ISSN 2709–3662 (Print)
ISSN 2709–3670 (Online)
https://doi.org/10.52587/JAF050202
Journal of Agriculture and Food
2021, Volume 2, No.2, pp. 63-78

Evaluation of oat (*Avena sativa* L.) accessions for fodder yield and quality under drought stress

Asma Shaheen, Amir Bibi[1*], Muhammad Awais[1], Nisar Ahmad[2], Farwa Shoaib[1], Zainab Shahbaz[1], Bilquees Fatima[3], Imtiaz Akram Khan Niazi[4]

Abstract

Oat is being cultivated as cereal and multi-cut forage crop in temperate and subtropical regions of the world. However, elite germplasm of oats was found susceptible to abiotic stresses including drought stress. Therefore, 15 oat accessions were evaluated for various traits using completely randomized factorial design under four irrigation levels, with depreciation of one irrigation at each level. Field was irrigated at 21, 33, 45, 57 and 70 days after sowing (DAS) under control condition (T1), while 2nd level received four irrigations at 21, 33, 45 and 70 DAS (T2), third level received three irrigation at 21, 35 and 57 DAS (T3) and fourth level received two irrigations at 21 and 35 DAS (T4). Data was recorded after 70 days of sowing for different physiological, growth and quality parameters. Significant variation ($P \leq 0.05$) was detected among all accessions in response to various irrigational levels. There was continuous decrease in the studies due to depreciation of irrigation at each level. Control treatment had the highest growth and quality parameters. Shoot fresh biomass was decreased by decreased by 57% (T2), 60% (T3) and 69% (T4). Moreover, traits such as leaf area, number of tillers plant^{-1}, and root biomass was also decreased by 38%, 55% and 85% respectively due to T4 treatment. Traits such as protein contents and neutral detergent fiber were not affected by water stress treatment. Three accessions such as G7, G9, and G11 were discriminated as drought-tolerant and three genotypes namely G4, G8, and G14 were drought-susceptible accessions. Identified accessions may be cultivated in drought prone areas or may be used as parents for development segregating populations.

Keywords: Irrigation levels, seedling, traits, economical traits, QTLs

Article History: **Received:** 28th November, 2021; **Revised:** 28th December 2021 **Accepted:** 10th January, 2022

[1]Dept. of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. [2]Center for Agricultural Biotechnology and Biochemistry, University of Agriculture, Faisalabad. [3]Institute of Horticultural Sciences, University of Agriculture, Faisalabad, [4]Pakistan Fodder Research Institute, Sargodha, * Corresponding author: ameerbibi@gmail.com

Introduction

Oat (*Avena sativa* L.) is an important cereal (ranked 6th), and source of nutritious forage, which originated in Mediterranean region. It is a fast-growing, nutritious, succulent, and palatable fodder crop (Niazi et al., 2021) and well adapted to temperate and cool subtropical climates. Forage yield is prone to various abiotic stresses particularly water and heat stress, which reduces the optimum growth period and induces early senescence, ultimately decereasing forage yield and growth period (Niazi et al., 2020). Sustainable supply of forage is critical for the livestock production and dairy sector (Ali, 2016).

Forage supplies show decreasing availability in response to heat and water stress, resultantly feed supply is 1/3 times lower than that required, and the shortage is further increased due to a 2% annual decrease in the area under fodder crops every year (Kadam et al*.,* 2020). Fodder crops were generally being shifting to the marginal land due to intense competition from industrial and food crops. Therefore, breeding crops with adaptability to poor growth condition and reduce the yield losses due to enviornmental and soil induce stresses is critical for the life stock production (Bhatti et al*.,* 2009).

Oat crop offer many advantages as forage crop (Ahmad et al*.,* 2014). It may be grown as an emergency forage crop when normal growing seasons become shortened or during hay supply disruptions. It showed adaptability to diversity of soils and show good chances of survival even in less productive soil as compared to other grain cereals. However, oats are more vulnerable to drought stress due to high transpiration rate other cereals (Tulu et al*.,* 2020).

Drought is by far the most imperative cause, restricting crop efficiency in the arid as well as semi-arid regions of the world (Ali et al., 2017). Imposed moisture stress decrease biomass production by disrupting physiological, growth, and quality parameters. Several drought response factors such as abscisic acid mediated stomatal closure help to reduce water losses. Decrease in leaf area and leaf water potential helped p to maintain plant turgor and enhance chances of survival but also decrease yield potential of field crops including oat (Jaleel et al., 2009; Rauf et al. 2016).

Introgression of drought resistant was required to reduce yield losses under stress conditions. Selection of plants such as cuticular waxes, leaf hairiness and pollen fertility has been suggested for selection of drought resistant advanced lines (Hussain et al., 2019). Several plant parameters such as seedling vigor, relative water contents or water use efficiency has been suggested for selection of better genotypes under stress environment (Rauf et al*.,* 2007). Forage yield *per se* may also be exploited to select plant population with better response to water stress (Moosavi et al., 2011; Tahir et al., 2014). In order to screen oat germplasm accessions, a study was formulated to discriminate germplasm on the basis of various physiological, forage biomass and yield characteristics and to select the drought resistant accession which may able to maintain growth and water status helping them to avoid water accessions. Identified accessions will be used to grow in target environment or utilize in breeding program for development of high yielding lines with better water stress resistance.

Materials and Methods

Experimental Description

The study was carried out in the field area of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan during winter season 2020. Fifteen Oat genotypes were sown in pot experiment preceded by heavy irrigation. Oat germplasm was received from USDA, USA. The experiment was laid out in completely randomized design (CRD) with three replications under two factor factorials. Factor included accessions and irrigation levels. Irrigation had four levels i.e., five irrigations at 21, 33, 45, 57 and 70 days after sowing (T1), four irrigations at 21, 33, 45 and 70 DAS (T2), three irrigations at 21, 35 and 57 DAS (T3) and two irrigations at 21 and 35 DAS (T4). Five plants of each genotype from each replication and treatment were evaluated for the following physiological, growth and quality parameters.

