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The effect of drought stress on *Triticosecale rimpaui* growth and crop yield production

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Profitability and plant development are mostly impaired by drought. Triticale (*X. Triticosecale rimpaui*) is one of the most successful man-made cereals, synthesized to combine unique wheat grain quality with rye's stress tolerance. In this study, *T. rimpaui* plant was exposed to regular water supply (100% FC) and three stages of water shortage (75%, 50%, and 25% FC). Soil properties and growth characteristics of *T. rimpaui* in the vegetative growth stage and agronomical parameters at the crop yield stage under different water gradients were determined. The results showed that the soil's pH value significantly decreased to values lesser than control's only under moderate and severe water deficiency–induced stress conditions. Plant growth and plant pigments content reduced gradually with the increase of drought stress conditions to values lower than that of the control's (100% FC). Soluble carbohydrates and free amino acids' shoot contents were not affected significantly by all studied water stress levels compared with the controls. In the grains, carbohydrates significantly decreased only under moderate and severe water stress conditions. Soluble proteins in the shoots and grains were gradually decreased under all studies' drought levels. It was clear that drought stress less affected triticale's yield when crosschecked with vegetative growth.

Keywords: Drought stress; Triticale; Minerals; Plant growth; Crop yield

INTRODUCTION

Harmful environmental circumstances, e.g., biotic and abiotic strains, immensely harm plant productivity, growth, and food security (Daryanto, 2016, Farooq, M2017)**.** Drought stress is an example of abiotic stress, which is a scenario of low water availability for an extended interval of time. The global population is steadfastly increasing, estimated to exceed 2.4 billion by 2050 (United Nations, 2015). It is imperative to account for this increase in food production and quality up to 70%. Climatic stresses, like drought, cold, heat, and salinity drastically affect plant production worldwide (Wani and Sah, 2014).

Plants responses severally to biochemical, physiological, and molecular influences, which alters their many cellular processes and morphology to content with stresses induced by environmental factors (Ismail, 2020). Drought stress hinders plants' survival, enforcing a decreased growth index in terms of height, biomass, leaf size, and root proliferation (Bai et al. 2006). Many pieces of research exhibited that plants alter their ion balance, metabolic rate, carbon assimilation, enzymatic activity, leaf gasses' exchange, endogenous hormone content, and secretion of osmotic regulating substances, and suffer an increased oxidative damage value due to the threats of droughts (De Souza and Magalhaes, 2013; Sucu et al. 2017). The aforementioned drought-caused disturbances reduce yield (Chowdhury, 2016; Hussain, M 2018).

To guard against drought stress, plant species begin with the anticipation of signals induced due to stress prompted by plant cells. Generally, the signals relate to the cellular signaling pathways and multiple genes that specifically regulate physio-morphological and molecular reactions (Zhu, 2016). Abscisic Acid (ABA) is a vital influencer for multiple factors related to the growth of plants, e.g., germination and dormancy of seeds, embryo maturation, floriation, and growth of roots. Besides, ABA takes part in diminishing the negative plant-related stress effects. Thanks to ABA, plant species are capable of adapting to an ever-changing environment while maintaining under-drought physiological processes. The physiological processes of plants can be modulated by the varying expression of different ABA-responsive genes controlling the opening and closing of the stomatal aperture (Zhu, 2002; Dong, 2015). Due to drought-caused stress, the plant leaf stomata contract (Mehri et al. 2009; Ji et al. 2014). Moreover, some adaptive alterations take place in the structure of the plant leaf, e.g., diminished leaf moisture content and thickness, thusly improving the capacity of water retention capacity and photosynthesis and reducing transpiration (Cao et al. 2018).

Triticale (X *Triticosecale Wittmack*) is a cross between A and B wheat genomes (*Triticum turgidum* L., *Triticum aestivum* L.) and the rye genome R (*Secale cereale* L.), developed to combine the superior quality and bountiful yield of commercial wheat with the rye's stress tolerance and disease resistance (Zillinsky, 1974). Triticale crossing can be traced back to Wilson in 1876. Some modern triticale cultivars can compete with wheat when a concerted effort to sustain research is exerted (Mergoum et al. 2004). Tests on specific classes of marginal soils show that triticale can prevail over the best wheat cultivars (Mergoum et al. 2004). Triticale can have a spring, winter, or facultative growth habit and can resemble wheat or rye in appearance (Mergoum et al. 2009).

Triticale could immensely contribute to the now prominent healthy food market by availing new cereal products. Triticale's chemical composition seems to incline toward wheat more than rye. With wheat as a reference, triticale possesses somehow higher levels of the majority of nutritious compounds. One of triticale's renowned features is its content of protein (Stankowski et al. 2017); triticale's protein content exceeds that of wheat, with a more beneficial essential amino acid balance. These features are beneficial for poultry and swine industries, rendering triticale more nutritionally valuable than wheat despite its baking characteristics (Gatel et al. 1985). Triticale can act as a baking supplement with wheat because of its minimal content of gluten (McGoverin et al. 2011). Triticale grain's starch content resembles that of wheat, and it is present in higher quantities than rye's (61%, 60%, and 54%DM) (USDA, 2018). Triticale can even be used in brewing and there is potential for increased use with further breeding (Glatthar et al. 2005).

Plants' reactions to drought stress vary, and thus they demonstrate differing drought resistance (Chen et al. 2013; Ghane and Nikam, 2017). Therefore, the aim of this study emphasizes the evaluation of triticale tolerance under drought stress during various growth stages to assess the effect of different drought levels on triticale vegetative growth and crop yield production.

MATERIALS AND METHODS

2.1 Experimental Design

This study occurred at King Abdulaziz University Experimental Station, Saudi Arabia, in winter (October–January) of 2019, which inclines toward moderate temperatures and minimal humidity. During the experiment, the average daily maximum temperature was 37.13ºC daily minimum temperature was 19.08ºC. There was no rainfall during the timeframe of the experiment. Seeds of *Triticosecale rimpaui* were sown in pots carrying 5 Kg homogenously mixed sand and clay soil (2:1) and irrigated with tap water using field capacity. After the appearance of the third true leaf, six homogenous plants were left in each pot. Then, the pots were divided into four sets; these sets were irrigated with tap water at control parameters (100%), 75%, 50%, and 25% from field capacity, respectively. The experiment was conducted in a Randomized Complete Block Design in three replicates. Plant samples were gathered at two different growth stages after one month of drought treatment for vegetative growth analysis and after 3.5 months for agronomy parameters.

2.2 Soil Analysis

Following the end of the period of the experiment, 10 g of soil from each treatment was extracted in flasks containing10 ml of distilled water. The flasks were shaken overnight to mix their contents. Using a filter paper, the mixtures were then filtered to displace the liquid from the soil, the latter being then used for the soil pH and electrical conductivity measurements.

