Available Online at http://www.journalajst.com

ISSN: 0976-3376

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

*Asian Journal of Science and Technology*
*Vol. 10, Issue, 07, pp.9892-9899, July, 2019*

# RESEARCH ARTICLE

# MORPHOPHYSIOLOGICAL AND YIELD ATTRIBUTE ANALYSIS OF *TRITICUM AESTIVUM L.* (9 VARIETIES) UNDER DROUGHT STRESS

*Summy Yadav, Disha Patel, Mohini Patel, Shrusti Shah, Shaily Dave, Saloni Khatri and Jayati Trivedi

Biological and Life Sciences, Ahmedabad University, Commerce Six Roads, Navrangpura, Ahmedabad-380009

## ARTICLE INFO

***Article History:***
Received 19th April, 2019
Received in revised form
14th May, 2019
Accepted 17th June, 2019
Published online 31st July, 2019

***Key words:***
Drought Resistance, Osmotic Regulation, Phenological Analysis, Physiological Analysis, Yield Analysis Introduction

## ABSTRACT

Wheat (*Triticum aestivum* L.) is the major vital crop all over the world and also a staple food cultivated over wide range of climatic conditions. Drought conditions during cultivation play a key role. The effects of drought range from morphological to molecular levels. Many stages of plant development are affected by drought. In present study growth related traits, phenological, physiological and yield analysis of wheat under drought and irrigated condition with 9 different varieties was done. Both drought and irrigated varieties were compared and a significant study was observed. The findings of the study reveal that some of the varieties showed positive results towards drought mechanism. GW503, GW173, GW273, GW366 and GW496 were tolerant varieties and amongst them GW496 was the highest tolerant variety whereas GW1255, LOC-1 and GW11 were susceptible varieties. Plant growth regulators and certain physiological mechanisms get activated during drought conditions. Plant drought resistance mechanism comprises of escape, tolerance and avoidance mechanisms. Osmotic regulations help to uphold cell water balance over accumulation of solutes in cytoplasm, reducing the detrimental effects.

***Citation: Summy Yadav, Disha Patel, Mohini Patel, Shrusti Shah, Shaily Dave, Saloni Khatri and Jayati Trivedi,* 2019.** "Morphophysiological and Yield Attribute Analysis of Triticum aestivum L. (9 varieties) Under Drought Stress", *Asian Journal of Science and Technology*, 10, (07), 9892-9899.



## INTRODUCTION

*Triticum aestivum L.* belongs to family Poaceae (Gramineae). Wheat is the main crop growing mainly in Rabi season. It is broadly cultivated under varied agro-ecological conditions (Hassani, Marker, and Lal 2017). According to chromosome number sets, wheat was separated into three groups: diploids (2n=14), tetraploids (2n=28) and hexaploids (2n=42) (Singh and Mittal 2016). The mature wheat kernel (caryopsis) contains ~83% endosperm, 14.5% bran and 2.5% embryo.Wheathaswater, carbohydrate, fat and gluten as major wheat protein contributing amino acids for nutrition. Wheat germ encompasses folate, thiamin, magnesium, vitamin B6, iron, selenium, vitamin E, zinc and fibre (Kumar *et al.,* 2011). The bran and germ layers of whole wheat are rich in beneficial phytochemicals called flavonoids, lignans and saponins. Drought being an intricated abiotic stress, acts at any stage of plant growth to various extent. Abiotic environmental factors, water resources and atmospheric conditions are the main source (71%) of yield reductions. Drought affects from morphological to molecular levels and are apparent at all phenological stages of plant growth at which the droughtoccurs (Fahad *et al.,* 2017).

***Corresponding author:* Summy Yadav,**
Biological and Life Sciences, Ahmedabad University, Commerce Six Roads, Navrangpura, Ahmedabad-380009.

Three major periods of plant development-vegetative, pre-anthesis and terminal stage are affected by drought (Shavrukov *et al.,* 2017).Physiological responses of plants to drought include leaf wilting, reduced leaf area, leaf abscission and thereby reducing water loss through transpiration (Waseem *et al.,* 2011).Growth of plants under drought contributes much to ease the problem of extreme water usagein agriculture. Cell growth is one of the utmost drought sensitive physiological processes triggered by reduced turgor pressure (Fahad *et al.,* 2017). Under severe drought stress, cell elongation of higher plants can be repressed by interruption of water flow from the xylem to the adjacent elongating cells. Impaired mitosis, cell elongation and expansion confer reduced plant height, leaf area and crop growth under drought (Fahad *et al.,* 2017). Drought resistance comprises of escape, avoidance and tolerance mechanisms. Osmotic alteration helps sustaining cell water balance with the active accumulation of solutes in cytoplasm, minimizing the detrimental effects of drought (Singh and Mittal 2016).

## MATERIALS AND METHODS

This investigation was done in Rabi season at Biological and Life Sciences (Ahmedabad University). Seeds were procured from Gujarat state Seed Corporation Limited.9 different varieties of wheat- GW503, GW496, G451, GW11, LOC-1, GW1255, GW173, GW27, and GW366 were sown for irrigated and drought conditions in month of November. Each variety from GW503 to GW366 was marked as varieties V1 to V9 respectively.

- *Phenological Analysis:*
- *Days to 50% flowering*
- *Days to 50% maturity*

***Growth related traits:*** *Root Length per Plant (RL) and Root Dry Weight per Plant (RDW. Shoot Length per Plant (SL) and Shoot Dry Weight per Plant (SDW)*

***Physiological Analysis:*** Three replicates of 20mg from each variety were chosen and the following are the observations taken for physiological analysis.

***Relative Water Content % (RWC):*** The experimental study included fresh weight, dry weight and turgid weight of fourth leaf from each replicate. For fresh weight (FW), leaves from each plant variety were taken and weighed and then were saturated in tap water for 2-3 hours and their turgid weight (TW) was measured. The samples were then dried at 55$^o$C in oven for 1 hour and weighed for their dry weight (DW). Relative water content for all the samples was calculated using following formula. (Yadav *et al.,* 2015)

RWC% = (FW-DW) / (TW-DW)*100.

***Relative Stress Injury % (RSI):*** Fresh leaves were homogenized in 10 ml of distilled water for one hour and their electrical conductivity was measured before and after giving heat stress for one hour at 70$^o$C in water bath. Percentage of relative stress injury was calculated using following formula (Summy, Boora, and Sharma 2016)%:

$RSI = (EC_2 – EC_1 / EC_2)*100$

Where,

**$EC_1$:** electrical conductivity of sample before keeping it in hot water bath and
**$EC_2$:** electrical conductivity of sample after keeping it in hot water bath.