Characters Studied and Observation Procedure

Fully expanded flag leaves were selected randomly from each replication and weighted by using an electric balance to get a fresh weight. The leaves were then dipped in 1 ml water in Petri dishes and were kept for 24h, after that reweighted to get turgid weight. Dry weight of the leaf samples was determining by incubating them at 70°C for 24 hours and then reweighed. The following formula given below was used to calculate the relative water content of leaves was determined (Ali and Awan, 2009).

$$LRWC\ (\%) = [(FW - DW)/(TW - DW)] \times 100$$

Where,

LRWC = Leaf Relative Water Content
FW = Fresh Weight
DW = Dry Weight
TW = Turgid Weight

Chlorophyll content was measured using a self-calibrating, portable chlorophyll meter (Minolta SPAD-502) on flag leaves of plants in each replication by method describe by Babar et al., 2006. Seedlings were dissected into roots and shoots and length-based traits were measured in cm by using mearing tape. Leaf area was determined by measuring the values of leaf length and width in the following formula

$$Leaf\ Area\ (cm2) = \mathrm{L} \times \mathrm{W} \times 0.75$$

Where,

L=Length of leaf
W= width of a leaf
0.75= constant

Number of leaves and number of tillers per plant were counted manually. Shoot and root fresh weight plant^{-1} was measured on digital electrical balance while dry shoot and root weight was measured by putting shoots and roots in paper bags separately and dried in the oven at 70ºC for constant dry weight (Kaydan & Yagmur, 2008). The average dry shoot and root weight per plant was taken. For checking the quality parameter 50 g of oat sample (leaves and stem) was prepared for each genotype. These samples were dried in an oven at 60 ^{0}C for 2 days before grinding. The grounded sample was used for the analysis of the following quality parameter (Negi et al., 2018) i.e. Protein contents, Acid detergent fiber, Neutral detergent fiber, Ash contents and Crude fiber.

Statistical Analysis The data for all the traits was statistically analyzed to determine the significance ($P \leq 0.05$) of traits for accessions and irrigational levels through computer based R Software (Team, 2019).

Results and discussions

1. Effect of irrigation treatment on physiological and growth parameters of oat genotypes

Leaf Relative Water Contents The results showed that leaf relative water content (LRWC) was significantly ($P \leq 0.05$) influenced by irrigation treatments at different critical crop growth stages (Table 1). Data ranged from 65.10-96.78% (T1), 60.31-93.9% (T2), 52.65-85.82% (T3), 39.88-54.90% (T4) within each treatment. It was observed that high relative water contents (82.41%) were found in T1 where five irrigations were applied followed by T2 (73.37%), T3(64.42%), and the lowest T4(46.35%) where four, three and two irrigations were applied respectively. Accessions also respond differentially to various irrigation levels for LRWC. Accession 7 exhibited the highest LRWC (87.10%) followed by G9 (80.33%) and G12 (72.48%) where minimum LRWC was observed in G15(58.56) followed by G8(59.70%) and G1 (60.05%) as shown in (Fig. 1a). LRWC has been suggested as criterion for discrimination of field crop germplasm. Studies showed that drought resistant accessions had higher LRWC when compared with susceptible accessions (Subrahmanyam et al*.,* 2006; Ashfaq et al*.,* 2016). It was identified that accessions with LRWC able to show better growth due to higher cuticular waxes, greater root length and low cell membrane injury (Shehzad et al. 2021).

Table 1. Comparison for physiological, growth and fodder quality in *Avena sativa* under four irrigation treatments

Variables	T1		T2		T3		T4	
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
RWC	65.1-96.78	82.41	60.31-93.91	73.37	52.65-85.82	64.42	39.88-54.9	46.35
CC	42.66-53.66	47.55	32.33-57.66	47.03	25.00-57.66	46.42	27.66-54.66	45.88
LA	1.51-12.15	5.44	1.27-10.3	4.4	1.12-7.95	3.45	1.07-7.32	3.4
NLP	5-23.33	14.53	3.66-20	11.8	2.66-11.00	7.24	2.33-11.00	6.53
NTP	1.33-5.33	5.22	1.33-4.33	3.75	1.23-4.23	2.51	1.23-3.23	2.4
RL	21.1-49.33	31.48	19.50-37.16	29.71	17.83-34.33	26.51	15.23-34.83	24.42
FSWP	1.24-2.78	1.71	0.47-1.34		0.74-0.34	1.31	0.69 0.35	0.53

FRWP	1.03 3.27	2.09	0.9 2.36	1.54	0.24 0.69	0.41	0.24-0.44	0.32
SDWP	0.21 0.51	0.35	0.2 0.53	0.31	0.13 0.37	0.25	0.12-0.35	0.22
RDWP	0.24 0.8	0.46	0.21 0.61	0.38	0.13 0.43	0.24	0.13-0.25	0.18
PC	7.83 12.56	10.4	8.47 15.33	11.67	9.76 14.63	12.57	10.13- 17.06	13.81
ADF	1.1 6.9	2.59	1.46 7.4	3.28	2.03 7.83	3.69	1.2-8.95	4.43
NDF	7.33 19.83	13.38	7.73 22.3	15.4	12.63 23.76	19.08	11.33- 24.5	18.79
Ash Contents	8.33 13.33	10.52	7.93 10.7	9.48	7.36 9.93	8.9	6.9-9.8	8.54
Crude Fat	3.03 3.86	3.57	2.76 3.56	3.37	2.93 3.74	3.32	3.1-3.34	3.31