Soil pH:

A pH meter (Mettler Toledo AG) was used to gauge the level of pH of the solution according to Conklin (**2005**).

Soil Electrical Conductivity (EC):

An EC meter was utilized to evaluate the electrical conductivity for soil extracts using decmins/m as a concentration for soil anions following the method of Page et al. (1982).

Soil Moisture:

Soil water content was measured according to the method provided by Yousef (1999) and Conklin (2005). Soil samples (100 g) were placed in an oven at 105°C for 24 hours. The samples were subsequently weighed before being placed in the oven again to dry further. The soil samples were repeatedly oven dried until no further change in weight was observed. The following formula was used to calculate the amount of water in the soil sample:

$$\left[\frac{\text{Wet soil (g)} - \text{Dry soil (g)}}{\text{Wet soil (g)}}\right] \times 100$$

2.3 Plant Analysis at Vegetative Growth Stage

After one month of drought treatment, plant samples were collected and transported to the laboratory for the following analysis:

Plant Growth

The samples were washed with distilled water and gently dried with tissue paper. Freshly harvested shoots and roots were weighed and recorded after two hours for each experiment plant, three replicate each. Shoot and root lengths (cm) were measured using a ruler. Root volume was measured according to Asanoah's method (1984). The volume of water residing in the cylinder was gauged before and after immersing the roots into the cylinder. The roots' volume was gauged as follows: root volume = volume of the water after immersing the roots into the cylinder – volume of the water before immersing the roots. Leaf area (cm^2) was determined according to Larcher's (1995) method using the following equation:

Leaf Area = RLB.

Where R= coefficient determined by a correlation of L and B of the plant leaf, L= Leaf length, and B = maximum leaf breadth.

Then, the samples were wrapped in foil paper and oven dried by JSON-100 Natural Convection Oven at 70℃ for 48 hours until each sample reached a constant weight, allowing the determination of the dry weight.

Photosynthetic Pigments

Chlorophylls and carotenoids concentrations were measured with UV-VIS spectroscopy according to Lichtenthaler (1987) in ethanol extracts at 60°C with some modifications by Su et.al (2010).

Soluble Carbohydrates

The soluble carbohydrate content in the plant shoots was estimated by colorimetric anthrone method where carbohydrates are dehydrated, by concentrated sulphuric acid to form furfural which condenses with anthrone reagent to give a green color (Fales, 1951; Sctilegel, 1956).

Soluble Proteins

Soluble protein content in the shoot extracts was estimated according to the Lowry method for protein quantitation (Lowery et al., 1951).

Total Free Amino Acid

Free amino acid content in the shoot extracts was estimated per the method of Moore and Stein,1948.

2.4 Minerals Analysis

For each treatment, dry soil, shoots, and root samples were used to determine the mineral nutrients contents. Phosphorus, potassium, calcium, magnesium, and sodium concentration (mg/l) was measured using the atomic absorption spectrometer at the Analytical Chemistry Unit (ACAL), RICI MAAZ Chemical & Environmental Testing Laboratory, Dammam.

2.5 Crop Yield Parameters

After the conclusion of the experimental period, the number of seeds per six plants (pot), the number of spikes per six plants (pot), and the weight of 100 seeds (g) were determined for each water level. Furthermore, seeds carbohydrates, proteins, and total amino acid contents were determined according to the previous methods.

Statistical Analysis

The outcomes were assayed statistically via the SPSS package software, version 21.0 (SPSS, Chicago, USA). Variances across different water levels were evaluated with a one-way Analysis of Variance (ANOVA), followed by a 5% ($P < 0.05$) significance level post hoc test. The values were represented as the mean of three replicates with their Standard Deviation (SD).

RESULTS

4.1 Soil Properties

Data represented in figure 1 illustrate the influence of varying tiers of water stress on soil pH and EC values and moisture percentage. The value of the soil's pH immensely diminished to be lesser than that of the control's only under moderate (50% FC) and severe (25% FC) water stress conditions (figure 1A). However, soil electrical conductivity was not significantly affected by all studied water stress levels compared with that of the control's as inferred from results shown in figure 1B. Soil moisture percentage significantly decreased under all investigated drought levels, where they were lesser than those of the control's (figure 1C).

4.2 Soil Minerals

The effect of all studied drought conditions on soil minerals content is represented in table 1. No significant effect on all studied water stress levels was recorded on calcium, magnesium, and sodium ions concentration compared with the control soil samples. However, phosphorus and potassium ions concentration significantly increased by about 60.57% and 57.34 % higher than that of controls, respectively, under moderate drought conditions (50%).

4.3 Plant Growth

Figure 2 provides information about drought stress influence on triticale fresh and dry biomass. According to the results represented in figure 2A, shoot and root fresh weight immensely diminished to be less than that of the control under all studied drought levels. Shoots' fresh weight significantly decreased by about 27% at all studied drought levels. However, root FW was gradually decreased by increasing the drought conditions by about 8.14%, 14.22%, and 26.97% less than control's under drought levels of 75%, 50%, and 25% FC, respectively. Additionally, shoots and roots' dry weight decreased gradually by increasing water shortage conditions (figure 2B). Shoots DW decreased by about 25.97%, 38.96%, and 57.14% less than control's to be fewer than 75%, 50%, and 25% FC, respectively. Root DW significantly decreased by about 50.57%, 62.06%, and 77.11% at 75%, 50%, and 25% FC less than control's, respectively.

As shown in figure 3, drought stress influence on the shoot and root length significantly diminished to be less than that of control under all analyzed drought levels.

Regarding shoot length (figure 3A), it significantly decreased by about 12%, 28.99%, and 46.99% less than that of control under drought levels of 75%, 50%, and 25% FC, respectively.

Concerning root length, it significantly decreased by about 35.30% at all studied drought levels.

Figure 3B illustrates the effect of drought stress on leaf area. The effect on leaf area was gradually decreased by increasing drought conditions by about

19.26%, 53.82%, and 68.55% to be less than that of control under drought levels of 75%, 50%, and 25% FC, respectively.

Figure 3C illustrates the effect in root volume that was significantly decreased by about 19.14% less than that of control under moderate drought conditions (50%).

4.4 Plan Pigments

According to the results represented in figure 4, the chlorophyll A, B, and carotenoids values immensely diminished to be less than that of control across all studied drought levels. Chlorophyll A significantly decreased by about 32.99%, 54.04%, and 54.49% less than that of control under drought levels of 75%, 50%, and 25% FC, respectively.

Chlorophyll B gradually decreased by increasing drought conditions by about

43.36%, 47.30%, and 57.55% less than that of control's under drought levels of 75%, 50%, and 25% FC, respectively. Regarding carotenoids, they gradually decreased with the increase of drought conditions by about 24.72%, 23.07%, and 33.65% less than that of control under drought levels of 75%, 50%, and 25% FC, respectively.

