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Combine Effects of Drought and High Temperature on Water Relation Traits in Wheat Genotypes under Late and Very Late Sown Condition

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A B S T R A C T

Combine effects of drought and high temperature, causes significant reduction in wheat (*Triticum aestivum* L.) quality and yield worldwide. The objective of this study was to quantify independent and combined effects of drought and high temperature stress in eight bread wheat genotypes at anthesis and 21 days after anthesis (DAA). To determine the effect of combine stress present experiment were conducted in randomized complete block design with five replications. In order to assess the relative capability of stress tolerance water relation parameters (relative water content, water potential and osmotic potential) and grain yield per plot were studied. Results of genotype × environmental interaction showed grain yield reduction was significant under drought stress. Wheat genotypes showed significant reduction under terminal heat and drought stress condition, except DHTW-60 and C-306. The multiple statistical procedures used in this study showed that osmotic potential, water potential and grain yield is the most important trait for tolerant genotype selection. It is suggested that more emphasis should be given on the physiological characters for selecting wheat genotypes with higher grain yield under both (drought and high temperature) condition.

Keywords

Wheat, Drought, High Temperature and Water Relation traits.

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Introduction

Bread wheat (*Triticum aestivum* L.) is used mainly for human consumption and supports nearly 35% of the world population by providing 55% of the carbohydrates and 20% of the food calories consumed globally (Saleem, 2015). In India, 29% of the total cultivable area faces drought condition out of which 10% is under severe drought (Singh and Vaishali, 2016). The response to stress depends on the wheat genotype, the specific temperature and the time in which the temperature regimen is imposed during the developmental programme (Ihsan *et al.*, 2016). Combine effect of high temperature and drought affect germination, tiller production, vegetative growth and dry matter production, reproductive development, grain yield (Boyer and Westgate, 2004; Prasad *et al.*, 2008) and grain quality (Britz *et al.*, 2007; Prasad *et al.*, 2011). Combination of drought and high temperature stress alter physiological and molecular processes such as photosynthesis, accumulation of lipids, and transcript expression (Rizhsky *et al.*, 2004), the combination had a significantly higher detrimental effect on growth and productivity of crops compared with each stress applied individually (Savin and Nicolas, 1996; Shah and Paulsen, 2003).

Drought and high temperature are a major constrain for wheat productivity in many regions of the world. Major abiotic stress in India that affects wheat is high temperature and drought. The abiotic stresses are estimated to reduce yields to less than a half of that possible under ideal growth conditions (Barnabas *et al.,* 2008; Prasad *et al.,* 2008).). Drought and high temperature not only affects the physiology but also affects the morphology, metabolism and biochemical properties of plants (Pandey *et al.,* 2015).

These responses include stomatal closure, repression of cell growth and photosynthesis and activation of photorespiration. High temperature stress is a major yield limiting factor adversely affecting wheat development and growth and causes low yield in many regions of the world (Modarresi *et al.,* 2010).

In India drought and high temperature usually occur simultaneously, high temperature and drought affect photosynthesis through disruptions in the structure and function of thylakoid membrane, reductions in chlorophyll content (Xu *et al.,* 1995) and accelerate leaf senescence (Al- Khatib and Paulsen, 1984; Machado and Paulsen, 2001) whereas, drought affect osmotic adjustment in plants by increasing the rate of evapotranspiration and decline the rate of photosynthesis and increase photorespiration (Lawlor, 1979; Munjal and Dhanda, 2016).

The aim of present study was to investigate the independent and combined effects of drought and high temperature imposed from tillering to physiological maturity on water relation traits and grain yield of eight wheat genotypes under timely, late and very late sown condition.

Materials and Methods

Raising of crop and plant material

Two-year experiment was conducted during winter season of mid-November to April, 2015-16 and 2016-17 with eight selected wheat genotype *viz.*, AKAW-3717, C-306, DHTW-60, HD-2967, HTW-11, Kundan, WH-730 and WH-1105. In control (irrigated) and drought-stressed experiments (with pre-sowing irrigation only), genotypes were sown at optimum planting date, while for heat-stressed experiment sowing date was delayed. Timely sowing was done on 17 November, 2015 and 13 November, 2016; late sowing on 14 December, 2015 and 16 December, 2016 and very late sowing 13 January, 2016 and 11 January, 2017. The experiment was conducted in the field and laboratory of Wheat and Barley section, Department of Genetics and Plant Breeding, College of Agriculture, CCS HAU, Hisar.

