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EVALUATING PHYSIOLOGICAL TRAITS FOR DROUGHT TOLERANCE IN WHEAT VARIETIES UNDER DIFFERENT IRRIGATION CONDITIONS

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Abstract: Wheat (*Triticum aestivum* L.) is a staple food for more than 35% of the world's population and it is also the first grain crop in most of the developing countries. In arid/semiarid region the major constraint limiting wheat production is inadequate rainfall reducing average yield up to 50% and over. Water deficit stress is the most common environmental stress affecting about 32% of the 99 million hectares which is under wheat cultivation in developed countries. Drought stress (DS) reduces plant growth and manifest several morphological, physiological and biochemical alteration leading to massive loss in yield. In this study three wheat varieties were grown in the field of Water Technology Centre, IARI, NewDelhi with controlled and scheduled irrigation environments. Physiological parameters such as photosynthetic rate, relative water content (RWC), chlorophyll SPAD, transpiration rate, leaf temperature and agronomic traits such as grain yield, total biomass and harvest index were recorded under controlled and scheduled irrigation environments andPhysico-chemical properties of experimental soil was also studied. Wheat variety HD3059 perform well in comparison to HD 3226 and HD 2967 for physiological and agronomic parameters under scheduled irrigation environments suggested that the wheat variety HD3059 has great potential as compare to the other two varieties under scheduled irrigation environments.

INTRODUCTION

Global wheat production in the major production regions is being threatened by recurrent drought that is predicted to increase with climate change (Li *et al.* 2009). Drought tolerant wheat varieties are the ultimate means of safeguarding the crop against adverse effects of drought. However, drought tolerance (DT) is a complex trait that is controlled by numerous genes, each with minor effects (Bernardo 2008). Due to its polygenic inheritance and genotype by environment interaction, DT typically has low heritability (Blum 2010; Khakwani*et al.* 2012). Despite these challenges, determination of the genetic diversity existing within and between wheat populations remains the basis for elucidation of the genetic structure and for improvement of quantitative traits, including DT. In wheat, greater genetic variability can be explored with germplasm from its centers of origin and diversity (Dvorak *et al.* 2011). Besides cultivated wheat varieties and breeding stocks, extensive variability for DT remains within wild relatives and landraces (Nevo and Chen 2010; Dodig*et al.* 2012). Manipulation of this diversity to improve DT among cultivars may be achieved through genetic modification or selection for adaptive mechanisms (Blum 2010).

Drought stress reduces plant growth and manifests several morphological, physiological and biochemical alterations leading to massive loss in yield (Farooq *et al.* 2012).Knowledge of phenotypic traits contributing to improved yields under stress is fundamental to the

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understanding of the complex physiological and genetic mechanisms of wheat adaptability (Reynolds *et al.* 2005).Drought tolerance is seen in almost all plant species but its extent varies from species to species and even within species due to differences in phonological, morphological, biochemical, physiological and molecular adaptive mechanisms (Bhattacharya 2021). DT does not exist as a unique and easily quantifiable plant attribute, it is a complex physiological, morphological and molecular character connected with relative water content (RWC), relative water loss (RWL), chlorophyll fluorescence, cell membrane stability (CMS). Total chlorophyll content and the Chl a/b ratio were found to reduce under water stress conditions. A decrease in this index was faster in drought sensitive than in drought tolerant genotypes (Guo *et al.* 2018). According to Shertneva *et al.* (2020), chlorophyll, fluorescence measurement appears very promising for screening of genotypes forDT but no reliable markers have been identified to select the most promising cultivars at an early stage.

Keeping in mind the above facts, the objectives of this research work were to study the impact of drought stress on physiological traits such as photosynthetic rate, relative water content (RWC), chlorophyll SPAD, transpiration rate, leaf area index, leaf temperature and agronomic traits such as grain yield, total biomass and harvest indexin wheat varieties under controlled and scheduled irrigation environments.

MATERIALS AND METHODS

Soil samples from the experimental field was collected as per the standard procedure. Physical and chemical characterization were done under standard laboratory techniques.