4.5 Primary Metabolites

Figure 5 provides information about drought stress influence on soluble carbohydrates and proteins and free amino acids in shoots and grains.

According to the results represented in figure

5A, soluble carbohydrates in shoots showed no significant effect on all studied water stress levels compared with control. Regarding grains, they significantly decreased by about 1.84% and 9.72% less than that of control under drought levels of 50% and 25% FC, respectively. As shown in figure 5B, the effect of different water levels on soluble protein in shoots gradually decreased by increasing drought conditions by about 31.64%, 48.04%, and 53.12% less than that of control's under drought levels of 75%, 50%, and 25% FC, respectively. Soluble proteins in grains gradually decreased with the increase of drought conditions by about 55.90%, 62.15%, and 69.44% less than that of control under drought levels of 75%, 50%, and 25% FC, respectively. Figure 5C provides information about drought stress influence on free amino acids in shoots and grains: The free amino acids in shoots had no significant effect on all studied water stress levels recorded compared with control. In grains, a significant decrease by about 13% less than control under drought levels of 50% and 25% FC, respectively, was detected.

4.6 Plant Minerals

Data summarized in table 2 illustrate drought stress influence on calcium, magnesium, phosphorus, potassium, and sodium. For calcium, phosphorus, potassium, and sodium, there was no significant effect on all studied water stress levels recorded compared with control. However, Magnesium ion concentration significantly increased by about 10.95% higher than that of control under severe drought conditions (25%).

Data summarized in table 3 illustrate drought stress influence on calcium, magnesium, phosphorus, potassium, and sodium. For calcium, phosphorus, and sodium, there was no significant effect on all studied water stress levels recorded compared with control. Regarding the magnesium ions, concentration significantly increased by about 29.77% higher than that of control under severe drought conditions (25%).Unlike potassium, which significantly decreased by about 16.49% less than that of control under severe drought conditions (25%).

4.7 Crop Yield Parameters

Data summarized in figure 6 exhibit the number of spikes and seeds per pot and the weight of 100 seeds under different levels of water stress. All studied water levels reduced the number of spikes per pot to a comparable value (about 55% less than control) (figure 6A). Seeds per pot immensely diminished compared with control's only under moderate (50% FC) and severe (25% FC) drought conditions by about 57.89% and 68.42%, respectively (figure 6B). The weight of 100 seeds significantly decreased by about 7.36%, 31.04%, and 68.42% less than control's under drought conditions of 75%, 50%, and 25% FC, respectively (figure 6C).

Table 1: Soil minerals (mg/l) under different water levels

Water Level (FC%)	Calcium	Magnesium	Phosphorus	Potassium	Sodium
100%	13.95 ± 2.62^{a}	5.75 ± 0.19^{ab}	0.76 ± 0.05^{a}	2.38 ± 0.45^{a}	0.44 ± 0.00^{ab}
75%	17.33 ± 0.84^{a}	5.17 ± 2.34^{ab}	0.77 ± 0.19^{a}	2.10 ± 0.54^{a}	0.40 ± 0.01^{a}
50%	14.68 ± 1.13^{a}	7.44 ± 1.07^{b}	1.22 ± 0.08^{b}	3.76 ± 0.02^{b}	0.47 ± 0.02^{b}
25%	17.86 ± 0.47^{a}	3.36 ± 0.59^{a}	0.68 ± 0.07^{a}	2.05 ± 0.56^{a}	0.43 ± 0.00^{ab}

Different letters represent the statistical significance between all water levels at $P < 0.05$.

Table 2: Plant shoots minerals (mg/l) under different water levels

Water Level (FC%)	Calcium	Magnesium	Phosphorus	Potassium	Sodium
100%	2.70 ± 0.00^{a}	2.92 ± 0.04^{ab}	9.15 ± 0.23^{a}	61.15 ± 7.90^{a}	0.54 ± 0.04^{a}
75%	6.65 ± 2.48^{a}	2.37 ± 0.20^{a}	8.63 ± 1.20^{a}	59.34 ± 7.22^{a}	0.48 ± 0.20^{a}
50%	4.01 ± 1.17^{a}	2.71 ± 0.09^{ab}	8.34 ± 1.13^{a}	47.79 ± 0.11^{a}	0.75 ± 0.12^{a}
25%	10.32 ± 6.94^{a}	3.24 ± 0.48^{b}	8.24 ± 0.90^{a}	46.82 ± 3.01^{a}	0.66 ± 0.03^{a}

Different letters represent the statistical significance between all water levels at $P < 0.05$.

Table 3: Plant root minerals (mg/l) under different water levels

Water Level (FC%)	Calcium	Magnesium	Phosphorus	Potassium	Sodium
100 %	7.52 ± 0.44^{a}	4.40 ± 0.18^{b}	3.31 ± 0.02^{a}	13.22 ± 0.05^{ab}	1.00 ± 0.07^{a}
75 %	17.18 ± 11.15^{a}	3.05 ± 0.54^{a}	3.36 ± 0. 62^{a}	14.50 ± 1.48^{ab}	1.47 ± 0.52^{a}
50 %	11.13 ± 1.94^{a}	2.90 ± 0.59^{a}	3.37 ± 0.22^{a}	16.92 ± 2.02^{b}	1.22 ± 0.43^{a}
25 %	14.97 ± 1.39^{a}	5.71 ± 0.10^{c}	2.93 ± 0.73^{a}	11.04 ± 1.92^{a}	1.24 ± 0.08^{a}

Different letters represent the statistical significance between all water levels at $P < 0.05$.

