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Growth and Yield Performance of Wheat (*Triticum aestivum* L.) to under Water Stress Conditions

Tamirat Wato

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ABSTRACT

Background: Drought is one of the most important abiotic factors that limit the growth and development of plants all over the world. In Ethiopia, wheat is the second most important crop and occupies third in total production in the African countries. Low productivity as compared to the national production scale is due to water stress. The present work aimed to study the effect of water stress on the growth and yield performance of wheat.

Methods: The experiment was conducted in an exceeding greenhouse at East Gojjam Zone, Debre Markos University in 2017-2018 to assess the effects of wheat to water stress applied at different growth stages. The experiment comprised of two water stress treatments, maintained by withholding water at tillering, anthesis and at each stage. Different growth and yield performance data were collected and analyzed by SAS software.

Result: Water stress caused a reduction in leaf relative water contents, water potential, osmotic potential, turgor potential, growth and yield components of the wheat. The results indicated that successive stress at growth stages caused a severe reduction in vegetative growth parameters of wheat. Therefore, the results indicated that the high value of relative water content was related to exaggerated yield and its components of crops. The water-stressed treatment has reduced the growth and yield performance of wheat than unstressed treatments. This was due to a reduction in the osmotic activities of plants.

Key words: Relative water content, Water stress, Wheat, Yield performance.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one in all the foremost important cereal crops, it is the staple diet for over one-third of the world population and contributes a lot of calories and protein to the world diet than the other cereal crop (Ashrafi and Morad, 2014). In Ethiopia, wheat is a widely cultivated cereal crop. It's cultivated under rainfed conditions and also the area close to the tail end of canals wherever the shortage of water is commonly skilled.

Drought/water stress, salinity and diseases are the foremost serious threats to its productivity. Globally, water stress is one of the most important factors in arid and semi-arid areas of the globe that limits the crop yield and its elements (Dar and Ram, 2016). Hence, drought/water deficit is determined in irrigated areas because of the lean offer of water and canal closure (Hafeez *et al.,* 2003). It affects each aspect of plant growth and also the yield by modifying the anatomy, morphology and physiology (Hafiz *et al.,* 2004). Development of cultivars with high yield is the main goal in water-limited environments, however, success has been modest because of the variable nature of drought (Yaseen, 2018) and also the quality of genetic management of plant responses (Fahad *et al.,* 2017). The yield of wheat is quite low in such areas due to a shortage of water (Ashrafi and Morad, 2014).

The response of plants to water stress depends on several factors such as developmental stage, severity and duration of stress and cultivars genetics (Beltrano and Marta, 2008). Drought stress may occur throughout the growing season, early or late season, but its effect on yield reduction is high when it occurs after anthesis (Nouri-Ganbalani *et al.,* 2009). Drought stress after anthesis usually results in smaller grain size (Jamieson *et al.,* 1995) both from direct effects on the grain and also because of accelerated flag leaf senescence.

Department of Plant Science, College of Agriculture and Natural Resource P.O. Box 334, Bonga University, Ethiopia

Corresponding Author: Tamirat Wato, Department of Plant Science, College of Agriculture and Natural Resource P.O. Box 334, Bonga University, Ethiopia Email: tamiratwato1@gmail.com

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Morphological characters such as root length, spike density, grain number per spike, 1000-gain weight, (Moustafa *et al.,* 1996; Akbari *et al.,* 2012), physiological traits such as rate of root respiration and phenological characters like the number of days to heading, anthesis and maturi-ty affect wheat tolerance to the moisture shortage in the soil (Plaut, 2004; Akbari *et al.,* 2012). Water stress mainly affects the morphology and metabolic processes of the plant.

The extent of modification depends upon the cultivars, growth stage, duration and intensity of stress (Araus *et al.,* 2002; Mark and Antony, 2005; Akbari *et al.,* 2012). Water stress at anthesis reduces pollination and thus a smaller number of grains are formed per spike which results in the reduction of grain yield (Ashraf, 1998; Ahmed *et al.,* 2017).

Some crop growth stages can cope-up with water shortage very well, while others are more susceptible and water shortages at such stages may result from the highest yield losses. The overall effect of moisture stress depends on the intensity and length of stress (Bukhat, 2005). Water stress imposed during later stages might additionally cause a reduction in the number of kernels/ear and kernel weight (Gupta *et al.,* 2001; Ahmed *et al.,* 2017). Plants under normal and agricultural situations are exposed to stress continually. Drought limits plant growth and field crop production more than any other environmental stress (Zhu, 2002). According to Abdoli *et al.* (2015) who reported that drought is the most common environmental stress affecting about 32% of the 99 million hectares under wheat cultivation in developing countries and at least 60 million hectares under wheat cultivation in developed countries.