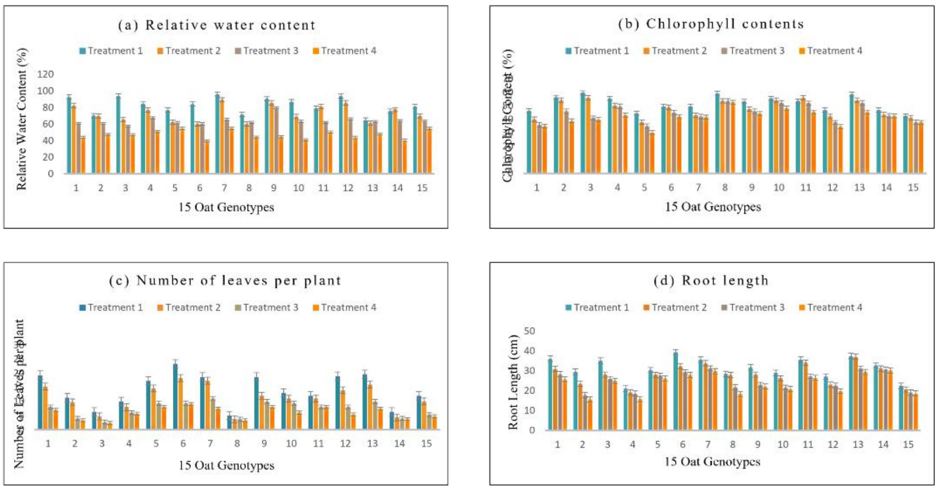

Fig. 1. Effect of 4 irrigation treatments on physiological and growth parameters of 15 oat genotypes

Chlorophyll contents (%)

Drought stress significantly reduced chlorophyll contents. Data range between 42.66-53.66% (T1), 32.33 – 57.66% (T2), 25.00 -57.66% (T3), 27.66-54.66% (T4) as shown in (Table 1). It was observed that high chlorophyll contents (82.41%) were found in T1 where five irrigations were applied followed by T2(73.37%), T3(64.42%), and the lowest T4(46.35%) where four, three and two irrigations were applied respectively. Accessions respond differentially to various irrigation intervals for chlorophyll contents. Accession 7 exhibited the highest chlorophyll contents (87.10%) followed by G9(80.33%) and G12 (72.48%), where the lowest chlorophyll contents was reported in G15(58.56%) followed by G8(59.70%) and G1 (60.05%) as shown in (Fig. 1b). Sensitivity of chlorophyll contents due to water stress was also observed in other studies (Flexas et al., 2002 and Schutz & Fangmeier, 2001). They reported that leaf chlorophyll contents, photosynthetic rate, and stomatal conductance tend to be lower in drought conditions. Chlorophyll contents triggered more reduction in all oat genotypes with the increased levels of drought stress due to disintegration of thylakoid membranes of cells (Kidokoro et al., 2009). Studies have also showed that decrease in chlorophyll contents occurred under water stress regime due to incomplete leaf development and reduced cell extension (Kalaji et al., 2016).

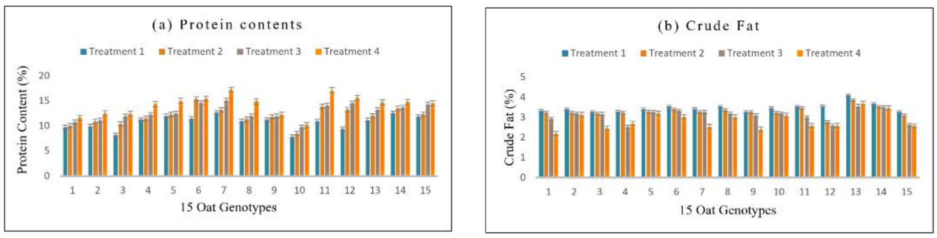

Fig. 2. Effect of 4 irrigation treatments on physiological and growth parameters of 15 oat genotypes

Number of tillers Plant^{-1}

The data (Table. 1) exhibited that number of tillers plant^{-1} (TLP) was significantly influenced ($P \leq 0.05$) by application of irrigation at different crop growth stages. Data range from 1.33 – 5.33 (T1), 1.33 – 4.33 (T2), 1.23 -4.23 (T3), and 1.23-4.23 (T4). Tillering ability of oat plant was greatly affected under water deficit conditions. TLP were observed in T1 (5.22) where five irrigation treatments were applied followed by T2(3.75), T3(2.51), and lowest in T4(2.40) where four, three, and two irrigations were applied respectively. Accessions also performed differentially under different irrigation levels. Accession 9 (4.16) had the highest TLP followed by G13 (3.83), G1(3.58), G6 and G10(3.416) while G8(1.33) followed by G3(1.41) and G14(1.58) exhibited the lowest TLP as indicated in (Fig. 2). The data revealed that the application of irrigation water at different levels plays an important role to enhance the tillers per plant. Previous studies in other forage crops such as sorghum and oats also showed that irrigation frequency is significantly effective in determining the number of leaves and tillers per plant (Patel et al., 2008), (Tahir et al., 2014) in oats (Naseer et al., 2006). The data also depicted that the TLP were primary yield component and provide significant contribution to forage and crop stand.

Number of leaves Plant^{-1}

Number of leaves plant-1 (No. L/P) was highly influenced by application of different level of irrigations as shown in (Table 1). The data ranged from 5.00 – 23.33 (T1), 3.66 – 20 (T2), 2.66 - 11 (T3), 2.33 - 11.00 (T4). It was observed that the highest No. L/P (14.53) were found in (T1) where five irrigations were applied followed by T2(11.80), T3(7.23), and the lowest in T4(6.3) where four, three and two irrigations were applied respectively. Accession changed their relative ranking across the irrigational levels. The highest No. L/P were reported in accession G6 (15) followed by G13(14.75), G7(13.58), and G5(13.08) while the lowest number of leaves were found in G8(3.9) followed by G3(4) and G14(5.33) as depicted in (Fig. 1(c)). The above results illustrated that No. L/P were highly affected by different irrigation levels which are in confirmation with the results reported by (Tahir et al., 2014; Akhtar et al., 2013) in oats and (Moosavi et al., 2011) in sorghum who reported that reduction in irrigation produce a lower number of leaves and reduce leaf weight.