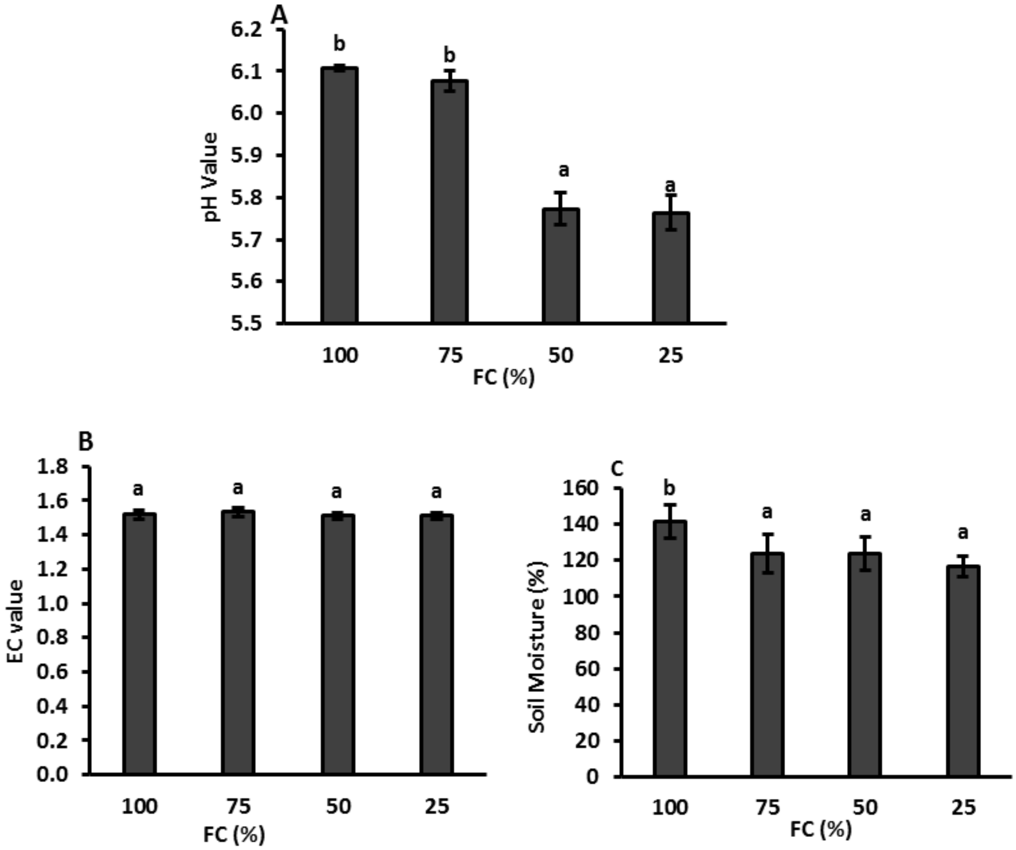

Figure 1: Soil pH value (A), EC value (B), and moisture (%) (C) of soil extracts under different water levels, each histogram is a mean value of three replicates and the vertical bars indicate ± SD. The different letters illustrate the statistical significance between all water levels at $P < 0.05$.

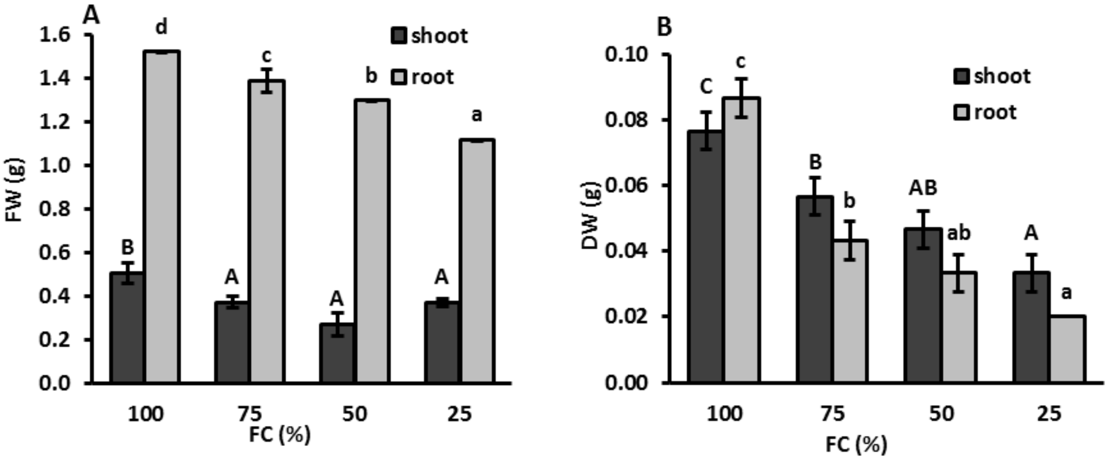

Figure 2: Fresh weight (FW) (A) and dry weight (DW) (B) for shoot and root of triticale plant grown under different water levels, each histogram is a mean value of three replicates and the vertical bars indicate ± SD. The different letters represent the statistical significance between all water levels at P < 0.05.

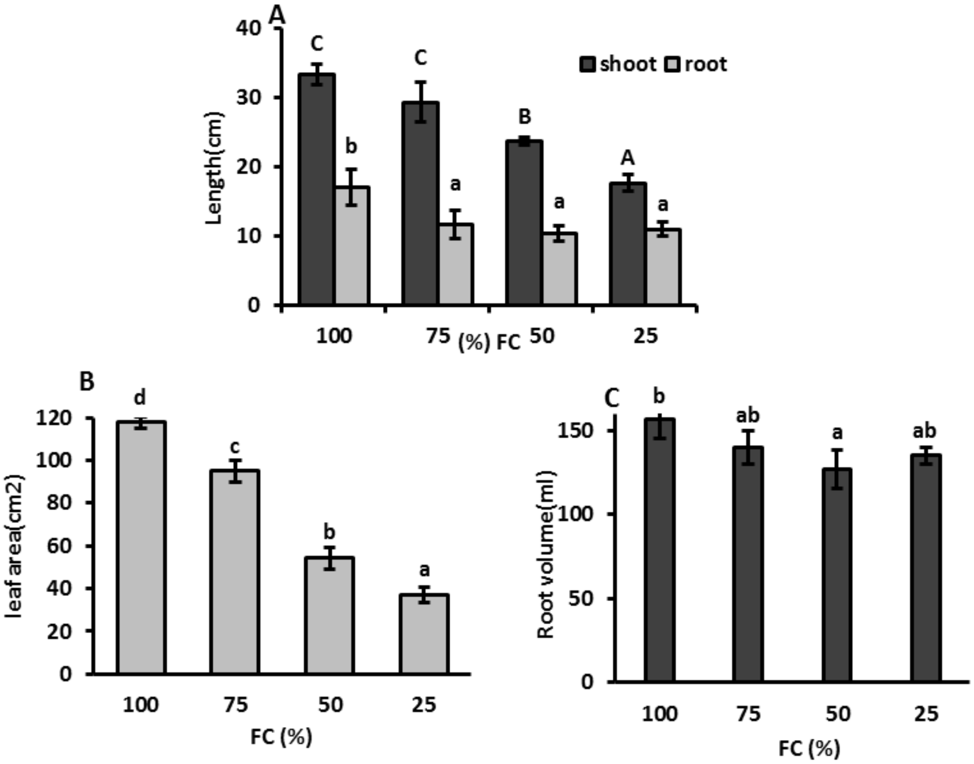

Figure 3: Shoot and root length (A), leaf area (B), and root volume (C) of triticale plant grown under different water levels, each histogram is a mean value of three replicates and the vertical bars indicate ± SD. The different letters demonstrate the statistical significance between all water levels at P < 0.05.