***Chlorophyll (Chl) and Carotenoid Estimation (Car):*** Wheat leaves from three replicates of each plant were grinded and extracted in 2ml acetone (70%) and centrifuged for 4 minutes at 5000rpm. The supernatant was collected and homogenized in 2ml acetone and its absorbance was measured at three different wavelengths 470nm, 646.8nm and 663.2nm respectively for determination of chlorophyll and carotenoid content. Cholrophyll a, b and carotenoid content was calculated using the following formulas (Nayak *et al.,* 2014):

$\text{Chl-a} = 12.25A_{663.2} – 279A_{646.8}$, $\text{Chl-b} = 21.5A_{646.8} – 5.1A_{663.2,}$

$C_{x+c}= (1000A_{470} – 1.82Ca–85.02Cb)/198)$

Where,

A = absorbance at specific wavelengths after calculating chlorophyll factor and carotenoid estimation and **$C_{x+c}$**= carotenes and xenthophylls

***Yield Attributes:*** *Spike length per plant (SpL) and Spike weight per plant (SpW)*

*Number of grains per spike (NOG) and Weight of grains per spike (WOG). Statistical analysis using Pearson correlation matrix*

Correlation analysis of irrigated plants and drought plants

## RESULTS

*Phenological Analysis*

***Days to 50% flowering:*** In irrigated plants varieties G451, GW11 and in drought condition plant GW11 were earliest to obtain 50% flowering i.e. 52 days.Varietieslike LOC-1, GW1255, GW173 and GW366had moderate growth and flowered in 57 days. G451 had its flowering on 57$^{th}$ day in drought condition plants. Variety GW503 in irrigated plants and GW496 and GW273 in drought condition plants had its flowering on 60$^{th}$ day and the slowest to obtain 50% flowering was on 61$^{st}$ day in varieties GW496 and GW273 of irrigated plants and variety GW503 in drought condition plants.

***Days to 50 % Maturity:*** Varieties G451 and GW11 were first to obtain 50% maturity in 55 days in irrigated plants andGW11in drought plants, whereas varieties like LOC-1, GW1255, GW173 and GW366 had moderate growth in 61 days in irrigated as well as in drought condition plants. G451 in drought condition plant also had its maturity on 61th day. The slowest to obtain 50% maturity were variety GW503 in irrigated plants and varieties GW496 and GW273 in drought condition plants i.e. on 62$^{nd}$ day. And on 64$^{th}$ day GW496 and GW273 in irrigated plants and GW503 in drought condition plants had their 50% maturity.

***Growth Related Traits:***

***Root Length per plant and Root Dry Weight per plant***

***Root Length per plant:*** Under drought stress, root length was highest in variety G451 (7.5 cm) compared to others which indicates high tolerance towards the drought stress. Whereas varieties GW503 (5.93 cm) and GW496 (6.03 cm) showed moderate tolerance towards the drought stress. And the varieties GW11 (1.83 cm), GW1255 (2.4 cm), LOC-1(2.93 cm), GW173 (2.3 cm), GW366 (1.0 cm) and GW273 (3.13 cm) showed very low tolerance (Table 1.1). Root length was higher in irrigated plants in varieties GW503 (13.42 cm), G451 (8.9 cm), LOC-1 (3.6 cm), GW1255 (2.4 cm), GW173 (2.73 cm), GW273 (7.83 cm) and GW366 (2.26 cm) than those of the drought condition plants.

***Root Dry Weight per plant:*** From values observed through conducted experiment, variety G451 (0.90 gm) showed highest value of RDW from all other varieties of wheat which indicates this variety has high tolerance mechanism towards drought stress. Whereas, varieties GW503 (0.021 gm) and GW496 (0.027 gm) showed moderate tolerance and the plants which were unable to overcome drought stress were termed as susceptible plants like in varieties GW11 (0.003 gm), LOC-1 (0.008 gm), GW1255 (0.013 gm), GW173 (0.012 gm) and GW273 (0.012 gm) (Table 1.1). Root dry weight was higher or equal in irrigated plants than drought stressed plants in all the varieties.

***Shoot Length per plantand Shoot Dry Weight per plant Shoot Length per plant:*** The data showed a great variance in the values of shoot length of irrigated as well as drought condition plants. In drought condition plants, variety GW496 (53.7 cm) showed highest value compared to others which indicates high tolerance towards the drought stress. Whereas, varietiesGW503 (39.17 cm), GW11 (43.26 cm), GW366 (36.36 cm), LOC-1 (46.0 cm) and GW173 (38.3 cm) showed lesser value than the variety GW496 (53.7 cm), which indicates that they have moderate tolerance towards the drought stress. And varieties G451 (24.6 cm), GW1255 (34.86 cm) and GW273 (32.6 cm) showed very low tolerance towards drought stress indicating poor resistance mechanisms towards water stress (Table 1.1).

***Shoot Dry Weight per plant:*** In all the varieties shoot weight was greater in irrigated plants than drought stressed plants. In seed plant subjected to drought stress, variety G451 (0.81 gm) showed highest value from all other varieties of wheat which indicates that this variety has high tolerance mechanism towards drought stress. Varieties GW503 (0.44 gm) and GW496 (0.64 gm) showed moderate tolerance whereas varieties GW11 (0.24 gm), LOC-1 (0.21 gm), GW1255 (0.22 gm), GW173 (0.22 gm), GW273 (0.16 gm) and GW366 (0.20 gm) were unable to tolerate dehydration (Table 1.1). In irrigated plants varieties GW503 (0.90 gm), G451 (0.86 gm), LOC-1 (0.24 gm), GW1255 (0.24 gm) and GW273 (0.29 gm) showed significantly greater shoot dry weight than those of the drought condition ones.

***Physiological Analysis:***

***Relative Water Content %:*** The RWC range was set according to the tolerance level. Values above 80% were considered as highly tolerant, between75-80% were said to be moderately tolerant and below75% were termed as susceptible. Under irrigated conditions RWC% for all the varieties ranged from 69.57% to 90.98% and from 60.75% to 86.38% in drought condition plants. In drought stressed plants highest RWC% was recorded in varieties GW1255 (85.94 %), GW273 (81.27 %) and GW366 (86.38 %). Moderately tolerant plants were varieties GW496 (78.57 %) and GW11 (79.03 %). Susceptible plants were higher in number bearing very low tolerant mechanisms in varieties GW503 (60.75 %), G451 (52.85), LOC-1 (60.56 %) and GW173 (73.30 %) (Table 1.2). In irrigated plants, varieties GW11 (80.48 %), GW1255 (90.98 %), GW273 (90.65 %) and GW366 (86.61 %) had the highest values of RWC% whereas varieties GW496 (77.80 %), G451 (75.22%) and GW173 (79.65 %) had moderate RWC%. The lowest RWC% having plants were GW503 (72.40 %) and LOC-1 (69.57 %). RWC% was significantly higher in varieties GW503 (72.40 %) and G451 (75.22 %).

