother Gabo Siraj. He attended his primary school at Sude elementary school at Sude Woreda. He also attended his secondary and preparatory education at Hamda Diksis and Huruta town respectively. He joined Adama Science and Technology University Asella Campus in October 2010 and graduated with BSc degree in Land and Watershed Management in July 2012. He have been joined Ethiopian Federal Agricultural Technical and Vocational Training College on October 25/2014 as junior instructor of Soil and Water Conservation at Gewane Agricultural Technical Vocational and Educational Training College. After serving two year he joined the School of Graduate Studies of Hawassa University Institute of Technology in July 2016 to pursue his MSc Degree in Water Resource Engineering and Management.