Experimental Design and Treatments

This study was carried out during 2019-20 at the experimental site of the Department of Water Technology Centre (WTC), Indian Agriculture Research Institute (IARI)s, New Delhi. The experiment was conducted in a randomized complete block design with three replications. The plot size was 4.0 m × 5.0 m. The spacing between plots and blocks were 0.75 and 1.0 m, respectively. Three varieties HD3059, HD3226 and HD2967 were sown in the field of WTC, IARI in mid-November and harvested in mid-April. All the physiological data and agronomical were recorded. Controlled treatments received four irrigations while the scheduled irrigation received only two irrigations. The following physiological traits were recorded.

Chlorophyll content (%) SPAD

Chlorophyll content was measured by chlorophyll meter Minolta SPAD 502. Chlorophyll meter was placed on flag leaf base, center and the tip and readings were noted. Three plants from each replication of both treatments were randomly selected and then averaged to note chlorophyll content for each treatment.

Relative water content (RWC)

Fresh leaves from each treatment were collected and weighed to record fresh weight (FW). Turgid weight (TW) was measured after placing it in distilled water for 4 hr. Thereafter, oven-dried the selected leaf segments at 72 °C for 48 h and weighed again to find out dried weight (DW). RWC was calculated using the formula given by Barrs and Weatherley (1962).

RWC (%) = (Fresh weight − Dry weight / Turgid weight − Dry weight) × 100%

Canopy temperature (°C)

Canopy temperature was measured by using Infrared Thermometer (Model AG-42, Tela-temp Crop, Fullerton, CA.). One measurement per polythene bag was taken from nearly 50 cm above the canopy with an angle of 30° from the horizontal. Data presented for each treatment was the mean of three sets of measurements made pre-heading between 12:00 and 16:00 hours.

Agronomic parameters

Grain yield and total biomass were calculated according to one meter square (g m^2) for each variety, and then converted to tons per hectares. Biomass was estimated from the above-ground tissues including the tillers per plant and spikes. Harvest index was calculated by dividing the grain yield by the biological yield.

RESULTS AND DISCUSSION

The experimental field soil was normal in pH (7.65±0.09) with Sandy Loam texture. The organic carbon content was falls under low category (0.45±0.08 %), the other detailed properties of soil are listed in the Table 1.

Table 1: Physico-chemical properties of experimental soil

Parameters	*Values*
pH	7.65±0.09
EC (dS/m)	0.65±0.12
Organic carbon (%)	0.45±0.08
Available N (kg ha^{-1})	306±11.12
Available P (kg ha^{-1})	26.2±2.47
Available K (kg ha^{-1})	163±8.82
Bulk density (g/ml)	1.45
Hydraulic Conductivity (ml hr^{-1})	1.34±0.03
Clay (%)	15.7
Silt (%)	29.1
Sand (%)	55.2
Texture	Sandy Loam

Physiological parameters

Relative water content is an important characteristic that measures water status in plants reflecting the ongoing metabolic activities in tissues and that may be used as a reliable indicator of DT. The RWC in flag leaf at 12 DAA was profoundly affected by DS in all wheat varieties. The results indicated that variety HD3059 and HD3226 maintained a greater amount of water in the leaves under DS than HD2967. A less reduction of RWC in response to DS has been noted for DT variety HD3226. The results of our study were in close agreement with the findings obtained by (Boyer *et al.* 2008; Belay *et al.* 2021), who reported that wheat plants subjected to DS significantly reduced the RWC. Reduction of RWC in leaves might be associated with the loss of water as well as the variations of water uptake among the genotypes. Increased leaf water retention (LWR) through less reduction of RWC due to DS could be attributed to rolling of leaves, which results in serious decline of exposed surface area, and thus might be used as an indicator for determining the DT potential of crop plants (Singh and Patel 1996).