***Relative stress injury %:*** Value of relative stress injury above 90% was considered as susceptible varieties, value between 81-89% was moderately tolerant and below 80% was considered as highly tolerant plant. In irrigated conditions, RSI% ranged from 71% to 98.05% and in drought stressed plants it ranged from 72.44% to 98.51%. Under drought condition, varieties GW503 (97.53 %), GW496 (91.60 %), GW11 (96.41 %), LOC-1 (98.51 %) and GW1255 (95.44 %) were susceptible due to poor resistance mechanisms in plants while variety G451 was moderately tolerant (82.22 %) and varieties GW173 (77.28 %), GW273 (75.31 %) and GW366 (72.44 %) were highly tolerant. In drought condition plants, varieties G451 (82.22 %), GW273 (75.31 %) and GW366 (72.44 %) had low RSI% than the irrigated plants (Table 1.2).

***Chlorophyll and Carotenoid estimation***

***Chlorophyll-a (Chl-a):*** Under irrigated conditions, chlorophyll a observed was from 1µg/ml to 3.74µg/ml and in drought stressed plants it was observed from 0.58µg/ml to 5.19µg/ml. In irrigated condition plants, varieties GW503 (1.0µg/ml), LOC-1 (0.78 µg/ml), GW1255 (1.48 µg/ml), GW173 (1.79µg/ml) had lowest range of chlorophyll-a content whereas variety GW273 (7.46 µg/ml) had the highest. Varieties GW496 (2.26 µg/ml), G451 (2.77 µg/ml), GW11 (3.05 µg/ml), GW366 (3.74 µg/ml) had moderate range of chlorophyll a content. In drought condition, varieties GW496 (1.25 µg/ml), G451 (0.58 µg/ml), GW11 (0.36 µg/ml) and LOC-1 (1.25 µg/ml) had lowest chlorophyll a content. Varieties GW503 (2.59 µg/ml) and GW366 (2.59 µg/ml) had the highest chlorophyll a content while varieties GW1255 (2.62 µg/ml), GW173 (4.08 µg/ml), GW273 (5.19 µg/ml) had moderate range. At the vegetative stage all the varieties in irrigated condition showed significantly higher chlorophyll-a content than the drought varieties except in variety LOC-1 (1.25 µg/ml).

***Chlorophyll-b (Chl-b):*** Under irrigated conditions, chlorophyll-b content observed was from 0.55µg/ml to 4.32µg/ml and in drought stressed plants it was observed from 0.05µg/ml to 3.06µg/ml. In irrigated condition plants, varieties GW503 (0.55 µg/ml), GW496 (0.93 µg/ml), LOC-1 (0.92 µg/ml) had lowest chlorophyll-b content whereas variety GW273 (4.32 µg/ml), GW366 (4.13 µg/ml) had the highest. Varieties G451 (1.86 µg/ml), GW11 (1.73 µg/ml), GW1255 (1.66 µg/ml), GW173 (1.09 µg/ml) had moderate chlorophyll-b content. In drought condition, varieties GW496 (0.05 µg/ml), G451 (0.13 µg/ml), GW11 (0.22 µg/ml), LOC-1 (0.26 µg/ml) and GW1255 (0.70 µg/ml) had lowest range of chlorophyll-b content. Variety GW273 had the highest chlorophyll-b content while varieties GW503 (1.60 µg/ml), GW173 (1.76 µg/ml) and GW273 (2.51 µg/ml) had moderate range of chlorophyll-b content. At the vegetative stage varieties GW496 (0.93 µg/ml), G451 (1.86 µg/ml), GW11 (1.73 µg/ml), LOC-1 (0.92 µg/ml), GW1255 (1.66 µg/ml), GW273 (4.32 µg/ml) showed significantly higher chlorophyll-b content in irrigated varieties than the drought ones.

***Carotenoids (Car):*** Under irrigated conditions, carotenoid content observed was from 0.31µg/ml to 1.94µg/ml and in drought stressed plants it was observed from 0.17µg/ml to 1.44µg/ml. In irrigated condition plants, varieties GW503 (0.31 µg/ml), GW496 (0.83 µg/ml), LOC-1 (0.47 µg/ml), GW1255 (0.44 µg/ml) and GW173 (0.64 µg/ml) had lowest range of carotenoid content whereas variety GW273 (1.94 µg/ml) had the highest. Varieties G451 (1.10 µg/ml), GW11 (1.16 µg/ml) and GW366 (1.26 µg/ml) had moderate range of carotenoid content. In drought condition plants, varieties GW503 (0.84 µg/ml), GW496 (0.41 µg/ml), G451 (0.46 µg/ml), GW11 (0.17 µg/ml), LOC-1 (0.33 µg/ml), GW1255 (0.85 µg/ml) and GW366 (0.79 µg/ml) had lowest carotenoid content. Varieties GW273 (1.44 µg/ml) had the highest while varieties GW173 (1.15 µg/ml) had moderate range. In irrigated plants varieties GW496 (0.83 µg/ml), G451 (1.10 µg/ml), GW11 (1.16 µg/ml), LOC-1 (0.47 µg/ml), GW1255 (0.44 µg/ml), GW273 (1.94 µg/ml) and GW366 (1.26 µg/ml) showed significantly higher carotenoid content than the drought ones.

*Yield Attributes*

*Spike Length per plant and Spike Weight per plant*

***Spike Length per plant:*** Spike length was recorded higher in irrigated plants than drought condition plants due to appropriate nutrient use efficiency by plant. Spike length was comparatively higher in irrigated plants (Table 1.3). Under irrigated condition GW503 (12.65 cm) showed highest spike length. Lowest spike length was showed by variety GW173 (10.6 cm) and moderate spike length was showed by varieties GW496 (12.0 cm), G451 (9.7 cm), GW11 (10.96 cm), LOC-1 (12.63 cm), GW1255 (12.8 cm), GW273 (11.06 cm) and GW366 (11.4 cm). In drought stressed condition GW173 (12.23 cm) showed highest spike length as compared to all the other varieties in drought conditions. Lowest spike length was shown by variety G451 (9.7 cm) while intermediate length of spike was showed by varieties GW503 (11.6 cm), GW496 (11.96 cm), GW11 (10.30 cm), LOC-1 (12.57 cm), GW1255 (11.1 cm), GW273 (9.56 cm) and GW366 (11.03 cm). In irrigated plants varieties GW503 (12.65 cm), G451 (9.7 cm), GW11 (10.96 cm), LOC-1 (12.63 cm), GW1255 (12.8 cm), GW273 (11.06 cm) and GW366 (11.4 cm) had significantly higher length of spike than in drought stressed plants.