Leaf Area

Flag Leaf Area (LA) was highly impacted by number of irrigations. Data range from 1.51 – 12.15 cm^2 (T1), 1.27 – 10.30 cm^2 (T2), 1.12 - 7.95 cm^2 (T3), 1.23-4.23 cm2 (T4). It was shown that the highest LA (5.44 cm2) was found in T1 where five irrigations were applied followed by T2 (4.40 cm^2), T3(3.41 cm^2), and the lowest in T4(3.42 cm^2) where four, three and two number of irrigations were applied. The accessions also respond differentially to various irrigation levels for LA. The highest LA was observed in accession G8 (8.71 cm^2) followed by G3 (8.33 cm2), G2 (6.3 cm^2), and G7 (5.28 cm^2) while the lowest LA was observed in accession G5 (1.43 cm^2) followed by G13 (1.5 cm^2) and G15 (2.27 cm^2). The results indicated that water stress highly impacted LA. It has been reported that leaf development was highly sensitive to drought conditions that result in reduced LA which leads toward less photosynthesis and low yield (Singh et al., 2000). Decrease in LA was considered a response to reduce transpirational losses under water and accession with smaller leaf area was considered an adaptability to water stress condition in grain crops (Hussain et al., 2019). However, it is also primary forage yield components, thus genotypes with better plant height and leaf area may be preferred for selection (Bazzaz et al., 2014). Accessions showing higher leaf area may be able to withdraw higher moisture from deeper soil profile (Bazzaz et al., 2014).

Root Length

Root length (RL) was significantly ($P \leq 0.05$) influenced by irrigation treatments at different critical crop growth stages (Table 1). Data ranged between 21 - 49 cm (T1), 19-37 cm (T2) 17-34 cm(T3), and the lowest 15-34 cm in (T4). The highest RL was observed in T1(35.45 cm) where five irrigations were applied followed by T2 (29.71 cm) and T3(26.64cm) and minimum in T4 (24.42cm) where four, three and two irrigations were applied respectively. Roots are the first line of defense against water stress and accessions with deeper root system tend to have higher chances of survival under water stress condition (Rauf et al. 2016). Significant genetic variability within germplasm was noted for RL (Shehzad et al., 2021). The highest RL was recorded in accession G13 (36.04 cm) followed by G9 (34.29cm), and G7 (34.16 cm), while the lowest RL was recorded in accession G4 (20.95 cm) followed by G2 (22.62 cm) and G15 (24.25) as shown in Fig. 1(d). The above results indicated that water stress significantly reduced the RL of oat seedlings, however the tolerant genotypes were least affected under such conditions (Dhanda et al., 2004; Canales et al., 2019). Total RL and root dry weight tended to be lower in drought conditions as compared to well-irrigated plants. As root length is laborious traits, state of the art technologies such as 2-D root mapper, and QTL mapping of direct selection of deeper root length may be recommended to facilitate breeding, while indirect selection methods such as canopy temperature discrimination may be used to select genotype with deeper root length (Rauf et al., 2016).

Shoot Fresh and Dry Weight Plant^{-1}

Fresh and dry weight plant-1 was significantly affected by different levels of irrigation. Data from (Table 1) indicated that value range from 1.24-2.78g(T1), 0.47-1.34g (T2), 0.34-1.31g (T3) and 0.355-1.00g (T4) in case of shoot fresh weight plant-1 (SFWT/P) where for shoot dry weight plant-1 (SDWT/P) the values vary from 0.21-0.53g (T1), 0.20-0.51g (T2), 0.13-0.37g (T3) and 0.12-0.35g(T4). It was noticed that T1 had highest SFWT/P (1.71g) when five irrigations were applied, followed by T2 (0.74g), T3 (0.69g), and T4 (0.53g) when four, three, and two irrigations were applied, respectively. Similarly, for SDWT/P the highest value (0.35g) was observed in T1 where five irrigations were applied followed by T2(0.31g), T3(0.25g) and the lowest T4(0.22g) where four, three and two irrigations were applied respectively. Accessions respond differentially to various irrigation levels for fresh and dry shoot weight. Accession G7 exhibited the highest SFWT/P (1.19g) followed by G9(1.13g) and G10 (1.02g), whereas the lowest SEWT/P was reported in G15(0.53g) followed by G1 (0.54g) and G14 (0.71g). The highest Accession G7 exhibited the highest SDWT/P (0.37g) followed by G9(0.36g) and G10 (0.299g) where minimum SDWT/P was reported in G1(0.223g) followed by G15(0.236g) and G14 (0.253g). Fresh and dry shoot weight was significantly decreased in drought condition as compared to control in all oat genotypes. A decrease in shoot weight in response to water stress was also noted by Kamran et al., 2009. The superior root and shoot mass following drought stress have been considered as reliable, drought selection criteria for different plant species, including oat (Dhanda et al., 2004) and wheat (Khakwani et al., 2011; Baloch et al., 2012; Qureeshi et al., 2021).

Root Fresh and Dry Weight

Irrigations at different crop growth stages increased root fresh and dry weight significantly ($P \leq 0.05$) (Table 1). Root fresh weight plant-1 (RFWT/P) ranged from 1.03 - 3.27g (T1), 0.90 – 0.36g (T2) 0.24 – 0.69g (T3), and the lowest 0.24-0.44g in (T4) where the RDWT/P range from 0.24-0.80g (T1), 0.21-0.61g (T2), 0.13-0.43g (T3) and 0.13-0.25g (T4). It was observed that RFWT/P was significantly ($P \leq 0.05$) influenced by the application of different levels of irrigation level. The highest RFWT/P was observed in T1 (2.09g) where five irrigation treatments were applied followed by T2(1.54g), T3(0.41g), and the lowest T4(0.32g) where four, three, and two irrigations were applied respectively. Similarly, maximum RDWT/P was observed in T1 (0.46g) where five irrigations were applied against T2(0.38g), T3(0.24), and T1(0.18g) where four, three, and two irrigations were applied respectively. Accession G7 showed the highest root RFWT/P (1.40 g) followed by G8 (1.39g), G9 (1.38g) while the lowest root fresh weight was noted in G15 (0.65g) followed by G5 (0.81g). The highest RDWT/P was observed in genotype 7 (0.54g) followed by G13(0.48g), G3(0.4159g) and G8

(0.4152g) while that of G14(0.24) followed by G15(0.25) and G1(0.27) showed the lowest root dry weight plant-1 as (indicated in Fig 3). The results confirmed that under drought conditions, a longer root was the characteristic of a drought tolerant variety, as root growth was relatively less affected by water stress. Therefore, root morphology and biomass are very significant for selection of drought-tolerant genotypes. The decreasing trend for seedling dry weight was also found in many studies (Kamran et al., 2009; Ahmad et al., 2013; Marcińska et al., 2013), who observed that water stress had a significant effect on plant dry matter production.