Variety that established high LWR under DS tend to have significantly higher potential for preserving water balance in leaves, which reflects their DS tolerance. As DS leads to scarcity of water in the root zone, plants slow down water loss by closing stomata for surviving under DS. Therefore, RWC and leaf rolling hold perspectives for utilization in breeding programs aimed at improving the drought tolerance and boosting genetic potential for higher grain yields (Lonbani *et al* 2011). Variation of RWC among the genotypes may be owing to diverse genetic potential for absorbing water from the rhizosphere and extending the depth of roots to exploit lower soil horizons for moisture extraction. Plants strive to alleviate the damaging effects of stress by altering their metabolism to cope with stress. However, the genotypes with reduced leaf water loss due to DS are believed to be more drought tolerant (Kakwani *et al.* 2012), and RWC may be used as a useful indicator in order to screen out wheat genotypes having superior DT. As far as RWC is concerned, the genotype HD3226 followed by HD3059 may be suggested as drought-tolerant, owing to a minimum relative reduction of RWC.

In order to screen out drought-tolerant wheat genotypes, Chl. content has been assessed successfully by many researchers (Chowdhury *et al.* 2021). Drought tolerant genotypes maintain high Chl content, essential for photosynthesis, and higher Chl. content that is lower reduction due to DS in wheat genotypes is voted as tolerant genotypes (Ahmed *et al.* 2020; Chowdhury *et al.* 2021) . In addition, Chl has been regarded as a vital chloroplast component, which is crucial for photosynthesis and photosynthetic rate (Sharma *et al* 2020). It is an indicator of the photosynthetic activity, biosynthesis of assimilates (Manivannan *et al.* 2007)and senescence (Bijanzadeh *et al.* 2010). However, the Chl content in flag leaves of wheat genotypes was significantly influenced by water regimes at 24 DAA. Acute DS hampers photosynthesis by destroying Chl components, damaging the photosynthetic systems, along with decreasing the uptake of nutrients from soil solution and translocation within the crop plants (Rana *et al.* 2017).

Furthermore, DS also damages the thylakoid membranes; adversely affecting Chl synthesis, accumulation, and distribution of assimilates

(Wright *et al*, 2009). The Chl content of the leaf may be used as an index for source evaluation; therefore, Chl content decline under DS has been considered as a pronounced non-stomatal limiting factor (Urban *et al*, 2018). Additionally, Chl content has been recognized as an index to determine plants tolerance to DS (Khayatnezhad *et al.* 2021). From overall information, it may be concluded that HD3226 is a tolerant Variety since it contains the highest amount of Chl than the other genotypes.

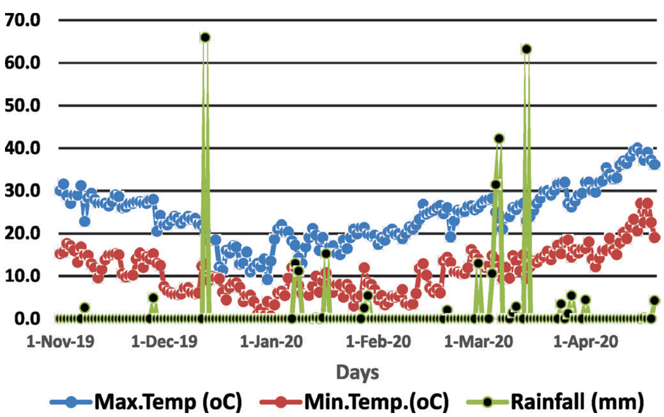

Figure 1: Maximum and minimum temperature and rainfall during wheat cropping season.

Grain yield and yield components

The grain yield of wheat genotypes was significantly influenced by DS in the field (Figure 2b). Other studies also showed that a stress environment reduces grain yield in wheat compared to control (Qaseem *et al* 2019; Zhang *et al* 2018). DS had unusual effects on the grain yield, depending on the developmental stage in which it occurs. Significant reduction in grain yield due to post-anthesis water stress may result from a reduction of the production of photo-assimilates (source limitation), power of the sink to absorb photo-assimilates and the grain filling duration (Poudel *et al.* 2020). The yield variation under DS can be attributed to the diverse genetic