***Spike Weight per plant:*** As spike length was higher, spike weight would also be high in irrigated plants due to accumulation of grains and their weight. In irrigated plants, variety GW496 (0.92 gm) showed highest spike weight as compared to all the other varieties in drought condition. Lowest spike weight was shown by variety GW366 (0.20 gm) while intermediate spike length was showed by varieties GW503 (0.87 gm), G451 (0.49 gm), GW11 (0.28 gm), LOC-1 (0.32 gm), GW1255 (0.32 gm), GW173 (0.29 gm) and GW273 (0.27 gm). Under drought condition GW496 (0.84 gm) showed highest spike weight. Lowest spike weight was shown by variety G451 (0.002 gm) and moderate spike weight was shown by varieties GW503 (0.3 gm), GW11 (0.28 gm), LOC-1 (0.34 gm), GW1255 (0.40 gm), GW173 (0.40 gm), GW273 (0.12 gm) and GW366 (0.20 gm). In irrigated plants varieties GW503 (0.87 gm), GW496 (0.92 gm), G451 (0.49 gm) and GW273 (0.27 gm) had significantly higher weight of spike than in drought stressed plants (Table 1.3).

*Number of grains per spikeand Weight of grains per spike*

***Number of grains per spike:*** Number of grains was comparatively higher in irrigated plants due to sufficient amount of nutrient supply and regular mechanisms of plants. Under irrigated conditions variety GW503 (15.25) had highest number of grains. Lowest number was observed in variety GW366 (5.0) while varieties GW496 (14.34), G451 (14.0), GW11 (9.0), LOC-1 (12.33), GW1255 (7.67), GW173 (8.34) and GW273 (6.67) had intermediate number of grains. In drought stressed conditions, highest number of grains was observed in variety GW496 (18.0). No grains were observed in variety G451 while varieties GW503 (8.33), GW11 (9.66), LOC-1 (11.0), GW1255 (12.0), GW173 (12.6), GW273 (4.0), GW366 (10.3) had intermediate number of grains. In irrigated plants varieties GW503 (15.25), G451 (14.0), LOC-1 (12.33) and GW273 (6.67) had significantly higher number of grains than in drought stressed plants. (Table 1.3)

***Weight of grains per spike:*** Weight of grains was directly proportional to number of grains so, as irrigated plants had high number of grains, weight will also be high with some exceptions described in below mentioned results (Table 1.3). Under irrigated conditions variety GW496 (0.53 gm) had highest weight of grains. Lowest weight was observed in variety GW366 (0.13 gm) while varieties GW503 (0.41 gm), G451 (0.25 gm), GW11 (0.24 gm), LOC-1 (0.21 gm), GW1255 (0.32 gm), GW173 (0.23 gm) and GW273 (0.22 gm) had intermediate weight of grains. In drought stressed condition, highest weight of grains was observed in variety GW496 (0.76 gm). Varieties GW503 (0.27 gm), GW11 (0.238 gm), LOC-1 (0.21 gm), GW1255 (0.28 gm), GW173 (0.23 gm), GW273 (0.11 gm) and GW366 (0.10 gm) had intermediate weight of grains. In irrigated plants varieties GW503 (0.41 gm), G451 (0.25 gm), GW11 (0.24 gm), GW1255 (0.32 gm) and GW273 (0.22 gm) had significantly higher weight of grains than in drought stressed plants.

***Correlation analysis of Irrigated plants:*** Root length is significantly related to root dry weight (0.906, 0.01%), shoot length (0.879, 0.01%), shoot dry weight (0.873, 0.01%), and spike length (0.878, 0.01%). Root length is significantly related to spike weight (0.675, 0.05%), number of grains (0.664, 0.05%), chlorophyll-a (0.595, 0.05%). Root length is negatively significantly related to carotenoids (-0.165, 0%). Root dry weight is significantly related to shoot length (0.981, 0.01%). Root dry weight is significantly related to shoot dry weight (0.979, 0.05%), spike length (0.983, 0.05%), spike weight (0.789, 0.05%), number of grains (0.782, 0.01%), RSI (0.617, 0.05%). Root dry weight is significantly related to chlorophyll-a (0.674, 0.05%), chlorophyll-b (0.559, 0.05%). Root dry weight is negatively related to carotenoids (-0.150, 0%). Shoot length is significantly related to shoot dry weight (0.996, 0.01%), spike length (0.997, 0.01%), spike weight (0.775, 0.01%), number of grains (0.770, 0.01%).Shoot length is significantly related to RSI (0.585, 0.05%), chlorophyll-a (0.633, 0.05%). Shoot length is negatively related to carotenoids (-0.174, 0%).

Shoot dry weight is significantly related to spike length (0.998, 0.01%), spike weight (0.779, 0.01%), number of grains (0.778, 0.01%). Shoot dry weight is significantly related to RSI (0.598, 0.05%), chlorophyll-a (0.650, 0.05%). Shoot dry weight isnegatively related to carotenoids (-0.174, 0%). Spike length is significantly related to spike weight (0.784, 0.01%), number of grains (0.782, 0.01%). Spike length is significantly related toRSI (0.605, 0.05%, chlorophyll-a (0.655, 0.05%). Spike length is negatively related to carotenoids (-0.169, 0%).Spike weight is significantly related to number of grains (0.989, 0.01%), chlorophyll-a (0.693, 0.01%). Spike weight is significantly related toweight of grains (0.599, 0.05%), RSI (0.666, 0.05%), RWC (0.595, 0.05%), chlorophyll-b (0.608, 0.05%). Number of grains is significantly related to weight of grains (0.608, 0.05%), RSI (0.675, 0.05%), RWC (0.603, 0.05%), chlorophyll-b (0.616, 0.05%). Number of grains is significantly related tochlorophyll-a (0.704, 0.01%). Weight of grains is significantly related to RSI (0.994, 0.01%), RWC (0.995, 0.01%), chlorophyll-a (0.975, 0.01%), chlorophyll-b (0.989, 0.01%), carotenoids (0.720, 0.01%). RSI is significantly related to RWC (0.991, 0.01%), chlorophyll-a (0.990, 0.01%), chlorophyll-b (0.990, 0.01%). RSIis significantly related tocarotenoids (0.670, 0.05%). RWC is significantly related to chlorophyll-a (0.971, 0.01%), chlorophyll-b (0.992, 0.01%). RWC is significantly related