Effect of irrigation treatments on forage quality parameters of oat genotypes

Protein Contents

The data from (Table 1) showed that crude protein (CP) significantly influenced ($P \leq 0.05$) under different irrigation levels. Data ranged from 7.833-12.56% (T1), 8.47-15.33% (T2), 9.76-14.63% (T3), 10.1-17.06% (T4). It was observed that the highest CP (13.81%) was found in T4 where two irrigations were applied followed by T3(12.57%), T2(11.67%), and the lowest in T1(10.40%) where three, four and five irrigations were applied respectively. Accessions respond differentially to various irrigation levels for CP. Genotype 6 exhibited maximum CP (14.29%) followed by G11(14%) and G14 (13.60%) whereas the lowest CP was reported in G10(9.05%) followed by G1(10.54%) and G3 (10.71%) as shown in (Fig. 2a). The results from the experiment showed that drought stress significantly ($P \leq 0.05$) increased the CP, and the above results were like the findings of Sasani et al., 2004.

ADF and NDF Percentage The results showed that ADF and NDF was significantly ($P \leq 0.05$) influenced by different levels of irrigation (Table 1). Data for ADF range from 1.20-8.93%(T1), 2.03-7.83%(T2), 1.46-7.40%(T3), 1.10-6.90%(T4) whereas for NDF the data ranged between 7.33-19.83%(T1), 7.73-22.30%(T2), 12.63-23.76%(T3) and 11.33-24.50% (T4). It was observed that higher ADF (4.43%) was found in T1 where five irrigations were applied followed by T2(3.69%), T3(3.28%), and the lowest in T4(2.59%) where four, three and two irrigations were applied respectively. Contrastingly, higher NDF (19.81%) was found in T4 where two irrigations were applied followed by T3(19.08%), T2(15.40%), and the lowest in T1(13.38%) where three, four and five irrigations were applied respectively. Accessions respond differentially to various irrigation levels for ADF and NDF. Accession G2 exhibited higher ADF (4.82%) followed by G7(4.78%) and G12 (4.45%) where lower ADF was reported in G8(2.50%) followed by G14(2.66%) and G5 (2.87%). In case of NDF Accession G3 exhibited higher NDF (18.81%) followed by G9(18.65%) and G2 (17.97%) whereas lower ADF was reported in G8(15.02%) followed by G14(15.27%) and G6(15.34%). According to the results, both ADF and NDF showed an increasing trend as irrigation level decreased. ADF and NDF are measured to be two significant characteristics of forage quality. High-quality forages contain a low level of both NDF and ADF. Drought stress significantly reduce fodder quality as reported by (Seguin et al., 2002) in alfalfa.

Ash Contents

Ash contents was highly affected by different levels of irrigations. Data range from 8.33-33.33%(T1), 7.93-10.70% (T2), 7.36-9.93% (T3), 6.90-9.80% (T4). The highest ash contents (10.52) was found in T1 where five irrigations were applied followed by

T2(9.48), T3(8.90), and the lowest in T4(8.54) where four, three and two irrigations were applied respectively. Accessions respond differentially to various irrigation levels for ash contents. Accessions G8 exhibited higher Ash contents (10.94%) followed by G4(9.93%) and G9 (9.98%) where lower Ash contents was reported in G12(7.71) followed by G1(8.11%) and G15(8.29%) as showed in (Fig. 4.1.31). Abiotic stress including water stress decreased ash contents in various forage species (Sasani et al., 2004; Tahir et al., 2014).

Crude Fat

Data from (Table 1) confirmed that crude fat (CF) was significantly reduced due to different irrigation levels. Average value of CF was d from 3.03-3.86% (T1), 2.76-3.56% (T2), 2.93-3.45% (T3), 3.10-3.34% (T4). It was observed that higher CF (3.57%) was found in T1 where five irrigations were applied followed by T2(3.37%), T3(3.32%), and the lowest in T4(3.31%) where four, three and two irrigations were applied respectively. Accessions respond differentially to various irrigation levels for CF. Accession G8 exhibited higher CF (3.65%) followed by G13(3.55%) and G6 (3.52%) whereas lower CF was reported in G1 (3.12%) followed by G10 (3.25%) and G3 (3.3%) as given in (Fig. 2b). Drought stress substantially reduces CF. CF contents of forage crop show significant decrease in response to various abiotic stress has been documented (Sasani et al., 2004; Tahir et al., 2014).