The combined effects of heat and drought on yield are more detrimental than the effects of each stress factor alone (Abdoli *et al.,* 2015), as seen in barley (Savin and Nicolas, 1996) and wheat (Prasad *et al.,* 2011; Mohsen *et al.,* 2015). These two stress factors induce many biochemical, molecular and physiological changes and responses that influence various cellular and whole plant processes that affect crop yield tolerance and quality (Mohsen *et al.,* 2015). Some studies suggest that drought stress influences the thermal of photosynthesis (Lu and Zhang, 1999; Mohsen *et al.,* 2015).

Ethiopia is one of the most important producers of wheat in Sub-Saharan Africa with an area of 1.95 million hectares. Despite its mentioned importance, total area and productions, its yield is very low (22.42 Qt/ha) (CSA, 2015/16) compared with the typical production area. This can be because of different factors like drought/water stress, lack of improved cultivars, different agroecology, diseases and bug pests. Among the factors one is water stress, it highly affects the expansion and development of the crops. Hence, economical and purposeful utilization of water is very important underwater shortage conditions. Therefore, the main objective of this study was to study the effect of water stress on the growth and yield performance of wheat.

MATERIALS AND METHODS

Description of experimental site

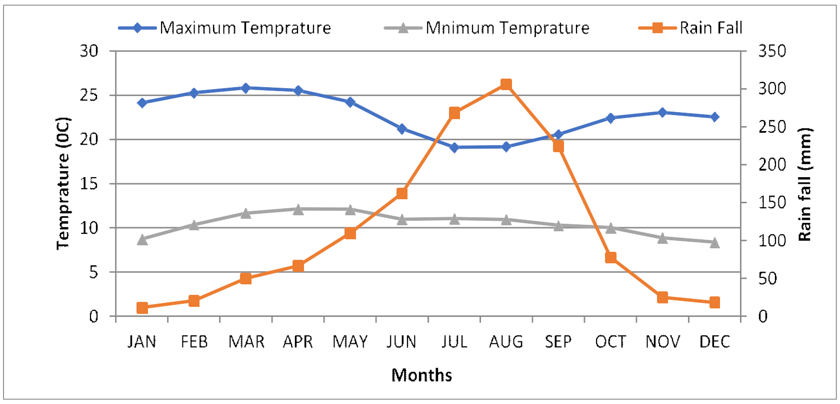
The experiment was conducted under the rain-fed condition at Debre Markos University research farm during the main cropping season of 2017-2018. Debre Markos is located in the East Gojjam Zone of Amhara National Regional State, at about 300 km Northwest of Addis Ababa Ethiopia. It is located at 10°20′ _N latitude and 37°43′ _E longitude with an altitude of 2446 m.a.s.l. The seasonal total rainfall of the area during the crop season was 1628 mm, with the average minimum and maximum temperature of 15°C and 28°C respectively (www.dmu.edu.et, Dec/21/2015). According to the Amhara National Regional State Bureau of Agriculture (ANRS, 1999) Report, the soil of the study area was dominantly nitosol.

Experimental design, treatments and materials

The experiment was examined to determine the bread wheat (Shinna (HAR-1868) at water stress applied at different growth stages) with a split-plot completely randomized block design using two treatments. The two treatments were water-stressed and unstressed replicated two times. The bread wheat variety [Shinna (HAR-1868)] was used for the experiment. The experiments were conducted to assess the physiological and growth response of wheat cultivar that was stressed throughout the stem elongation, flowering and grain-filling stages, whereas the management treatment was irrigated to field capacity throughout the season. Different materials were used throughout these practical exercises such as wheat seed, pot, water, soil, petri dish, plaster, Incisor, filter paper and Oven.