**Table 1.1. Mean, standard deviation and comparison of drought and irrigated plants of phenological characteristics for all varieties of wheat**

| Character/Variety | | GW503 | GW496 | GW451 | GW11 | LOC-1 | GW1255 | GW173 | GW273 | GW366 |
|---|---|---|---|---|---|---|---|---|---|---|
| Root Length per plant (cm) | IR | 13.4 ±2.38 | 5.26 ±0.28 | 8.9 ±0.26 | 1.76 ±0.20 | 3.6 ±0.36 | 5.66 ±1.52 | 2.73 ±0.15 | 7.83 ±1.70 | 2.26 ±0.75 |
| | DR | 5.93 ±2.10 | 6.03 ±0.05 | 7.5 ±2.17 | 1.83 ±0.20 | 2.93 ±0.05 | 2.4 ±0.17 | 2.3 ±1.65 | 3.13 ±0.32 | 1.0 ±1.3 |
| Root Dry weight per plant (gm) | IR | 0.049 ±0.005 | 0.027 ±0.018 | 0.90 ±0.79 | 0.012 ±0.0005 | 0.04 ±0.02 | 0.20 ±0.21 | 0.09 ±0.05 | 0.12 ±0.11 | 0.05 ±0.02 |
| | DR | 0.021 ±0.001 | 0.027 ±0.009 | 0.07 ±0.05 | 0.003 ±0.001 | 0.008 ±0.002 | 0.013 ±0.004 | 0.012 ±0.0002 | 0.012 ±0.003 | 0.006 ±0.004 |
| Shoot Length per plant (cm) | IR | 53.63 ±7.79 | 55.86 ±3.15 | 35.8 ±8.68 | 44.7 ±3.04 | 49.4 ±1.12 | 39.0 ±0.86 | 46.1 ±4.45 | 42.83 ± 1.66 | 31.7 ±1.3 |
| | DR | 39.1 ±7.17 | 53.7 ±0.72 | 24.6 ±3.24 | 43.26 ± 2.21 | 46.0 ±1.96 | 34.86 ± 2.70 | 38.3 ±4.85 | 32.6 ±1.27 | 36.36 ± 2.05 |
| Shoot Dry Weight per plant (gm) | IR | 0.90 ±0.24 | 0.43 ±0.32 | 0.86 ±0.027 | 0.13 ±0.002 | 0.24 ±0.01 | 0.24 ±0.02 | 0.21 ±0.06 | 0.29 ±0.16 | 0.20 ±0.01 |
| | DR | 0.44 ±0.02 | 0.64 ±0.38 | 0.81 ±0.43 | 0.24 ±0.006 | 0.21 ±0.053 | 0.22 ±0.03 | 0.22 ±0.10 | 0.16 ±0.06 | 0.20 ±0.05 |

**Table 1.2. Mean, standard deviation and comparison of drought and irrigated plants of physiological characteristics for all varieties of wheat**

| Character/Variety | | GW503 | GW496 | GW451 | GW11 | LOC-1 | GW1255 | GW173 | GW273 | GW366 |
|---|---|---|---|---|---|---|---|---|---|---|
| Relative Water Content (%) | IR | 72.40 ±2.50 | 77.80 ±3.41 | 75.22 ±4.85 | 80.48 ±7.62 | 69.57 ±4.64 | 90.98 ±4.89 | 79.65 ±5.49 | 90.65 ±2.32 | 86.61 ±4.93 |
| | DR | 60.75 ±7.31 | 78.57 ±2.40 | 52.85 ±7.21 | 79.03 ±3.82 | 60.56 ±1.54 | 85.94 ±1.45 | 73.30 ±6.28 | 81.27 ±7.60 | 86.38 ±5.91 |
| Relative Stress Injury (%) | IR | 79.7 ±6.16 | 88.13 ±2.55 | 98.05 ±0.61 | 76.08 ±2.74 | 96.22 ±3.04 | 72.53 ±1.53 | 71.0 ±3.60 | 94.24 ±4.02 | 79.7 ±6.17 |
| | DR | 97.53 ±1.78 | 91.60 ±0.56 | 82.22 ±1.24 | 96.41 ±2.43 | 98.51 ±1.40 | 95.44 ±2.69 | 77.28 ± 3.13 | 75.31 ± 5.49 | 72.44 ± 4.50 |
| Chlorophyll – a (µg/ml) | IR | 1.0 ±0.1 | 2.26 ±1.64 | 2.77 ±1.93 | 3.05 ±0.79 | 0.78 ±0.69 | 1.48 ±2.56 | 1.79 ±0.27 | 7.46 ±5.73 | 3.74 ±0.77 |
| | DR | 2.59 ±0.6 | 1.25 ±0.36 | 0.58 ±0.44 | 0.36 ±0.44 | 1.25 ±0.41 | 2.62 ±3.21 | 4.08 ±0.51 | 5.19 ±1.46 | 2.59 ±1.76 |
| Chlorophyll - b (µg/ml) | IR | 0.55 ±0.21 | 0.93 ±0.33 | 1.86 ±0.96 | 1.73 ±0.58 | 0.92 ±0.82 | 1.66 ±2.88 | 1.09 ±0.63 | 4.32 ±1.21 | 4.13 ±2.00 |
| | DR | 1.60 ±0.96 | 0.05 ±0.24 | 0.13 ±0.19 | 0.22 ±0.27 | 0.26 ±0.27 | 0.70 ±0.84 | 1.76 ±0.73 | 2.5 ±1.63 | 3.06 ±1.72 |
| Carotenoid (µg/ml) | IR | 0.31 ±0.06 | 0.83 ±0.37 | 1.1 ±0.59 | 1.16 ±0.32 | 0.47 ±0.41 | 0.44 ±0.76 | 0.64 ±0.15 | 1.94 ±1.23 | 1.26 ±0.14 |
| | DR | 0.84 ± 0.31 | 0.41 ±0.6 | 0.46 ± 0.34 | 0.17 ± 0.18 | 0.33 ± 0.15 | 0.85 ± 0.98 | 1.15 ± 0.04 | 1.44 ± 0.42 | 0.79 ± 0.32 |

**Table 1.3. Mean, standard deviation and comparison of drought and irrigated plants for yield attributes for all varieties of wheat**

| Character/Variety | | GW503 | GW496 | GW451 | GW11 | LOC-1 | GW1255 | GW173 | GW273 | GW366 |
|---|---|---|---|---|---|---|---|---|---|---|
| Spike Length per plant (gm) | IR | 12.65 ±1.04 | 12.0 ±0.95 | 9.7 ±075 | 10.96 ±0.23 | 12.63 ±1.16 | 12.8 ±0.7 | 10.6 ±1.85 | 11.06 ±1.28 | 11.4 ±0.96 |
| | DR | 12.65 ±1.04 | 11.96 ±1.50 | 1.16 ±2.02 | 10.3 ±0.72 | 12.57 ±1.15 | 11.1 ±2.68 | 12.23 ±0.32 | 9.56 ±0.97 | 11.03 ±0.89 |
| Spike Weight per plant (cm) | IR | 0.87 ±0.42 | 0.92 ±0.097 | 0.49 ±0.05 | 0.28 ±0.051 | 0.32 ±0.05 | 0.32 ±0.15 | 0.29 ±0.21 | 0.27 ±0.10 | 0.20 ±0.13 |
| | DR | 0.3 ±0.22 | 0.84 ±0.139 | 0.002 ±0.0046 | 0.29 ±0.18 | 0.34 ±0.09 | 0.40 ±0.13 | 0.40 ±0.10 | 0.12 ±0.11 | 0.20 ±0.02 |
| No of Grains per spike | IR | 15.25 ±2.87 | 14.34 ±3.78 | 14.0 ±3.46 | 9.0 ±1.73 | 12.33 ±2.08 | 7.67 ±4.93 | 8.34 ±4.16 | 6.67 ±4.16 | 5.0 ±3.60 |
| | DR | 8.33 ±1.154 | 18.0 ±5.29 | 0 | 9.66 ±1.52 | 11 ±2.64 | 12 ±6.08 | 12.6 ±4.16 | 4 ±4.35 | 10.3 ±2.30 |
| Weight of Grains per spike (gm) | IR | 0.41 ±0.18 | 0.53 ±0.20 | 0.25 ±0.03 | 0.24 ±0.017 | 0.21 ±0.04 | 0.32 ±0.02 | 0.23 ±0.086 | 0.22 ±0.003 | 0.13 ±0.10 |
| | DR | 0.27 ±0.07 | 0.76 ±0.10 | | 0.238 ±0.023 | 0.21 ±0.07 | 0.28 ±0.17 | 0.23 ±0.042 | 0.11 ±0.022 | 0.10 ±0.006 |