Treatment detail

Drought was created by withholding the irrigation at different stages (40 days after sowing (DAS), 80 DAS, 40+80 DAS (Both at 40 and 80 days after sowing) and for complete drought no irrigation was given throughout the year).

Osmotic potential

The leaf, which was used for water potential was frozen in a freezer below -20 °C for seven days. The frozen leaf material was then thawed and cell sap extracted with the help of a syringe. 10 µl of extracted cell sap was directly used for the determination of osmotic potential using an osmometer (Wescor 5520). Osmotic potential value obtained from the osmometer was in mmol kg^{-1}, which was converted to -MPa (pressure unit) according to the equation: OP (-MPa) = (-

R×T×osmometer reading)/1000; (R is the gas constant (0.008314) and T is the laboratory temperature (T = 298K).

Water potential

The fully expanded flag leaf of five plants of each treatment was used to determine the leaf water potential. The measurements were made from 8.00 to 10.00 a.m. with Scholander type pressure chamber (Model 3005. This pressure (-bar) was recorded as water potential in bar and the calculation for conversion of bar in MPa were done as following formula. -10 bar = 1 –Mpa.

Relative water content

The RWC was measured in flag leaf of five selected plant were weighed fresh (W_F), floated on distilled water at room temperature in the dark for 4 h, weighed again (W_T), and finally dried at 80°C for 48 h for dry weight determination (W_D). RWC was calculated according to the formula: RWC (%) = $(W_F-W_D)/(W_T-W_D) \times 100$.

Yield

Grain yield was recorded after harvesting and thrashing the plot. The thrashed grains were cleaned and yield was recorded in gram.

Sampling

Five plants of each genotype were randomly tagged for each treatment. Samples for water relation traits were collected from the tagged plants at anthesis and 21 days after anthesis. Grain yield data were recorded at maturity.

Results and Discussion

The water status of a crop plant is usually expressed in terms of water content, water potential or/and some other water relation related components (Sabir *et al.,* 2008; Javed *et al.,* 2011).

Osmotic potential (OP)

Osmotic potential was significantly reduced at anthesis and 21 days after anthesis in all four treatments (D40, D80, D40+80 and Drought) and environments (LS and VLS), whereas genotype DHTW-60 and C-306 has shown maximum osmotic potential. At anthesis (Fig. 1a) mean osmotic potential value was -1.31 MPa in irrigated environment (timely sown), -1.50 MPa (late sown) and -1.55 MPa in (very late sown), combine effects of drought and heat showed mean osmotic potential value was -1.75 MPa in irrigated environment (timely sown), -1.92 MPa (late sown) and -2.13 MPa plants whereas, at 21 days after anthesis (Fig. 1b) mean osmotic potential value was -1.37 MPa irrigated environment (timely sown), -1.55 MPa (late sown) and -1.71 MPa in (very late sown), combine effects of drought and heat showed mean osmotic potential value was -1.90 MPa irrigated environment (timely sown), -2.20 MPa (late sown) and -2.51 MPa. All through there were significant difference in osmotic potential among the genotype and treatments, the interaction between genotype and treatment were significant in all three environments. Our results are in agreement with those of Siddique *et al.,* (2000) and Akram, 2011 in wheat and Sharma *et al.,* (2016) in barley found decrease in osmotic potential on the onset of stress.