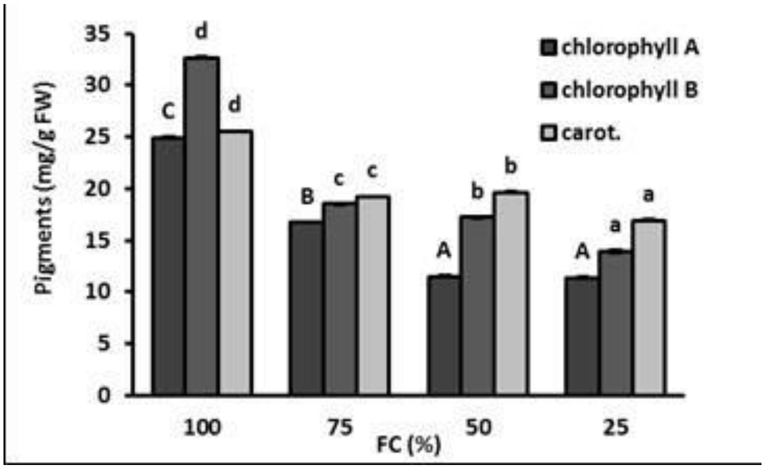

Figure 4: Pigments concentration of triticale plant grown under different water levels, each histogram is a mean value of three replicates and the vertical bars indicate ± SD. The different letters represent the statistical significance between all water levels at P < 0.05.

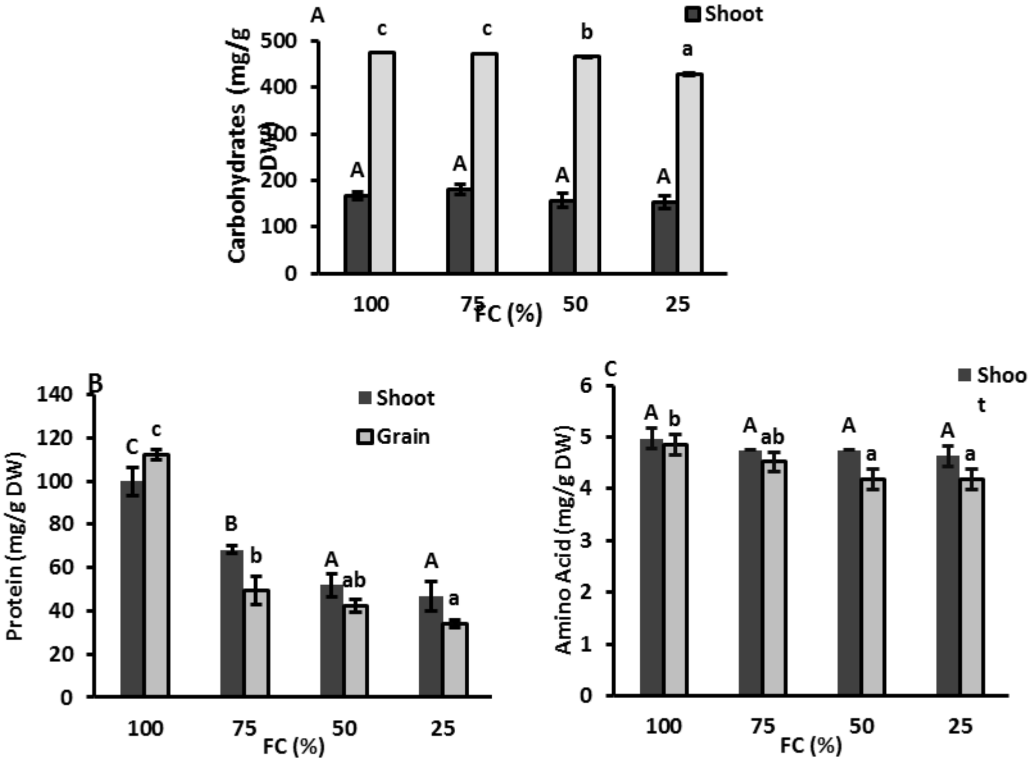

Figure 5: Carbohydrates (A), proteins (B), and free amino acids (C) in shoots and grains of triticale plant grown under different water levels, each histogram is a mean value of three replicates and the vertical bars indicate ± SD. The different letters illustrate the statistical significance between all water levels at P < 0.05.

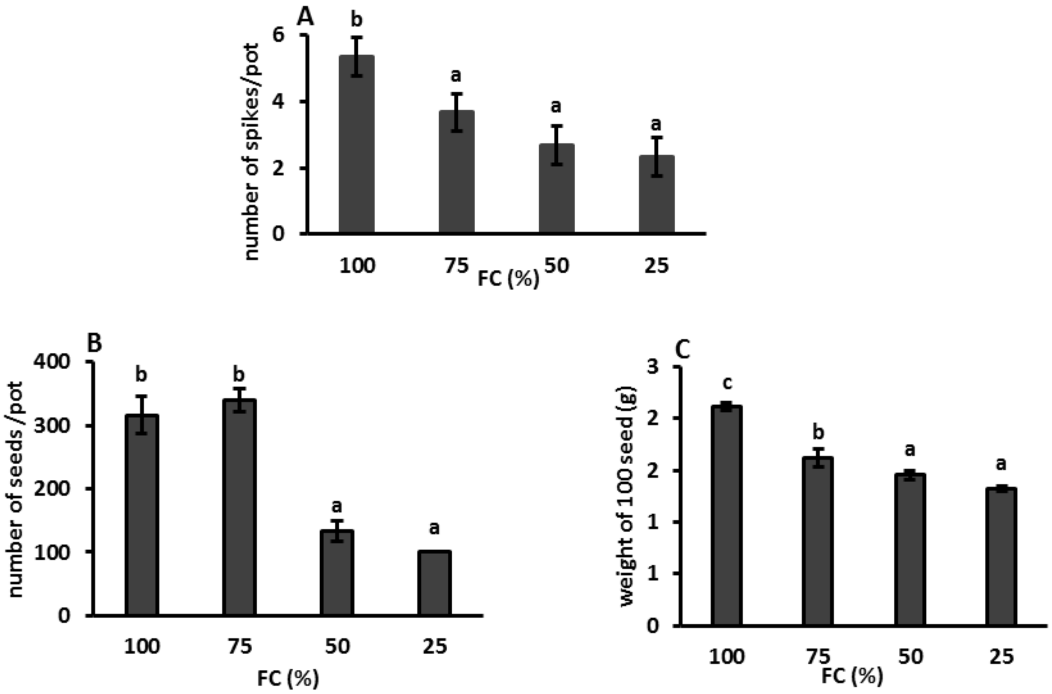

Figure 6: Number of spikes (A), seeds weight (B), and the number of grains (C) of triticale plant grown under different water levels, each histogram is a mean value of three replicates and the vertical bars indicate ± SD.

The different letters illustrate the statistical significance between all water levels at $P < 0.05$.