Correlation analysis

A correlation coefficient expresses the degree of relationship between two variables. It may show functional or genetic relationship among traits depending upon the appropriate population used in the study. Relationship among the yield traits may indicate pattern of biomass partitioning in crop plants (Ghafoor et al., 2013; Niaizi et al. 2020). In present experiment, genotypic and phenotypic correlations between various morphological and quality traits of oat accessions under four different irrigations are given in (Table 3). The data indicated the positive and highly significant genotypic and phenotypic correlation was found between the following parameters: RL with No. L/P, RL with TLP, No. L/P with TLP, LA with RFWT/P, SFWT/P with RDWT/P, RFWT/P with RDWT/P, SDWT/P with RDWT/P, RFWT/P with ASH, ADF with NDF, P with CF, and ASH with CF (Table 2a and Table 2b). A positive and highly significant genotypic correlation was found between the following parameters: RL with SFWT/P, RL with SDWT/P, RL with Chlorophyll content, Tillers per plant with SDWT/P, SFWT/P with SDWT/P, SFWP with Chlorophyll content, SFWT/P with CF, RFWT/P with RDWT/P, RFWT/P with Chlorophyll content, SDWT/P with Chlorophyll content, SDWT/P with LRWC, and SDWT/P with ASH contents. A positive and highly significant phenotypic correlation was found between LA with ASH contents. A positive and significant genotypic correlation was indicated between the following parameters: Tillers per plant with SFWP, LA with Chlorophyll content, and SDWT/P with CP. A positive and significant phenotypic correlation was found between the following traits: SFWT/P with RDWT/P, RFWT/P with SDWT/P. A negative but highly significant correlation had observed in the following parameters: No. L/P with LA, Tillers per plant with LA, ADF with CF, and NDF with CF. A negative but highly significant genotypic correlation was found between LRWC with CF. A negative but significant genotypic correlation was present between traits; Chlorophyll content with LRWC, RDWT/P with CF. A negative but significant phenotypic correlation was found between RFWT/P and Germplasm accessions may vary in their response to environmental conditions and genotype × environmental conditions, which may also affect their development and growth pattern and thus may have differential correlations among the traits (Kleunen and Fisher, 2005). In the present investigation, genotypic correlation was found to be stronger than phenotypic correlation in all four irrigation levels. This demonstrated that most of the traits were more explained by the genotypes of the accession and thus indicate some genetic linkage or pleiotropic effects among correlated traits, Positive and significant genotypic and phenotypic correlation of the number of leaves with the tillers plant-1 revealed that under drought conditions number of leaves and tillers plant-1 are important determinants of plant biomass. Root biomass was also become one of the most important traits under water deficit conditions (Qureeshi et al. 2021).

Longer root length, higher fresh, and dry root shoot weight were ideal for development of drought tolerant genotypes under drought conditions (Yucel et al., 2010). In the present study, RL was correlated with RDWT/P. The correlation analysis revealed that selection of longer root length, higher root shoot ratio, Leaf area could be a better option under water deficit conditions. A negative genotypic and phenotypic correlation of root length with fresh shoot weight plant-1 was found under all treatment conditions which indicated that higher root biomass occurred at the expense of above ground biomass (Khan et al., 2004).

Since water deficit conditions cause severe water scarcity in the root zone. As a result, the plant may slow down the loss of water from the leaves surface to survive by adapting some resistance strategies which include the decreasing trend in some physiological parameters including LRWC%, Chlorophyll contents, and LA. The LRWC was a useful measure of the water condition of leaf cells and displays an important correlation with stress tolerance. Previous research had also found a strong correlation between LRWC and drought tolerance (Moshelion et al., 2015). The positive correlation of the LRWC with LA and highly significant negative values with RSD in our research indicated that a high LRWC ensures the stability of a membrane and the cooler canopies to preserve leaf anatomy, sustaining leaf activities, and consequently defending the plants from drought stress. It has been shown that physiological traits could enable plants to survive and adapt under drought conditions thus maintaining growth and production (Almeselmani, 2012).

Table 2a. Genotypic (G) and phenotypic (P) correlation coefficient for forage traits of oat accessions under combined effect of drought stress (4 irrigation treatments)

Variables	RL		No. L/P		TLP		LA		SFWT/P		RFWT/P		SDWT/P	
	G	P	G	P	G	P	G	P	G	P	G	P	G	P
No. L/P	0.66**	0.30**												
TLP	0.79**	0.40**	0.91**	0.83**										
LA	-0.44	-0.23	-0.78**	-0.61**	-0.84**	-0.71**								
SFWT/P	1.04**	-0.02	0.33	0.18	0.56*	0.22	0.12	0.05						

RFWT/P	0.34	0.08	-0.35	-0.12	-0.18	-0.13	0.83**	0.45**	1.67**	0.27*				
SDWT/P	3.28**	0.06	-0.48	0.085	1.51**	0.17	1.00**	0.1	0.85**	0.14	7.008**	0.27 *		
RDWT/P	0.18	0.2	-0.05	-0.09	0.16	0.06	0.33	0.27*	1.75**	0.35**	0.80**	0.56**	6.64**	0.4**
CC	0.90**	0.11	0.15	0.06	0.09	0.19	0.53*	0.1	1.51**	0.08	2.63**	0.009	3.68**	0.31*
LRWC	-0.4	-0.08	-0.06	0.007	0.26	0.13	-0.35	-0.16	0.07	-0.05	-0.61*	-0.06	1.29**	-0.004
CP	-0.13	-0.12	0.029	-0.017	-0.09	-0.02	-0.13	-0.14	-0.83**	-0.18	-0.92**	-0.29 *	0.59*	-0.11
ADF	0.12	0.03	0.43	0.27*	0.36	0.18	-0.15	-0.09	0.48	0.14	-0.14	-0.008	0.67*	0.30*
NDF	0.15	0.07	0.54	0.18	0.39	0.18	0.01	0.006	0.43	0.23	0.06	0.05	0.38	0.16
ASH Contents	0.22	0.15	-0.3	-0.25	-0.24	-0.18	0.29	0.34**	0.44	0.2	0.82**	0.37**	4.58**	0.19
CF	0.14	-0.006	-0.32	-0.07	-0.42	0.18	0.26	0.18	-0.51*	-0.06	-0.11	0.1	2.21**	0.07

Table 2b. Genotypic (G) and phenotypic (P) correlation coefficient for forage traits of oat accessions under combined effect of drought stress (4 irrigation treatments)