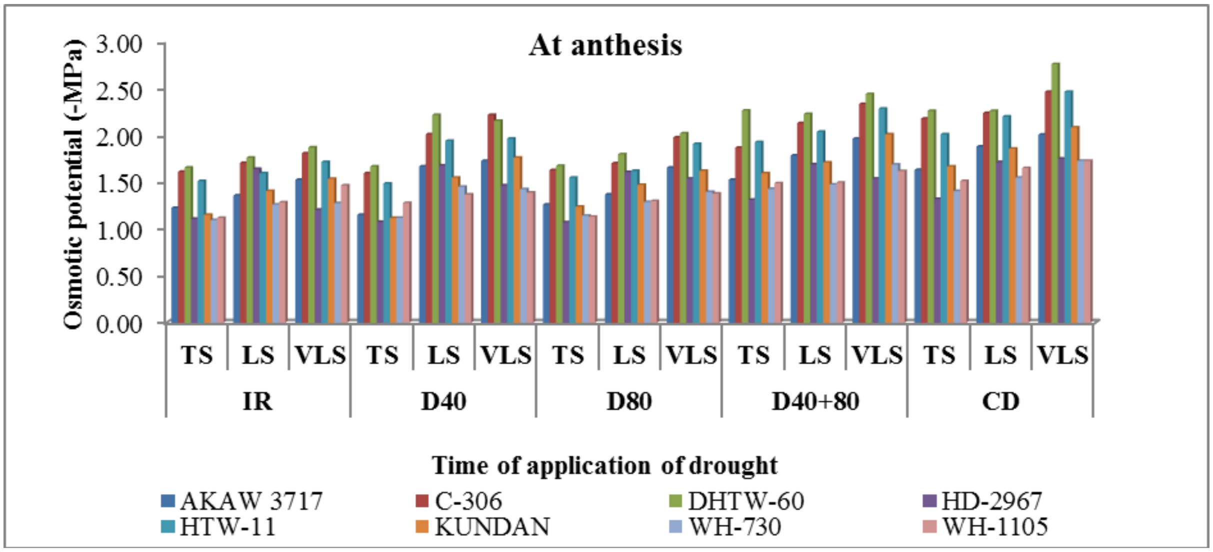
Water potential

Water potential was significantly reduced at anthesis and 21 days after anthesis in all three treatments (Irrigated, D40, D80, D40+80 and Drought) and environments, whereas genotype DHTW-60 and C-306 has shown maximum water potential.

Table.1 Grain yield per plot (g) in wheat genotypes under timely, late and very late sown conditions