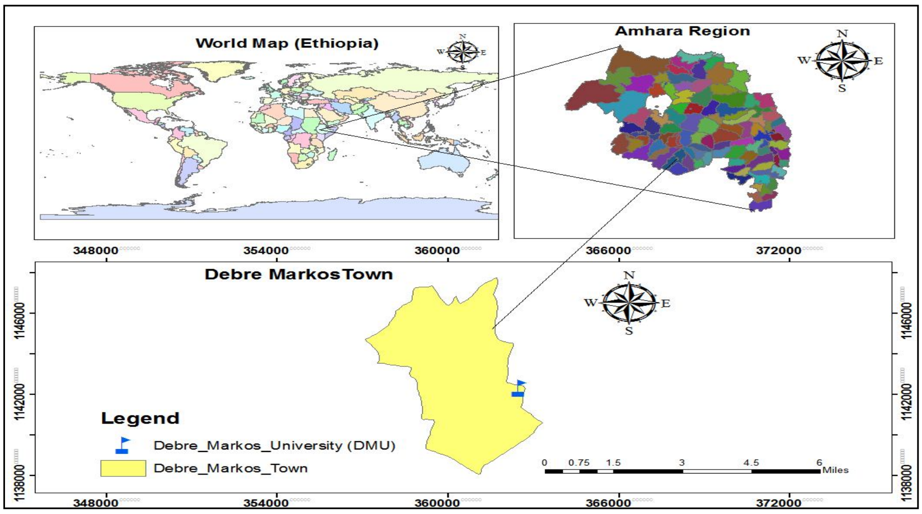
Experimental procedure

The experiment was started by taking three leaf samples from each water unstress and stressed treatments of the experiment when visible water stress symptoms like wilting were observed from each leaf. Then, the fresh weight of each sample was recorded and the sample was labeled. By adding the deionizer water in an airtight container and immersed with the leaf sheath stay for 16 hours in the



Source: Amhara Regional State, Debre Markos Metrological data station (2017/18).

Fig 1: Mean rainfall and temperature of the experimental area from during 30 years (1987-2017/18).



Source: Amhara Regional State, Debre Markos (2017/18).

Fig 2: Map of the study area.

refrigerator. Then, the sample was taken out of the refrigerator and weighed for 2 hours until the water bubble was removed by putting it on absorbent paper and presented as turgid weight. Then, after the sample was kept in an oven-dry at 78°C for 24 hours and after that dry weight was taken by putting the sample on balance. Thus, the relative water content and amount of water deficit was calculated by using the following formula. Finally, the soil moisture content from which the sample was taken is measured using the oven-dry method.

$$RWC = \frac{FW - DW}{TW - DW}$$

Where,

RWC: Relative water content, FW: Fresh weight, TW: Turgid weight, DW: Dry weight.

Soil sampling and analysis

Composite surface soil samples (0-20 cm depth) were collected for determination of physicochemical properties of the soils (soil texture, pH, organic carbon, total nitrogen (N), available phosphorus (P), cation exchangeable capacity and base saturation). The soil samples were air-dried and ground to pass through 0.2 mm sieves and subjected to different soil analysis following standard procedures. Soil pH as described by Jackson (1958) and soil texture by hydrometer method as described by Bouyoucos (1951). Total nitrogen determined by the Kjeldahl method and Available phosphorus was extracted using sodium bicarbonate as a method indicated by Olsen *et al.* (1965). Organic matter content was determined according to Walkley and Black (1934). Available potassium using flame photometer as specified in Jackson (1958).

Cultural practices

To evaluate water stress effects at different growth stages, wheat cultivar Shinna (HAR-1868) was used which was developed in 1999 from Adet Agricultural Research Center (Amahara region). This variety was suggested for irrigated hotter production regionsand is popular among millers. Agronomical practices were applied within the growing seasons. Fertilizers were broadcast as per the soil analysis results: 160 kg N ha^{-1}, 60 kg P ha^{-1} (as superphosphate) and 30 kg K ha^{-1} (as KCl) were applied before planting. Top-dressing of organic compound (urea) was done at different growth stages: 17 kg N ha^{-1} was applied throughout the vegetative stage and 8 kg N ha^{-1} throughout the flag-leaf stage. Seeds were planted with manually in rows spaced 25 cm apart. The entire space of every plot (experimental unit) was 4.5 m^2 associate degreed consisted of 4 rows oriented in an east-west direction. Weeds and diseases were controlled as per requirement and bird nets were accustomed to shield the crop from birds once planting and through the grain-filling stage.

Data collection

To quantify the effects of water stress on bread wheat cultivar, weather-related data, physiological data and development data, soil water content data were collected during the growing season.

Statistical data analysis

The Data were subjected to analysis of variance (ANOVA) procedures by using SAS version 9.3 with a general linear model procedure. Mean separation (mean differences comparison) was undertaken by the Least Significant Difference test at a 5 per cent level of significance.