DISCUSSION

Drought is one of the most damaging abiotic stress processes that harm crop yield. It harms crops' physiological and morphological characteristics, impairing grain development, and plant growth (Alghabari and Ihsan, 2018). Drought affects also soil nutrient availability and changes soil redox and pH (Naylor and Coleman, 2018). In the current study, drought stress significantly reduced soil pH only under moderate (50% FC) and severe (25% FC) drought parameters. EC is known to be high during water stress (Dilip and Milan, 2014). In the current study, drought stress did not significantly affect soil conductivity.

Heavier plant fresh and dry weights during limiting conditions are desirable characters. A prominent downside of water stress on crop plants is biomass production, fresh or dry, reduction (Farooq et al. 2009). Triticale shoots and roots fresh weight significantly diminished to be less than that of the control under all studied drought levels. Shoots and roots dry weight also diminished gradually with the increasing water shortage conditions. Water stress–induced diminished biomass was evident in almost all sunflower genotypes (Tahir and Mehid, 2001). However, a portion of genotypes exhibited exemplary stress tolerance more than others. Mild water stress had an effect on the shoot's dry weight, while shoot dry weight exceeded that of root dry weight loss under severe stress in sugar beet genotypes (Mohammadian et al. 2005). Moderate stress tolerance in terms of shoot dry mass plants was noticed in rice (Lafitte et al. 2007). Also, the outcomes exhibited that drought stress, where moderate or severe, immensely impaired triticale shoots and roots length, leaf area, and root volume immensely decreased to be less than well-watered plants. Drought halts plant growth and development by hindering metabolic processes and diminishing nutrient availability (Hu and Schmidhalter, 2005; Bohnert et al. 2006).

Water deficiency directly affects the rate of photosynthesis and chlorophyll content (Flexas et al. 2006; Chaves et al. 2009). According to the results represented in this study, chlorophyll A, B, and carotenoids content immensely diminished to be less than that of control under all studied drought levels. Reactive oxygen species are significantly accumulated under drought stress, which damages chloroplasts and ultimately causes chlorophyll degradation. This is probably another cause of lesser content of chlorophyll under drought stress parameters (Zaefyzadeh et al. 2009). Although reduced chlorophyll content carbohydrates concentration in triticale shoots and grains was not affected by all studied drought levels, which indicates higher photosynthetic efficiency. These findings with those of Mafakheri et al. (2011) who found that drought stress surged water-soluble carbohydrate concentration in three varieties of Cicer arietinum. Increased carbohydrate synthesis prospects for drought tolerance. High carbohydrate concentration, besides its water potential–decreasing role, takes part in halting oxidative damage and guarding the structure of membranes and proteins under moderate dehydration during periods of drought (Hoekstra et al. 2001). During drought stress, compatible solutes accumulate: of which is carbohydrates, which is claimed to be an effective stress tolerance mechanism (McKersie and Leshem, 1994). Similarly, the amino acid content in triticale shoot and grains did not diminish under all studied drought levels as shown in figure 5C. The adaptation of plants to water deficit is usually correlated with the increase in total amino acids (Pinheiro et al. 2004; Abogadallah, 2010). Many reports have recorded a surge in the level of some amino acids in the leaves of various plants during water stress (Jones et al. 1980; Navari et al. 1990). On the other hand, soluble protein in triticale shoot was gradually decreased by increasing drought conditions under all studied drought levels. Degradation of proteins could result from increased activity of protease or other catabolic enzymes, activated under drought stress, besides proteins' fragmentation caused by toxic effects of ROS diminishing protein content (Davies, 1987).

Macro-elements of soil in terms of calcium, magnesium, phosphorus, potassium, and sodium are extremely important for plant growth and development. The importance of these elements is clarified in many pieces of research (Soil Survey,2007; Ishida, et al. 2012; Jogaiah et al. 2012 and Osakabe, 2013) In the current study, soil minerals analysis showed no significant effect on all studied water stress levels for calcium, magnesium, and sodium ions concentration compared with control soil samples. However, phosphorus and potassium ions concentration significantly increased more than control, respectively, under moderate drought conditions. Furthermore, no significant effect on all studied water stress levels on the concentration of most studied macro-elements in plant shoots and roots were recorded compared with the tested control. Magnesium ions concentration significantly increased to be higher than control's in shoots and roots samples under severe drought conditions. While potassium concentration significantly decreased to be less than control's under severe drought conditions.

The productivity of plants during drought stress is adherent to dry matter partitioning and temporal biomass distribution (Kage et al. 2004). In the current study, most studied crop yield parameters were less than that of the control only under moderate and severe drought conditions. Abayomi et al. (2012) found that cereal grain yield correlated to Drought Susceptibility Index (DSI) Water Stress Index (WSI) (Rizza et al. 2004) . WSI integrates the actual plant-available soil water content (soil water content - water content at permanent wilting) during the growing season, and the DSI is based on the grain yield ratios under water stress and at normal soil moisture (Golabadi et al. 2006). The indices demonstrated a significant negative relationship between water stress and grain yield of barley (Rizza et al. 2004) and maize (Abayomi et al. 2012).Drought is a prominent environmental stress for plants, as it reduces production, obstructs growth, and diminishes grain filling (Farooq et al. 2009; Singh et al. 2015). Lemerle et al. (2001). Note that the number of tillers is the most important yield component in wheat, which was reduced with the increasing competition of weeds. Armin et al., (2011) reported that taking into consideration competition for nutrients, water, and light availability, plant growth is restricted and the number of tillers per plant is reduced. Similar results were also found by (Marof, 2008; Marof, 2013).

CONCLUSION

Triticale is an economically important grain that can be farmed as a valuable alternative to wheat, especially under stress conditions. The results of this study demonstrated its ability to withstand low drought conditions. However, moderate and severe drought conditions adversely affect triticale growth and crop productions. Drought stress–affected triticale yields more vegetative growth than crop yield.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

This work was carried out in collaboration with the authors. Authors AAMA and AASA designed the study, ME performed the statistical analysis and review the final manuscript, wrote the manuscript, NAA conduct all experimental studies. BAE participate in designing the study.

REFERENCES

Abayomi Y.A., Awokola C.D., and Lawal Z.O., 2012. Comparative evaluation of water deficit tolerance capacity of extraearly and early maize genotypes under controlled conditions. J. Agric. Sci., 4, 54-71.

Abogadallah GM. 2010. Antioxidative defense under salt stress. Plant Signal Behav., 5(4): 369–374.

Alghabari, F. M. (2018): Foliar application of Saudi desert plants extract improved some mungbean agronomic traits under drought stress. – Journal of King Abdulaziz University 27: 21-29.

Armin, M., H. gholami and H. Miri. 2011. Effect of Plant Density and Nitrogen Rate on Yield and Yield Components of Wheat in Wild oat-Infested Condition. Advances in Environmental Biology, 5(10): 3084-3090.