tocarotenoids (0.762, 0.05%) Chlorophyll-a is significantly related to chlorophyll-b (0.987, 0.01%). Chlorophyll-a is significantly related tocarotenoids (0.618, 0.05%). Chlorophyll-b is significantly related to carotenoids (0.729, 0.01%).

***Correlation analysis of Drought plants:*** Root length is significantly related to root dry weight (0.896, 0.01%), shoot length (0.886, 0.01%), shoot dry weight (0.845, 0.01%), spike length (0.897, 0.01%), spike weight (0.656, 0.01%). Root length is related to number of grains (0.678, 0.05%). Root dry weight is significantly related to shoot length (0.993, 0.01%), shoot dry weight (0.955, 0.01%), spike length (0.998, 0.01%), spike weight (0.769, 0.01%). Root dry weight is related to RSI (0.568, 0.05%). Shoot length is significantly related to shoot dry weight (0.979, 0.01%), spike length (0.991, 0.01%), spike dry weight (0.771, 0.01%), number of grains (0.782, 0.01%). Shoot length is significantly related RSI (0.564, 0.05%).

**Table 2.1. Correlation analysis of irrigated plants**

| | RL | RDW | SL | SDW | SpL | SpW | NOG | WOG | RSI | RWC | Chl-a | Chl-b | Car |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RL | 1.000 | | | | | | | | | | | | |
| RDW | $0.906^{**}$ | 1.000 | | | | | | | | | | | |
| SL | $0.879^{**}$ | $0.981^{**}$ | 1.000 | | | | | | | | | | |
| SDW | $0.873^{**}$ | $0.979^{**}$ | $0.996^{**}$ | 1.000 | | | | | | | | | |
| SpL | $0.878^{**}$ | $0.983^{**}$ | $0.997^{**}$ | $0.998^{**}$ | 1.000 | | | | | | | | |
| SpW | $0.675^{*}$ | $0.789^{**}$ | $0.775^{**}$ | $0.779^{**}$ | $0.784^{**}$ | 1.000 | | | | | | | |
| NOG | $0.664^{*}$ | $0.782^{**}$ | $0.770^{**}$ | $0.778^{**}$ | $0.782^{**}$ | $0.989^{**}$ | 1.000 | | | | | | |
| WOG | $0.439^{NS}$ | $0.553^{NS}$ | $0.523^{NS}$ | $0.532^{NS}$ | $0.541^{NS}$ | $0.599^{*}$ | $0.608^{*}$ | 1.000 | | | | | |
| RSI | $0.497^{NS}$ | $0.617^{*}$ | $0.584^{*}$ | $0.598^{*}$ | $0.605^{*}$ | $0.666^{*}$ | $0.675^{*}$ | $0.994^{**}$ | 1.000 | | | | |
| RWC | $0.393^{NS}$ | $0.508^{NS}$ | $0.471^{NS}$ | $0.488^{NS}$ | $0.495^{NS}$ | $0.595^{*}$ | $0.603^{*}$ | $0.995^{**}$ | $0.991^{**}$ | 1.000 | | | |
| Chl-a | $0.595^{*}$ | $0.674^{*}$ | $0.633^{*}$ | $0.650^{*}$ | $0.655^{*}$ | $0.693^{**}$ | $0.704^{**}$ | $0.975^{**}$ | $0.990^{**}$ | $0.971^{**}$ | 1.000 | | |
| Chl-b | $0.481^{NS}$ | $0.559^{*}$ | $0.510^{NS}$ | $0.527^{NS}$ | $0.533^{NS}$ | $0.608^{*}$ | $0.616^{*}$ | $0.989^{**}$ | $0.990^{**}$ | $0.992^{**}$ | $0.987^{**}$ | 1.000 | |
| Car | $-0.165^{NS}$ | $-0.150^{NS}$ | $-0.193^{NS}$ | $-0.174^{NS}$ | $-0.169^{NS}$ | $0.131^{NS}$ | $0.132^{NS}$ | $0.720^{**}$ | $0.670^{*}$ | $0.762^{**}$ | $0.618^{*}$ | $0.729^{**}$ | 1.000 |

**Table 2.2. Correlation analysis of Drought plants**

| | RL | RDW | SL | SDW | SpL | SpW | NOG | WOG | RSI | RWC | Chl-a | Chl-b | Car |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RL | 1.000 | | | | | | | | | | | | |
| RDW | $0.896^{**}$ | 1.000 | | | | | | | | | | | |
| SL | $0.886^{**}$ | $0.993^{**}$ | 1.000 | | | | | | | | | | |
| SDW | $0.845^{**}$ | $0.955^{**}$ | $0.979^{**}$ | 1.000 | | | | | | | | | |
| SpL | $0.897^{**}$ | $0.998^{**}$ | $0.991^{**}$ | $0.955^{**}$ | 1.000 | | | | | | | | |
| SpW | $0.656^{*}$ | $0.769^{**}$ | $0.771^{**}$ | $0.762^{**}$ | $0.774^{**}$ | 1.000 | | | | | | | |
| NOG | $0.679^{*}$ | $0.779^{**}$ | $0.782^{**}$ | $0.761^{**}$ | $0.791^{**}$ | $0.984^{**}$ | 1.000 | | | | | | |
| WOG | $0.329^{NS}$ | $0.417^{NS}$ | $0.413^{NS}$ | $0.397^{NS}$ | $0.429^{NS}$ | $0.402^{NS}$ | $0.434^{NS}$ | 1.000 | | | | | |
| RSI | $0.469^{NS}$ | $0.568^{*}$ | $0.564^{*}$ | $0.542^{NS}$ | $0.582^{*}$ | $0.614^{*}$ | $0.646^{*}$ | $0.967^{**}$ | 1.000 | | | | |
| RWC | $0.437^{NS}$ | $0.532^{NS}$ | $0.520^{NS}$ | $0.487^{NS}$ | $0.545^{NS}$ | $0.620^{*}$ | $0.650^{*}$ | $0.957^{**}$ | $0.994^{**}$ | 1.000 | | | |
| Chl-a | $0.486^{NS}$ | $0.535^{NS}$ | $0.528^{NS}$ | $0.504^{NS}$ | $0.548^{NS}$ | $0.534^{NS}$ | $0.570^{*}$ | $0.979^{**}$ | $0.990^{**}$ | $0.982^{**}$ | 1.000 | | |
| Chl-b | $0.501^{NS}$ | $0.553^{*}$ | $0.537^{NS}$ | $0.498^{NS}$ | $0.566^{*}$ | $0.551^{NS}$ | $0.588^{*}$ | $0.968^{**}$ | $0.987^{**}$ | $0.987^{**}$ | $0.996^{**}$ | 1.000 | |
| Car | $-0.152^{NS}$ | $-0.115^{NS}$ | $-0.131^{NS}$ | $-0.147^{NS}$ | $-0.107^{NS}$ | $0.036^{NS}$ | $0.050^{NS}$ | $0.840^{**}$ | $0.729^{**}$ | $0.754^{**}$ | $0.758^{**}$ | $0.749^{**}$ | 1.000 |