RESULTS AND DISCUSSION

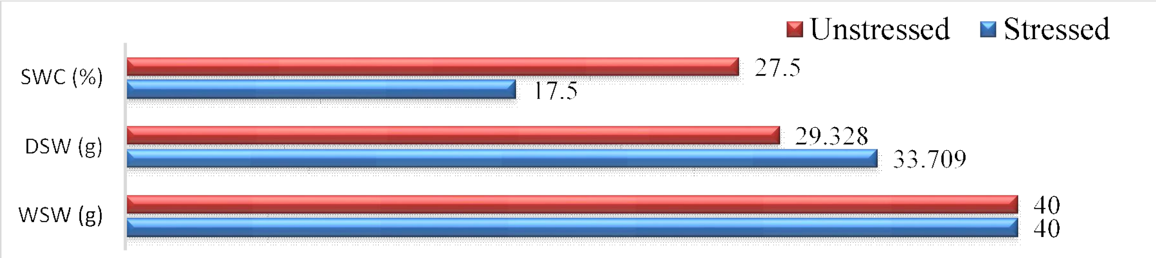
Physicochemical properties of the soil

It reveals that the experimental sites were characterized by a silt loam class (FAO, 1990) which favors the growth and development of wheat and showing moderately acidic in reaction (Tekalign, 1991). It is found in the range of suitability for wheat because it prefers types of soil with pH ranging

Table 1: Pre-sowing Physico-chemical properties of soil in the experimental site.

Type of test	Chemical properties							Physical properties			
								Particle size distribution (%)			
	pH	OC (%)	CEC (Meq/100g)	Total N (%)	Av. P (ppm)	K (Meq/100g)	EC	Sand	Silt	Clay	Textural class
Soil	7.82	1.55	22.53	0.24	0.59	0.79	11.4	22	58	20	Silty loam

Where, OC: Organic Carbon; TN: Total Nitrogen; Av. P: Available Phosphorus: K: potassium; EC: Electric Conductivity.



WSW: Wet Soil Weight, DSW: Dry Soil Weight and SWC: Soil Water Contents

Fig 3: Average relative water contents of soil samples taken from two treatments (stressed and unstressed).

from slightly acidic to alkaline (pH 5.2 to 8.0) (Rajan *et al.,* 2012). According to Havlin *et al.* (2005), total nitrogen content (TN) of soil can be classified as very low (<0.1%), low (0.1 - 0.15%), medium (0.15-0.25%) and high (>0.25%).

According to this classification, the total nitrogen content of the soils from the study area was found to be medium (0.243%), indicating that the nutrient was not optimum for crop growth. The analysis indicated that the soil has a very low level of available phosphorus (0.598 mg kg^{-1}), which indicates that soils having available content below 5 mg kg^{-1} categorized as very low (Bashour, 2007). It has been reported that the distribution and availability of P in the soil are regulated by biochemical processes and soil pH. According to Landon (1991), while the CEC was 22.530 meq/ 100g soils which are medium value. This indicated that the soil has a relatively medium capacity to hold cations for optimum growth of the crop.

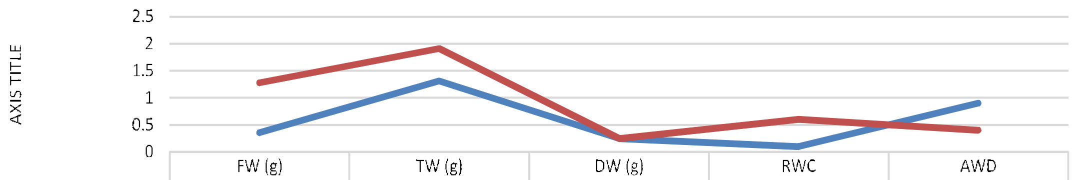
Effects of water stress on growth and yield performance of wheat

Water stress mainly influences the growth and yield performance of wheat. Water stressed plants at the vegetative stage decreased tension than the reproductive stage. Besides, it has also an impact on yield and yield components, yet, since the stress at this stage of development of leaf, stem development, chemical process, leaf and also the accumulation of very important is the impact in the plant.

Plant tissue water content may be expressed in several ways including the amount of water per unit dry or fresh weight and per unit weight of water at full hydration. Fresh weight seems to be less accurate for them to measure tissue water content because is highly influenced by changes in tissue dry weight (Reigosa, 2001). The relative water content (RWC) (Slatyer in 1967) is a useful indicator of the state of the water balance of a plant essentially because it expresses the absolute amount of water that the plant requires to reach artificial full saturation (Reigosa, 2001). Thus, there is a relationship between relative water content and water potential. This relation various significantly according to the nature and age of plant materials.