Variables	**RDWT/P**		**CC**		**LRWC**		**CP**		**ADF**		**NDF**		**Ash Contents**	
	G	P	G	P	G	P	G	P	G	P	G	P	G	P
CC	0.69**	0.06												
LRWC	0.14	0.15	-0.60*	-0.04										
CP	-0.46	-0.18	-0.3	0.012	0.14	0.12								
ADF	-0.09	-0.07	-0.08	-0.06	-0.09	-0.08	-0.09	-0.07						
NDF	-0.04	-0.02	-0.16	-0.14	0.18	0.09	-0.26	-0.17	0.9**	0.6**				
ASH Contents	0.41	0.25	0.92**	0.17	-0.52*	-0.38**	-0.06	0.05	-0.54	-0.22	-0.59	-0.18		
CF	-0.56*	0.02	0.49	0.15	-0.93**	-0.1	0.81**	0.28**	-0.47**	-0.39**	-0.53**	-0.43**	0.93**	0.22**

Conclusion

Our result showed that there was linear relationship between the growth and biomass accumulation and irrigation application. Oat accessions showed the highest biomass and growth at 5 irrigational level which was decreased sequentially at 4,3 and 2 irrigations. Yield components such as leaf chlorophyll contents, number of tillers plant-1, plant height, leaf area and number of leaves showed a decrease of 20-45% when control was compared with regimes received 2 irrigations. Moreover, irrigational treatments also increase leaf succulence as indicated from higher leaf water contents. However, it negatively affected leaf protein contents which is an interesting finding of the study. The accession such as G7, G9, and G11 were selected as drought tolerant while accessions such as G4, G8, and G14 were drought susceptible. These accessions may be used to develop populations for selection and molecular studies.

References

Ahmad, M., Dar, Z. A., & Habib, M. (2014). A review on oat (Avena sativa L.) as a dual-purpose crop. *Scientific Research and Essays*, *9*(4), 52–59.

Ahmad, M., Shabbir, G., Minhas, N. M., & Shah, M. K. N. (2013). Identification of drought tolerant wheat genotypes based on seedling traits. *Sarhad Journal of Agriculture*, *29*(1), 21–27.

Almeselmani, M. (2012). Physiological parameters for evaluating drought tolerance in durum wheat varieties grown in the field in Syria. *Journal of Biology*, *1*, 122–141.

Al-Suhaibani, N. A. (2006). Effect of irrigation intervals and nitrogen fertilizer rates on fresh forage yield of Sudangrass [Sorghum sudanense (Piper) Stapf.]. *Food Sci. Agric. Res. Center King Saud Univ*, *142*, 1–14.

Ashfaq, W., Ul-Allah, S., Kashif, M., Sattar, A., & Nabi, H. G. (2016). Genetic variability study among wheat genotypes under normal and drought conditions. *J. Glob. Innov. Agric. Soc. Sci*, *4*(3), 111–116.

Baloch, M. J., Dunwell, J., Khakwani, A. A., Dennett, M., Jatoi, W. A., & Channa, S. A. (2012). Assessment of wheat cultivars for drought tolerance via osmotic stress imposed at early seedling growth stages. *Journal of Agricultural Research*, *50*(3), 299–310.

Bazzaz, M. M., Al-Mahmud, A., & Khan, M. S. (2014). Effects of water stress on morpho-phenological changes in wheat genotypes. *Global Journal of Science Frontier Research*, *14*(10), 93–102.

Bhatti, J. A., Younas, M., Abdullah, M., Babar, M. E., & Nawaz, H. (2009). Feed intake, weight gain and haematology in Nili-Ravi buffalo heifers fed on mott grass and Berseem fodder substituted with saltbush (Atriplex amnicola). *Pakistan Veterinary Journal*, *29*(3), 133–137.

Canales, F. J., Nagel, K. A., Müller, C., Rispail, N., & Prats, E. (2019). Deciphering root architectural traits involved to cope with water deficit in Oat. *Frontiers in plant science*, *10*, 1558.

Dhanda, S. S., Sethi, G. S., & Behl, R. K. (2004). Indices of drought tolerance in wheat genotypes at early stages of plant growth. *Journal of agronomy and crop science*, *190*(1), 6–12.

Flexas, J., Bota, J., Escalona, J. M., Sampol, B., & Medrano, H. (2002). Effects of drought on photosynthesis in grapevines under field conditions: an evaluation of stomatal and mesophyll limitations. *Functional Plant Biology*, *29*(4), 461-471.

GH, M. T., Haq, A., Khaliq, T., Rehman, M., & Hussain, S. (2014). Effect of different irrigation levels on yield and forage quality of oat (Avena sativa). *Applied Science Report*, *3*(1), 42–46.

Ghafoor, G., Hassan, G., Ahmad, I., Khan, S. N., & Suliman, S. (2021). 04. Correlation analysis for different parameters of F2 bread wheat population. *Pure and Applied Biology (PAB)*, *2*(1), 28–31.

Hussain, M. M., Rauf, S., & Warburton, M. L. (2019). Development of drought-tolerant breeding lines derived from Helianthus annuus× H. argophyllus interspecific crosses. *Plant Breeding*, *138*(6), 862–870.

Jaleel, C.A., Manivannan, P., Wahid, A., Farooq, M., Somasundaram, R. & Panneerselvam, R. (2009). Drought stress in plants: a review on morphological characteristics and pigment composition. *International Journal of Agriculture and* Biolog*y*, 11(1), 100–105.

Kadam, S. S., Arif, M., Chaturvedi, K., & Mohsin, M. (2020). Enhancing productivity and quality of annual cereal forages through INM: A review. *Int. J. Curr. Microbiol. App. Sci*, *9*(5), 206–215.

Kalaji, H. M., Jajoo, A., Oukarroum, A., Brestic, M., Zivcak, M., Samborska, I. A., ... & Ladle, R. J. (2016). Chlorophyll a fluorescence as a tool to monitor physiological status of plants under abiotic stress conditions. *Acta physiologiae plantarum*, *38*(4), 102.

Kamran, M., Shahbaz, M., Ashraf, M., & Akram, N. A. (2009). Alleviation of drought-induced adverse effects in spring wheat (Triticum aestivum L.) using proline as a pre-sowing seed treatment. *Pakistan Journal of Botany*, *41*(2), 621–632.