Shoot dry weight is significantly related to spike length (0.955, 0.01 %), spike weight (0.762, 0.01%), number of grains (0.761, 0.01%). Spike length is significantly related to spike weight (0.774, 0.01 %), number of grains (0.791, 0.01 %). Spike length is significantly related to RSI (0.582, 0.05%), chlorophyll-b (0.566, 0.05%). Spike weight is significantly related to number of grains (0.984, 0.01%). Spike weight is significantly related to RSI (0.614, 0.05%), RWC (0.620, 0.05%). Number of grains is significantly related to RSI (0.646, 0.05%), RWC (0.650, 0.05%), chlorophyll-a (0.570, 0.05%), chlorophyll-b (0.588, 0.05%). Weight of grains is significantly related to RSI (0.967, 0.01 %), RWC (0.957, 0.01 %), chlorophyll-a (0.979, 0.01 %), chlorophyll-b (0.968, 0.01 %), carotenoids (0.840, 0.01 %). RSI is significantly related to RWC (0.994, 0.01 %), chlorophyll-a (0.990, 0.01 %), chlorophyll-b (0.987, 0.01 %), carotenoids (0.729, 0.01 %). RWC is significantly related to chlorophyll-a (0.982, 0.01 %), chlorophyll-b (0.987, 0.01 %), carotenoids (0.754, 0.01 %). Chlorophyll-a is significantly related to chlorophyll-b (0.996, 0.01 %), carotenoids (0.758, 0.01 %). Chlorophyll-b is significantly related to carotenoids (0.749, 0.01 %).

## DISCUSSION

Drought stress is a conservative loss of water resulting in stomatal closure and disruption in cell structure as well as plant metabolism (McDowell *et al.,* 2008). Variations due to phenotypes were significant for all the characters in two conditions (irrigated and drought). Various physiological and morphological characteristics for different varieties were observed under irrigated and drought conditions which could indicate proportion of drought tolerance. Phenological characteristics include days to 50% flowering and 50% maturity. Wheat under drought condition will try to complete its life cycle early by maintaining water status through increasing water absorption or reducing water loses.

Days to 50% flowering and maturity were observed after 52 days respectively. Under drought stress, roots extend their length in order to percolate water around itself and absorb sufficient amount of water to survive against drought conditions. Due to increase in length and more absorption of water through soil, biomass of roots also increases in water deficit conditions but results showed that water deficit plants had decrease in root length as well as root weight due to poor mechanisms of plant growth regulators (Farooq *et al.,* 2009). In irrigated condition, plants absorb water effectively along with nutrients present in soil so, more the absorption of water, more the nutrient availability in plants and so more the weight. Thus, root dry weight was higher in irrigated plants as compared to drought condition plants (Mohammad, Shah, and Asim 2000). G451 had highest root length and biomass which shows tolerance towards water deficit conditions. The mean comparison of traits was observed in the above-mentioned table which showed that irrigated plants had higher results in shoot related characteristics. Shoot length is higher due to adequate transpiration and translocation mechanism whereas in water deficit plants, shoot length observed was comparatively diminutive as plants need to overcome water and nutrient deficit conditions caused by drought (Mathobo, Marais, and Steyn 2017). Shoot dry weight depends on the inner mass and tillers of wheat (Mohammad *et al.,* 2000). Irrigated plants can accumulate water inside tissues due to sufficient amount of landed water whereas water deficient can't do so due to which inner mass decreases in case of water deficit plants (Farooq *et al.,* 2009). Results showed that G451 and GW496 had higher shoot length and weight compared to other varieties which indicates tolerance towards drought stress. But, inadequacy of water in plants leads them to decrease their shoot length to transport and translocate effortlessly compared to irrigated plants (Machado and Paulsen 2001).

Physiological characteristics have 5 main observations: RWC, RSI, chlorophyll-a, chlorophyll-b and carotenoids. Leaf production depends on water content and transpiration rate (Farooq *et al.,* 2009). With absorption of water from roots and passing on to leaves, plants will have high rates of transpiration and water content in leaves will increase effectively in irrigated plants unlikely in water deficit plants and water potential decreases in drought stressed plants (Machado and Malik 2009). There was no change found in GW366 indicating high tolerance mechanism. Relative stress injury is induced under stressed conditions providing measurement of injury caused to plants. Plants under such stressed conditions try to become resistant towards the extraneous factors where plants activate some genes providing tolerance towards the environment. Here, it can be stated that water deficit plants will have RSI relatively higher than irrigated varieties but in GW503 had no such injury. Chlorophyll and carotenoid content depend on photosynthetic reactions, ATP, NADPH (Farooq *et al.,* 2009).

Carotenoid is an accessory pigment which provides sunlight to chlorophyll as chlorophyll directly cannot capture sunlight and passes it to photosystem I and photosystem II which converts light energy into chemical energy which is obtained in the form of ATP and NADPH (Berk, Zipursky, and Freeman 2000). Now, with the help of end products of photo systems and fixed carbon dioxide, plants produce glucose. So, we can say that in wheat more the carotenoid present in chromoplast, more will be the sunlight captured and thus more will be the chlorophyll (Christopher, James Wynne, and Lobban 1981). Variety GW273 had the highest value of chlorophyll and carotenoid content present which indicates less damage to plants. Yield traits like spike length, spike weight, number of grains and weight of grains depend upon the mechanism controlled by plants in drought and irrigated condition. Normal mechanism (irrigated plants) will show high quality and quantity of spike and grains while plants in stressed condition will adapt different genetic modifications within themselves to overcome the stress due to which plants are incapable to develop good quality spike and produce sufficient grains (Farooq *et al.,* 2009). Spike length and spike weight are directly proportional to each other.