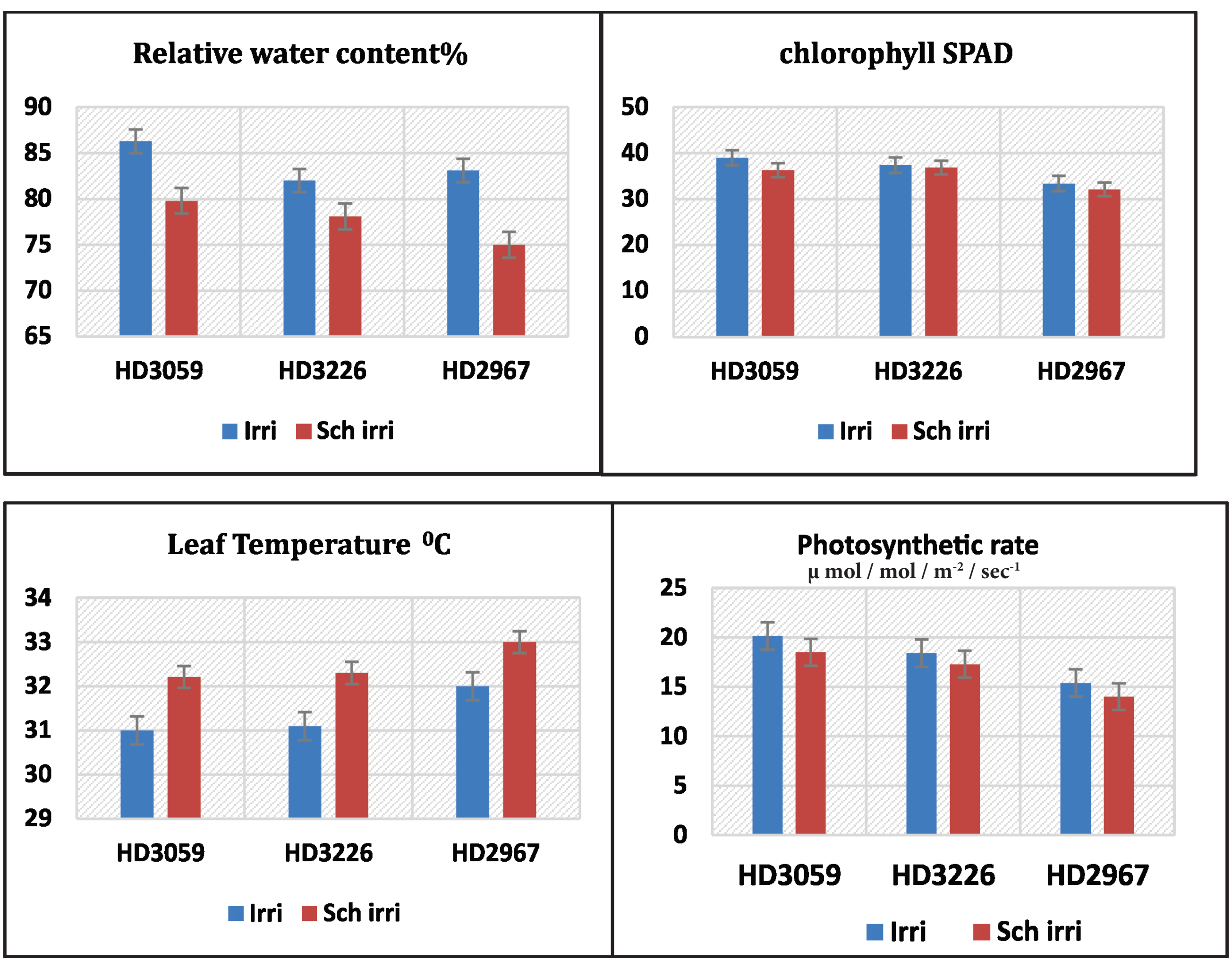

Figure 2 a: Physiological parameters in wheat variety under controlled and scheduled irrigation