Bai L, Sui F, Tida GE, Sun Z, Yinyan LU, Zhao G. Effect of soil drought stress on leaf water status, membrane permeability and enzymatic antioxidant system of maize. Pedosphere. 2006: 16:326–332.

Bohnert HJ, Gong Q, Li P, Ma S (2006) Unraveling abiotic stress tolerance mechanisms—getting genomics going. Curr Opin Plant Biol 9:180–188.

Cao LQ, Zhong QP, Luo S, Yuan TT, Guo HY, Yan C, et al. Changes in leaf structural characteristics of Camellia oleifera under drought stress. Forestry Science Research.2018: 31(3):136–143.

Chaves MM, Flexas J, Pinheiro C (2009) Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. Ann Bot Lond 103:551–560.

Chen LP, Zhao NX, Zhang L, Gao Y. Responses of two dominant plant species to drought stress and defoliation in the inner mongolia steppe of china. Plant Ecology. 2013: 214(2): 221–229.

Chowdhury, J.A.; Karim, M.A.; Khaliq, Q.A.; Ahmed, A.U.; Khan, M.S.A. Effect of drought stress on gas exchange characteristics of four soybean genotypes. Bangladesh J. Agric. Res. 2016, 41, 195–205.

Conklin, S. (2005). Spatial Patterns from EOF/PC Analysis of Soil Moisture and Their Dependence on Soil, Land-use, and Topographic Properties (Doctoral dissertation, Colorado State University).

Daryanto, S.; Wang, L.; Jacinthe, P.A. Global synthesis of drought effects on maize and wheat production. PLoS ONE 2016, 11, e0156362.

Davies KJA. 1987. Protein damage and degradation by oxygen radicals. I. general aspects. J. Biol. Chem., 262(20): 9895–9901.

De Souza TC, Magalhaes PC, De Castro EM, De Albuquerque PE, Marabesi MA. The influence of aba on water relation, photosynthesis parameters, and chlorophyll fluorescence under drought conditions in two maize hybrids with contrasting drought resistance. Acta Physiologiae Plantarum. 2013: 35(2): 515– 527.

Dilip H. and Milan M.L. (2014). Study of soil's nature by pH and soluble salts through EC of kalol-Godhra taluka territory. Der. Chemica Sinica, 2014,5(2):1-7.

Dong, T.; Park, Y.; Hwang, I. Abscisic acid: Biosynthesis, inactivation, homoeostasis and signalling. Essays Biochem. 2015, 58, 29–48.

Fales, F. W. (1951). The assimilation and degradation of carbohydrates by yeast cells. Journal of Biological Chemistry, 193(1), 113-124.

Farooq, M., A. Wahid, N. Kobayashi, D. Fujita and

S.M.A. Basra, 2009. Plant drought stress: effects, mechanisms and management. Agron. Sustain. Dev., 29: 185–212.

Farooq, M.; Gogoi, N.; Barthakur, S.; Baroowa, B.; Bharadwaj, N.; Alghamdi, S.S.; Siddique, K.H.M. Drought stress in grain legumes during reproduction and grain filling. J. Agron. Crop. Sci. 2017, 203, 81–102.

Flexas J, Bota J, Galmés J, Medrano H, Ribas-Carbó M (2006) Keeping a positive carbon balance under adverse conditions: responses of photosynthesis and respiration to water stress. Plant Physiol 127(3):343352.

Gatel, F.O., Lavorel, J., Fekete, F., Grosjean, J. (1985). Feeding value of triticale for monogastrics: weaned piglets, growing-finishing pigs and broilers. Pages 659- 670 in Genetics and Breeding of Triticale. M. Bernard and S. Bernard, ed. Institut National de la Recherche Agronomique, Versailles, France.

Ghane SG, Nikam TD. Growth and physiological alterations in niger cultivars under drought stress. Russian Journal of Plant Physiology.2017: 64(1): 109–115.

Glatthar, J., Heinisch, J. J., & Senn, T. (2005). Unmalted triticale cultivars as brewing adjuncts: effects of enzyme activities and composition on beer wort quality. Journal of the Science of Food and Agriculture, 85(4), 647–654.

Golabadi M., Arzani A., and Mirmohammadi Malbody S.A.M., 2006 .Assessment of drought tolerance in segregating populations in Durum wheat. African J. Agric. Res., 1(5), 162-171.

Hoekstra FA, Golovina EA, Buitink J. 2001. Mechanism of plant desiccation tolerance. Trends Plant Sci., 6(9): 431-438.

Hu YC, Schmidhalter U (2005) Drought and salinity: a comparison of their efects on mineral nutrition of plants. J Plant Nutr Soil SC 168:541–549.

Hussain, H. A., Hussain, S., Khaliq, A., Ashraf, U., Anjum, S. A., Men, S., Wang, L. (2018): Chilling and drought stresses in crop plants: implications, cross talk, and potential management opportunities. – Frontiers in Plant Science 9: 393.

Ishida, T; Osakabe, Y, and Yanagisawa, S. (2012). "Transcription factors: improving abiotic stress tolerance in plant," in Improving Stress Resistance to Abiotic stress, ed. N. Tuteja (Berlin, Germany: Wiley-Blackwell), 589-619.

Ismail A.H., Mehmood A., Qadir M., Husna A.I., Hamayun M. and Khan N. (2020). Thermal stress alleviating potential of endophytic fungus *Rhizopus oryzae* inoculated to sunflower (*Helianthus annuus* L.) and soybean (*Glycine max* L.). Pak. J. Bot. 52, 1857–1865.

Ji W, Fan YJ, Li C,Wei LZ, Jiang JS, Li BB, Jia WS.Changes of stomatal conductance and water potential dynamics in grape leaves under drought stress.Journal of China Agricultural University.2014: 19(4): 74–80.

Jogaiah, S; Govind, S. R., and Tran, L. S. (2012). Systems biology-based approaches toward understanding drought tolerance in food crops. Crit.Rev. Biotechnol. 33,23-39.

Jones MM, Osmond CB, Turner NC. 1980. Accumulation of solutes in leaves of sorghum and sunflower in response to water deficits. Funct. Plant Biol., 7(2):193-205.

Kage, H., M. Kochler and H. Stützel, 2004. Root growth and dry matter partitioning of cauliflower under drought stress condi-tions: measurement and simulation. European J. Agron., 20: 379–394.

Lafitte, H.R., G. Yongsheng, S. Yan and Z.K. Li, 2007. Whole plant responses, key processes and adaptation to drought stress: the case of rice. J. Exp. Bot., 58: 169–175.

Larcher, W., 1995. Physiological plant ecology: Ecophysiology and stress physiology of functional groups into plant morphology, physiology and pathology. Ph.D., Dissertation, University of California, Riverside.