Kaydan, D., & Yagmur, M. (2008). Germination, seedling growth and relative water content of shoot in different seed sizes of triticale under osmotic stress of water and NaCl. *African Journal of Biotechnology*, *7*(16), 2862–2868.

Khan, I.A., Habib, S., Sadaqat, H.A. & Tahir, M.H.N. (2004). Comparative evaluation and analysis of seedling traits for drought tolerance in maize. *Int. J. Agric. Biol*. 6(2), 246–251.

Kidokoro, S., Maruyama, K., Nakashima, K., Imura, Y., Narusaka, Y., Shinwari, Z. K., ... & Yamaguchi-Shinozaki, K. (2009). The phytochrome-interacting factor PIF7 negatively regulates DREB1 expression under circadian control in Arabidopsis. *Plant physiology*, *151*(4), 2046–2057.

Marcińska, I., Czyczyło-Mysza, I., Skrzypek, E., Filek, M., Grzesiak, S., Grzesiak, M. T., ... & Quarrie, S. A. (2013). Impact of osmotic stress on physiological and biochemical characteristics in drought-susceptible and drought-resistant wheat genotypes. *Acta physiologiae plantarum*, *35*(2), 451–461.

Moosavi, S. G., Seghatoleslami, M. J., Javadi, H., & Ansari-nia, E. (2011). Effect of irrigation intervals and planting patterns on yield and qualitative traits of forage sorghum. *Advances in Environmental Biology*, *5*(10), 3363–3368.

Moshelion, M., Halperin, O., Wallach, R., Oren, R. A. M., & Way, D. A. (2015). Role of aquaporins in determining transpiration and photosynthesis in water-stressed plants: crop water-use efficiency, growth and yield. *Plant, Cell & Environment*, *38*(9), 1785–1793.

Negi, H., Prasad, B., & Lohani, P. (2018). Estimates of genetic variability parameters in oat germplasm for improving fodder yield. *Journal of Hill Agriculture*, *9*(4), 371–376.

Niazi, I. A. K. (2021). Description of new high yielding forage Avena Sativa L. cultivar ‘Super Green Oats’. *Journal of Agriculture and Food*, *2*(1), 17–25.

Niazi, I. A. K., Akhtar, S., Kohli, S., Naveed, A., Rauf, S., & Shehzad, M. (2020). Oat (Avena sativa L.) advanced lines outperform existing cultivars for forage yield and its components under terminal heat stress. *Pakistan Journal of Agricultural Sciences*, *57*(2).327–331.

Numan, A., Muhammad, Z. A., Tariq, J., Shamsher, F. M., & Saleem, A. (2016). Assessing yield and yield associated traits of oat genotypes grown under the semi-arid conditions of Pakistán. *American-Eurasian Journal of. Agriculture Environment Science*, *16*, 1784–1789.

Patel, M. R., Sadhu, A. C., & Patel, J. C. (2008). Effect of irrigation, nitrogen and bio-fertilizer inoculation on N, P and K content and uptake of forage oat (Avena sativa L.). *Research on Crops*, *9*(3), 544–546.

Qureeshi, M. A., Hussain, F., Noorka, I. R., & Rauf, S. (2021). Screening of spring wheat (Triticum aestivum L.) germplasm against drought and heat stress. *Cereal Research Communications*, 1–10.

Rauf, M., Munir, M., ul Hassan, M., Ahmad, M., & Afzal, M. (2007). Performance of wheat genotypes under osmotic stress at germination and early seedling growth stage. *African journal of biotechnology*, *6*(8) 971–975.

Sasani, S., Jahansooz, M. R., & Ahmadi, A. (2004, September). The effects of deficit irrigation on water use efficiency, yield and quality of forage pearl millet. In *Proceedings of the 4th International Crop Science Congress Brisbane, Australia* (Vol. 26).

Schütz, M., & Fangmeier, A. (2001). Growth and yield responses of spring wheat (Triticum aestivum L. cv. Minaret) to elevated CO2 and water limitation. *Environmental Pollution*, *114*(2), 187–194.

Seguin, P., Mustafa, A. F., & Sheaffer, C. C. (2002). Effects of soil moisture deficit on forage quality, digestibility, and protein fractionation of Kura clover. *Journal of Agronomy and Crop Science*, *188*(4), 260–266.

Shehzad, M., Gul, R. S., Rauf, S., Clarindo, W. R., Al-Khayri, J. M., Hussain, M. M., & Hussain, M. (2021). Development of a robust hydroponic method for screening of sunflower (Helianthus annuus L.) accessions for tolerance to heat and osmotic stress. *Scientific Reports*, *11*(1), 1–14.

Singh, B., Bohra, A., Mishra, S., Joshi, R., & Pandey, S. (2015). Embracing new-generation ‘omics’ tools to improve drought tolerance in cereal and food-legume crops. *Biologia plantarum*, *59*(3), 413–428.

Subrahmanyam, D., Subash, N., Haris, A., & Sikka, A. K. (2006). Influence of water stress on leaf photosynthetic characteristics in wheat cultivars differing in their susceptibility to drought. *Photosynthetica*, *44*(1), 125–129.

Team, R. C. (2019). R: A language and environment for statistical computing.

Van Kleunen, M., & Fischer, M. (2005). Constraints on the evolution of adaptive phenotypic plasticity in plants. *New phytologist*, *166*(1), 49–60.

Yücel, D. Ö., Anlarsal, A. E., Mart, D., & Yücel, C. (2010). Effects of drought stress on early seedling growth of chickpea (Cicer arietinum L.) genotypes. *World Applied Sciences Journal*, *11*(4), 478–485.

Citation of Article

Shaheen, A., Bibi A., Awais, M., Ahmad, N., Shoaib, F., Shahbaz, Z., Fatima, B., & Niazi I.A.K. (2021). Evaluation of oat (*Avena sativa* L.) accessions for fodder yield and quality under drought stress. *Journal of Agriculture and Food, 2(2)*, 63–78.