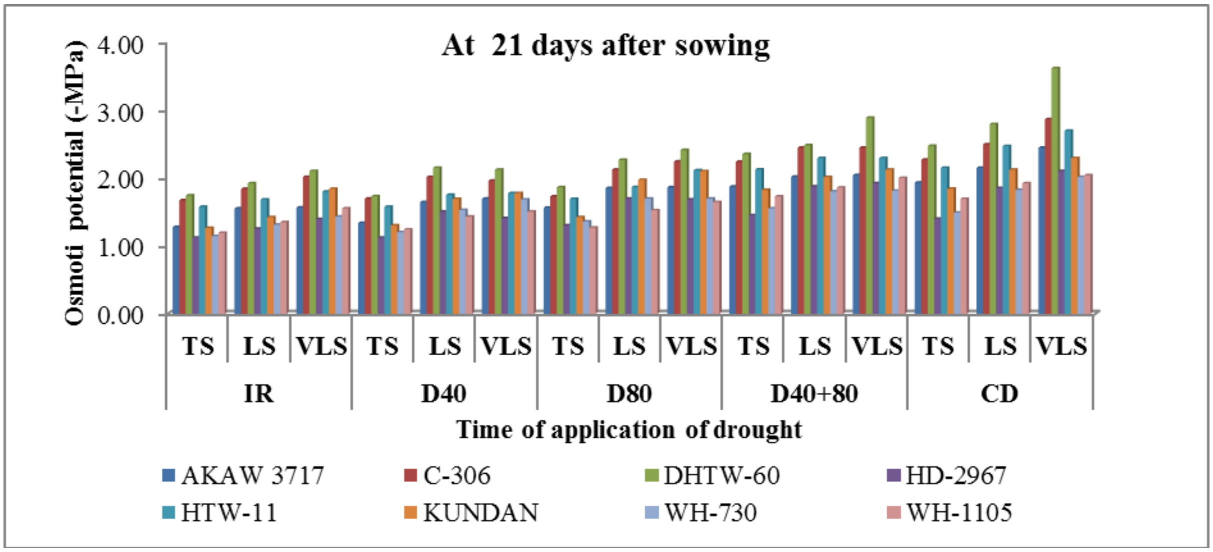
Genotype/	Timely Sown						Late Sown						Very Late Sown					
	Treatments						Treatments						Treatments					
	Control	D40	D80	D40+80	Drought	Mean (G)	Control	D40	D80	D40+80	Drought	Mean (G)	Control	D40	D80	D40+80	Drought	Mean (G)
AKAW 3717	867.0	644.7	720.0	552.7	261.3	609.1	569.0	426.0	495.3	359.3	185.0	406.9	328.7	180.3	259.7	47.3	34.7	170.1
C-306	1067.7	696.3	816.3	628.7	404.0	722.6	704.0	486.0	553.3	417.0	333.3	498.7	524.7	247.0	318.0	110.3	88.7	257.7
DHTW-60	1237.3	706.0	830.0	638.7	448.0	772.0	796.0	492.0	559.0	425.3	353.7	525.2	534.0	249.7	324.3	118.0	95.3	264.3
HD-2967	912.3	666.3	747.7	565.0	273.3	632.9	586.3	443.7	515.0	389.3	247.3	436.3	347.7	203.7	278.7	71.7	54.7	191.3
HTW-11	945.3	688.0	793.7	601.7	367.3	679.2	652.0	477.7	536.3	411.3	325.0	480.5	494.3	231.3	317.0	99.0	80.0	244.3
KUNDAN	880.7	647.0	736.7	563.7	220.7	609.7	577.7	437.3	498.7	372.7	196.7	416.6	333.7	198.0	273.3	59.3	45.7	182.0
WH-730	926.0	679.3	785.0	586.0	361.3	667.5	632.0	463.0	530.3	407.0	276.7	461.8	453.0	222.3	301.7	91.3	65.0	226.7
WH-1105	924.0	676.7	766.7	573.7	370.3	662.3	601.7	450.3	522.3	398.3	272.7	449.1	358.7	210.0	292.3	80.3	62.0	200.7
Mean (T)	970.0	675.5	774.5	588.8	338.3		639.8	459.5	526.3	397.5	273.8		421.8	217.8	295.6	84.7	65.8	
CD at 5%	**Treatment (T) = 10.00**			**TxG= 28.29**			**Treatment (T) = 6.90**			**TxG= 19.52**			**Treatment (T) = 3.89**			**TxG= 10.99**		
	Genotype (G)= 12.65						**Genotype (G)= 8.73**						**Genotype (G)= 4.92**					

Fig.1a Osmotic potential (-MPa) in wheat genotypes at anthesis under timely, late and very late sown conditions