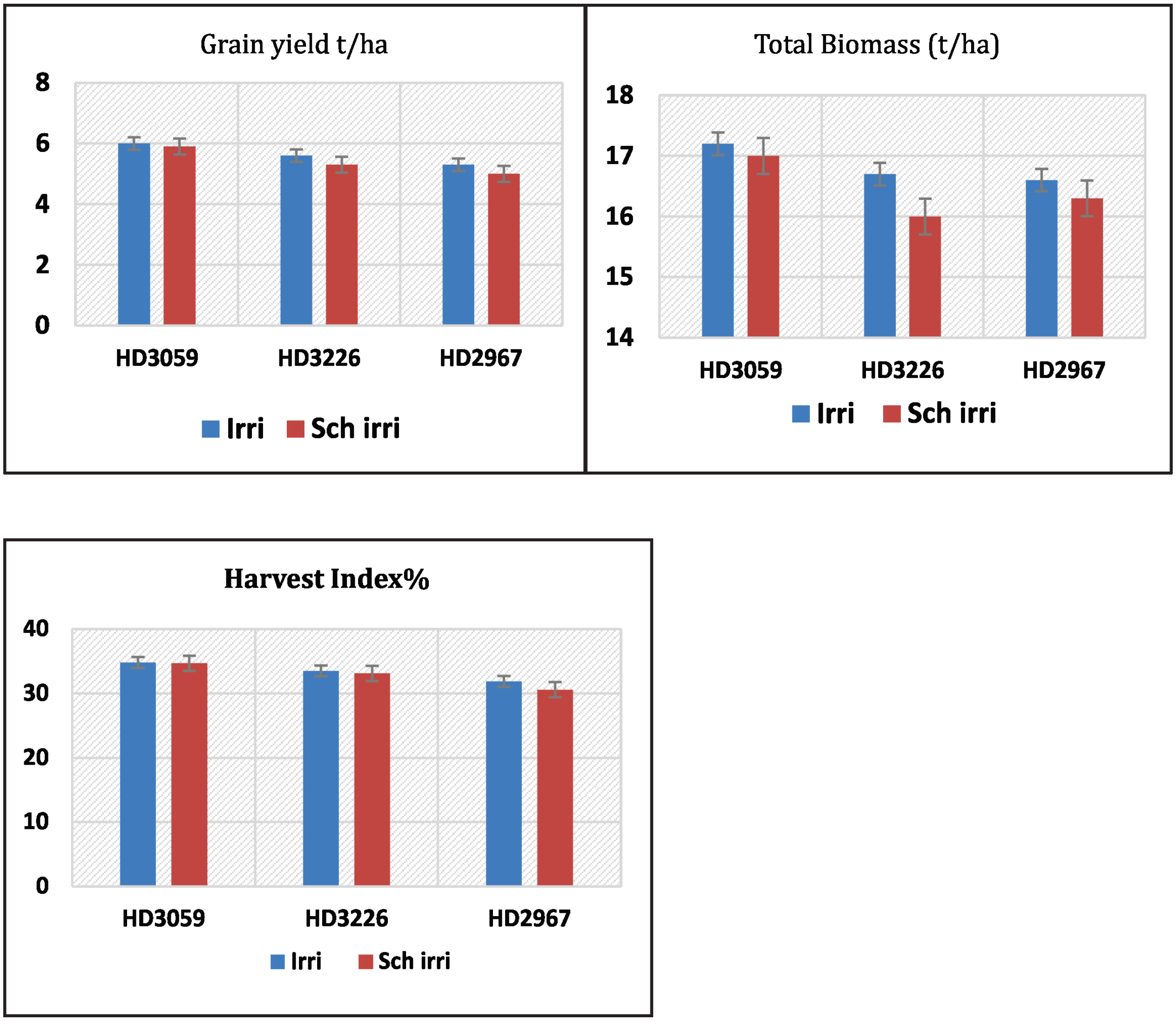

Figure 2 b: Agronomic parameters in wheat variety under controlled and scheduled irrigation.

background among the genotypes (Farooq *et al.* 2015; Quadir *et al* 2017; Nazir *et al* 2021), and activated genes in response to drought exhibited variation intheir expression (Yasir *et al* 2019).

CONCLUSION

In this study, the DS remarkably decreased the physiological parameters suchas RWC, photosynthetic rate, chlorophyll SPAD, leaf temperature in all wheat variety. However, the reductionwas comparatively lower in variety HD3059 and HD3226 than HD2967 indicating their superiority in terms of DT. Wheat variety HD3059 perform well in comparison to HD3226 and HD 2967 for physiological and agronomic parameters under scheduled irrigation environments suggested that the wheat variety HD3059 has great potential as compare to the other two varieties under scheduled irrigation environments.

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