Lemerle, D., G.S. Gill, C.E. Murphy, S.R. Walker, R.D. Cousens, S. Mokhtari, S.J. Peltzer, R. Coleman and D.J. Luckett. 2001. Genetic improvement and agronomy for enhanced wheat competitiveness with weeds. Aust. J. of Agric. Res., 52(5): 527-548.

Lichtenthaler, H. K. (1987). [34] Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. Methods in enzymology, 148, 350-382.

Lowery, G. H., & Newman, R. J. (1951). Notes on the ornithology of southeastern San Luis Potosi. The Wilson Bulletin, 63(4), 315-322.

Mafakheri A, Siosemardeh A, Bahramnejad B, Struik PC, Sohrabi Y. 2011. Effect of drought stress and subsequent recovery on protein, carbohydrate contents, catalase and peroxidase activities in three chickpea (Cicer arietinum) cultivars. AJCS, 5(10): 1255-1260.

Marof, S.M.A. 2008. Competitive interference between triticale x *Triticosecale Rimpaui* Wittmac and wheat Triticum spp. L. under two environmental conditions. Ph.D. Desertation. Coll. of Agric. Salahddin University. PP: 181.

Marof, S.M.A. 2013. Utilizing of new models to predict wheat yield losses due to weed competition. Kerkuk University, Agric. Coll. 2nd Sci. Confe. for Agric. Res., PP: 57-62.

McGoverin, C.M., Snyders, F., Muller, N., Botes, W., Fox, G., Manley, M. (2011). A review of triticale uses and the effect of growth environment on grain quality. J. Sci. Food Agric., 91, 1155–1165. DOI: 10.1002/jsfa.4338.

McKersie BD, Leshem YY. 1994. Stress and stress coping in cultivated plants. Kluwer Academic Publishers, London, pp. 256.

Mehri N, Fotovat R, Saba J, Jabbari F. Variation of stomata dimensions and densities in tolerant and susceptible wheat cultivars under drought stress. Journal of Food Agriculture & Environment. 2009: 7 (1): 167–170.

Mergoum, M., Singh, P. K., Peña, R. J., Lozano-del Río, A. J., Cooper, K. V., Salmon, D. F., & Gómez Macpherson, H. (2009). Triticale: A "New" Crop with Old Challenges. In Cereals (pp. 267–287).

Mergoum, Mohamed and, & Gómez-Macpherson, H. (2004). FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

Mohammadian, R., M. Moghaddam, H. Rahimian and S.Y. Sadeghian, 2005. Effect of early season drought stress on growth characteristics of sugar beet genotypes. Turkisk J. Bot., 29: 357–368.

Moore, S., & Stein, W. H. (1948). Photometric nin-hydrin method for use in the ehromatography of amino acids. Journal of biological chemistry, 176, 367-388.

Navari-Izzo, F., Quartacci, M. F., & Izzo, R. (1990). Water-stress induced changes in protein and free amino acids in field grown maize and sunflower. Plant Physiology and Biochemistry (Paris), 28(4), 531-537.

Naylor, D., Coleman-Derr, D., 2018. Drought stress and root-associated bacterial communities. Front. Plant Sci. 8, 2223.

Obeng-Asamoah, E. K. (1984). A limnological evaluation of Volta Lake. SCOPE/UNDP United Nations Development Programme, Sonderband, (55), 425-435.

Osakabe, Y; Arinaga, N; Umezawa, T; Katsura, S; Nagamachi, K. and Tanaka, H (2013a). Osmotic stress responses and plant growth controlled by potassium transporters in Arabidopsis. Plant cell 25,609-624.

Page, D. L., Dupont, W. D., Rogers, L. W., & Landenberger, M. (1982). Intraductal carcinoma of the breast: follow-up after biopsy only. Cancer, 49(4), 751-758.

Pinheiro C, Passarinho JA, Ricardo CP. 2004. Effect of drought and rewatering on the metabolism of Lupinus albus organs. J. Plant Physiol., 161(11): 1203-1210.

Rizza F., Badeck F.W., Cattivelli L., Li Destri O., Di Fonzo N., and Stanca A.M., 2004. Use of a water stress index to identify barley genotypes adapted to rainfed and irrigated conditions. Crop Sci., 44, 2127-2137.

Schlegel, H. G. (1956). Die verwertung organischer säuren durch Chlorella im licht. *Planta*, *47*(5), 510-526.

Singh M, Kumar J, Singh S, Singh V, Prasad S (2015) Roles of osmoprotectants in improving salinity and drought tolerance in plants: a review. Rev Environ Sci Biol 14:407–426.

Soil Survey Staff. (2007). National Soil Survey Characterization Data. Soil Survey Laboratory. National Soil Survey Center. USDA-NRCS, Lincoln, NE. May 20, 2006.

Stankowski, S., Sobolewska, M., Jaroszewska, A., Michalska, B. (2017). Impact of form and dose of nitrogen fertilizers on the technological value of spring triticale. Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech., 336(43)3, 167–178. DOI: 10.21005/AAPZ2017.43.3.18.

Su, B., & Ang, B. W. (2010). Input–output analysis of CO2 emissions embodied in trade: the effects of spatial aggregation. Ecological Economics, 70(1), 10-18.

Sucu S, Yağci A, Yıldırım K. Changes in Morphological, Physiological Traits and Enzyme Activity of Grafted and Ungrafted Grapevine Rootstocks Under Drought Stress. Erwerbs-Obstbau.2017: 08:1–10.

Tahir, M.H.N. and S.S. Mehid, 2001. Evaluation of open pollinated sunflower (Helianthus annuus L.) populations under water stress and normal conditions. Int. J. Agric. Biol., 3: 236–238.

United Nations, Department of Economic and Social Affairs, and Population Division. World Population Prospects: The 2015 Revision, Key Findings, and Advance Tables. Working Paper; No. ESA/P/WP.241; United Nations

Department of Economic and Social Affairs: New York, NY, USA, 2015.

USDA (2018). US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Legacy. Version Current: April 2018.

Wani, S.H.; Sah, S.K. Biotechnology and abiotic stress tolerance in rice. J. Rice Res. 2014, 2, 1105.

Yousef, A. E., & Lou, Y. (1999). Characteristics of Listeria monocytogenes important to food processors. Listeria: Listeriosis, and food safety, 131.

Zaefyzadeh, M., Quliyev, R. A., Babayeva, S. M., & Abbasov, M. A. (2009). The effect of the interaction between genotypes and drought stress on the superoxide dismutase and chlorophyll content in durum wheat landraces. Turkish Journal of biology, 33(1), 1-7.

Zhu, J.K. Abiotic stress signaling and responses in plants. Cell 2016, 167, 313–324.

Zhu, J.K. Salt and drought stress signal transduction in plants. Annu. Rev. Plant Biol. 2002, 3, 247–273.