Irrigated plants should have higher spike length and weight due to normal plant transpiration and translocation mechanisms and drought stressed plants should show low weight and length in comparison. But, in drought stressed plants observations state that GW173 and GW496 had highest spike length and weight. This can be due to high activation of mechanisms by which plants tried to overcome drought stress producing high rate of auxins, gibberellins in plants (Yadav and Sharma 2016). Similarly, weight and number of grains are directly proportional to each other (Farooq *et al.,* 2009). Under water stress condition, plants try to increase below ground area to absorb more amounts of nutrients from soil, xylem and phloem had performed better mechanisms in GW496. In comparison to other varieties, GW496 showed the highest resistance against drought stress. Though it showed low resistance towards water content, membrane injury unlike GW451 but yield development was highest in GW496 against any other factor. GW451 showed highest tolerance towards stress injury, water content, growth related factors but yield development observed was least in this variety which may be due to crop had developed mechanisms in order to survive but could not give sufficient productivity. GW1255, LOC-1 and GW11 had least resistance towards drought stress. All of these varieties had least productivity in terms of RWC, RSI, chlorophyll and carotenoid. GW503, GW173, GW273, GW366, GW496 were tolerant and they may combat the stress with moderate yield attributes. Thus, varieties can be used for crop production but yield would be moderate. Therefore, study shows that GW496 was highly tolerant towards drought stress and could be one of the varieties surviving against drought and act as drought tolerant plant.

**Acknowledgment**

We would like to heartily thank our research head, Dr. Summy Yadav for guiding us with the research. We are very thankful to Biological and Life Sciences, School of Arts and Sciences, Ahmedabad University, for providing us valuable sources and time for conducting the experiments successfully. We would also like to acknowledge all the lab coordinators who ensured the availability of materials and instruments whenever required.

## REFERENCES

Berk, Lodish, SL Zipursky, and WH Freeman. 2000. *Molecular Cell Biology*. 4th ed.

Christopher, S. Lobban, Michael James Wynne, and Lobban. 1981. *The Biology of Seaweeds*.

Fahad, Shah, Ali A. Bajwa, Usman Nazir, Shakeel A. Anjum, Ayesha Farooq, Ali Zohaib, Sehrish Sadia, Wajid Nasim, Steve Adkins, Shah Saud, Muhammad Z. Ihsan, Hesham Alharby, Chao Wu, Depeng Wang, and Jianliang Huang. 2017. "Crop Production under Drought and Heat Stress: Plant Responses and Management Options." *Frontiers in Plant Science* 8:1147.

Farooq, M., A. Wahid, N. Kobayashi, D. Fujita, and S. M. A. Basra. 2009. "Plant Drought Stress: Effects, Mechanisms and Management." *Agronomy for Sustainable Development* 29(1):185–212.

Hassani, Ibrhim, Shailesh Marker, and GM Lal. 2017. "Inter-Relationship Studies among Grain Yield and Its Component Characters in Wheat (Triticum Aestivum L.)." *Journal of Pharmacognosy and Phytochemistry* 6(4):186–91.

Kumar, P., R. K. Yadava, B. Gollen, R. K. Verma, and S. Yadav. 2011. "Nutritional Contents and Medicinal Properties of Wheat: A Review." *Life Sciences and Medicine Research* (1).

Machado, S. and Ali Hafeez Malik. 2009. *Nutrient Uptake, Transport and Translocation in Cereals: Influences of Environmental and Farming Conditions*. Alnarp.

Machado, Stephen and Gary M. Paulsen. 2001. "Combined Effects of Drought and High Temperature on Water Relations of Wheat and Sorghum." *Plant and Soil* 233(2):179–87.

Mathobo, Rudzani, Diana Marais, and Joachim Martin Steyn. 2017. "The Effect of Drought Stress on Yield, Leaf Gaseous Exchange and Chlorophyll Fluorescence of Dry Beans (Phaseolus Vulgaris L.)." *Agricultural Water Management* 180:118–25.

McDowell, Nate, William T. Pockman, Craig D. Allen, David D. Breshears, Neil Cobb, Thomas Kolb, Jennifer Plaut, John Sperry, Adam West, David G. Williams, and Enrico A. Yepez. 2008. "Mechanisms of Plant Survival and Mortality during Drought: Why Do Some Plants Survive

While Others Succumb to Drought?” *New Phytologist* 178(4):719–39.

Mohammad, Akmal, Sohail Mumtaz Shah, and M. Asim. 2000. “Yield Performance in Three Commercial Wheat Varieties Due to Flag Leaf Area.” *Pakistan Journal of Biological Sciences* 3(12):2072–74.

Nayak, Sumanta, Imranul Haque Choudhury, Nishika Jaishee, and Suprakash Roy. 2014. “Spectrophotometric Analysis of Chlorophylls and Carotenoids from Commonly Grown Fern Species by Using Various Extracting Solvents.” *Research Journal of Chemical Sciences* 4(9):63–69.

Shavrukov, Yuri, Akhylbek Kurishbayev, Satyvaldy Jatayev, Vladimir Shvidchenko, Lyudmila Zotova, Francois Koekemoer, Stephan de Groot, Kathleen Soole, and Peter Langridge. 2017. “Early Flowering as a Drought Escape Mechanism in Plants: How Can It Aid Wheat Production?” *Frontiers in Plant Science* 8:1950.

Singh, Narender and Vandita Mittal. 2016. “Molecular Studies on Drought Tolerance in Wheat Triticum Aestivum L.” Kurukshetra University.

Summy, K. S. Boora, and K. D. Sharma. 2016. “Physiological Traits in Relation to Yield Improvement in Chickpea ( *Cicer Arietinum* L.) under Depleting Soil Moisture Environment.” *Indian Journal of Genetics and Plant Breeding (The)* 76(2):209.

Waseem, Muhammad, Asghar Ali, M. Tahir, M. A. Nadeem, M. Ayub, Asif Tanveer, R. Ahmad, and M. Hussain. 2011. “MECHANISM OF DROUGHT TOLERANCE IN PLANT AND ITS MANAGEMENT THROUGHDIFFERENT METHODS.” *Continental J. Agricultural Science* 5(1):10–25.

Yadav, Summy, K. D. Sharma, Neeraj Kumar, and K. S. Boora. 2015. “Plant Water Status, Canopy Temperature and Chlorophyll Fluorescence in Relation to Yield Improvement in Chickpea (Cicer Arietinum L.) under Soil Moisture Stress.” *Journal of Agrometeorology* 17(1):11–16.

Yadav, Summy and Kamal Dutt Sharma. 2016. “Molecular and Morphophysiological Analysis of Drought Stress in Plants.” in *Plant Growth*, edited by E. C. Rigobelo. InTech.

*******