Fig 3 showed that as able to deduce from the data taken for soil sample from both stressed and unstressed treatment each with initial equal wet weights, the final weight (dry weight of soil sample) after putting it in an oven at 105°C for 12 hours, there was a greater weight loss from unstressed soil sample due to initial high water content of soil sample so, that due to high evaporation. On the other hand, the dry weight of the stressed soil sample there is no so much loss of weight compared to the unstressed soil sample. However, when compared to the relative water content of both soil sample, the stressed soil sample with 17.5% and the unstressed with 27.5% with a difference of relative water content of 10% by which the unstressed soil sample is greater than the stressed soil sample (Fig 3).

Fig 4, showed that plant growth on water-stressed wheat was reduced in fresh weight, turgid weight and dry weight of the leaves. This is caused due to as water content of the soil is decreased rate of transpiration is exceeds the rate of water absorption from the soil because plant becomes stressed, stressed plants reduce in all growth and development due to plant cell is flaccid, cell division and cell elongation are reduced because the cell is not turgid. The present finding conformed with Akram, (2011), they reported that the decrease in plant height and leaf size in response to water stress could be due to a decrease in relative turgidity and dehydration of protoplasm, which is associated with a loss of turgor and reduced expansion of cell and cell division. Moreover, water-stressed has also affected the rate of photosynthesis because of the reduced water source of protons and electrons in photosynthesis reactions (Mohsen *et al.,* 2015). This is in line with Saleem (2003) and Dar and Ram (2016) who reported that a



	FW (g)	TW (g)	DW (g)	RWC	AWD
Stressed	0.351	1.312	0.2445	0.099	0.901
Unstressed	1.278	1.91	0.245	0.6	0.4

Where, FW: Fresh weight, TW: Turgid weight, DW: Dry weight, RWC: Relative water content and AWD: Amount of water deficit.

Fig 4: Average of fresh weight, turgid weight and dry weight of the leaves sample taken from stressed and unstressed treatment.

substantial decline in plant height and leaf size has been reported when irrigation was withheld at the booting stage, however, tolerant genotypes attained more plant height.

CONCLUSION

Water stress is one of the main abiotic stresses that drastically affects the growth and development of the plant. Plants were found to own the capability to regulate environmental conditions, which is typically unstable due to the various environmental factors. Water stress has a forceful effect on the plant growth and yield performance of the wheat crop used in the experiment.

Reduction in plant height or stem elongation, leaf size, flowering and grain filling stage has been determined in all stressed crops within the experiment. The substantial decline in plant height, leaf size and grain filling has been reported once irrigation was withheld at the booting stage, however, water unstressed wheat treatments attained a lot of plant height (Saleem, 2003). Similarly, the decrease in plant height and leaf size in response to water stress can be due to a decrease in relative turgidity and dehydration of protoplasm, which is related to a loss of turgor and reduced enlargement of cell and cell. Furthermore, Fahad *et al.,* (2017) conjointly showed similar responses to wheat crop under water stress conditions. within the present study, water stresses markedly reduced crop growth and reduced shoot biomass decline in growth determined in several plants subjected to water stress is commonly related to a decrease in their photosynthetic capability.

From the results, it was often concluded that water stresses considerably altered the internal water status by decreasing relative water content, water potential and osmotic potential of wheat that consequently decreased the turgor potential. Water scarcity within the field led to adaptive changes in the physiological traits of bread wheat genotypes. Most of the growth parameters vital declines were determined once the stress was obligatory at the vegetative stage, yet, the most reduction within the variety of grains, grain yield and plant height occurred once the stress was imposed at the vegetative and anthesis stage. However, water stress at flowering and grain filling ought to be avoided as they are the foremost important growth stages in yield determination in wheat as a result of plants cannot recover.

Generally, as able to conclude from this experiment, the tissue relative water content of wheat crop was influenced by soil water content. The wheat growth and yield performance have fully grown on water-stressed soil had shown lower fresh weight and dry weight compared with a plant grown on unstressed soil. The stress at each stage of the growth may lead to a reduction in growth and yield performance. Water stress is a major threat to agricultural production and productivity. At any stage of plant development from germination to maturity, plant, water is extremely essential. Thus, the degree of unbalance of water to supply adverse effects on the crop and apply.

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