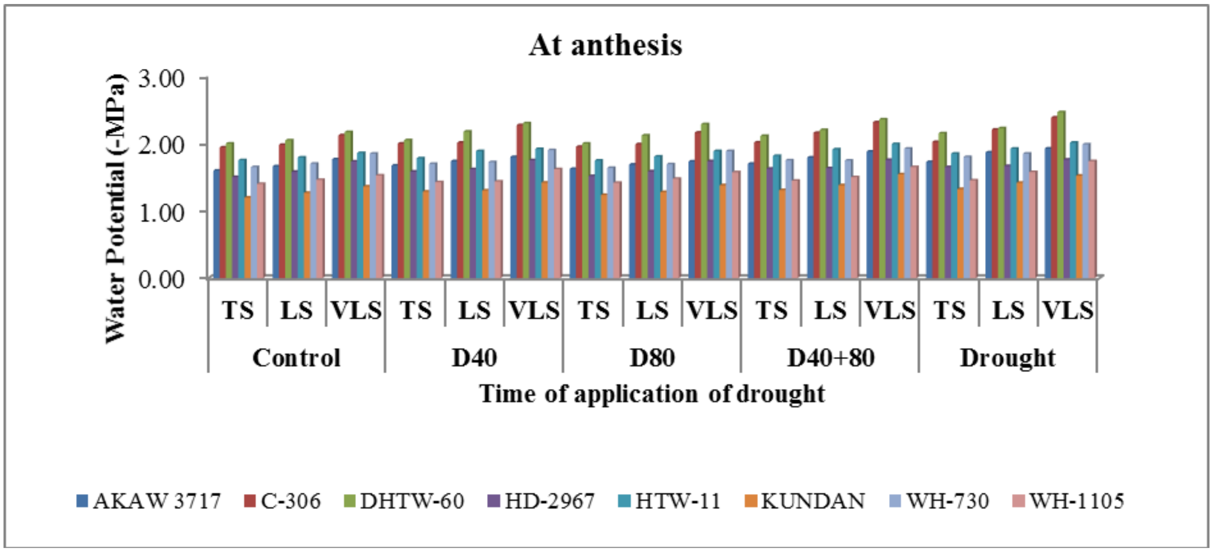
IR- Irrigated, **D40**- Drought at 40 days after sowing (DAS), **D80**- Drought at 80 DAS, **D40+80**- Drought at 40+80 DAS, **CD**- Complete drought, **TS**-Timely Sown, **LS**-Late sown and **VLS**- Very Late Sown

Fig.1b Osmotic potential (-MPa) in wheat genotypes at 21 days after anthesis under timely, late and very late sown conditions



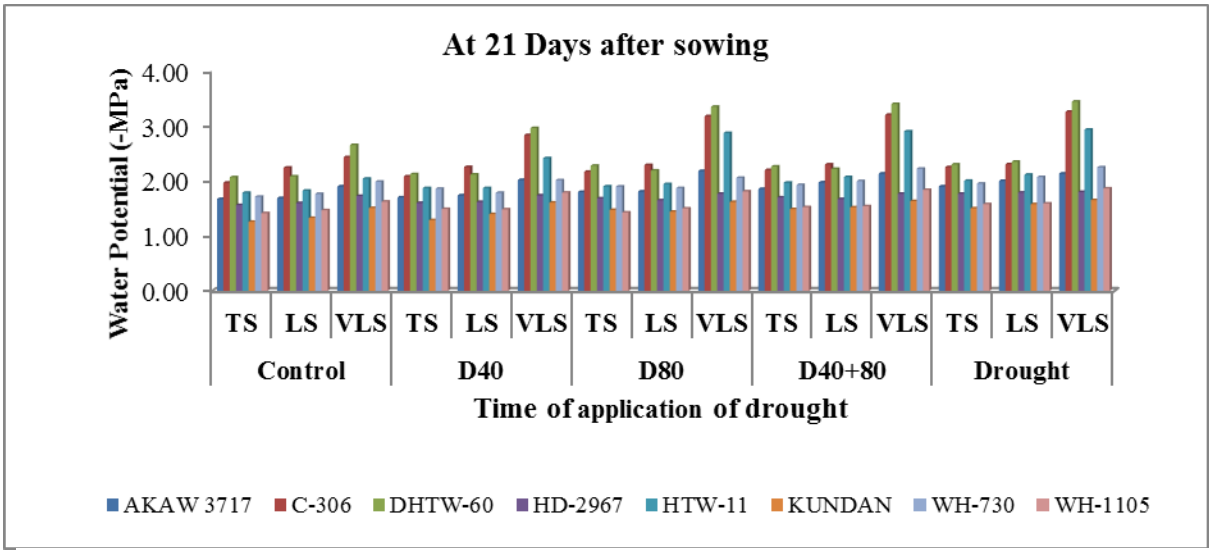
IR- Irrigated, **D40**- Drought at 40 days after sowing (DAS), **D80**- Drought at 80 DAS, **D40+80**- Drought at 40+80 DAS, **CD**- Complete drought, **TS**-Timely Sown, **LS**-Late sown and **VLS**- Very Late Sown

Fig.2a Water potential (-MPa) in wheat genotypes at anthesis under timely, late and very late sown conditions



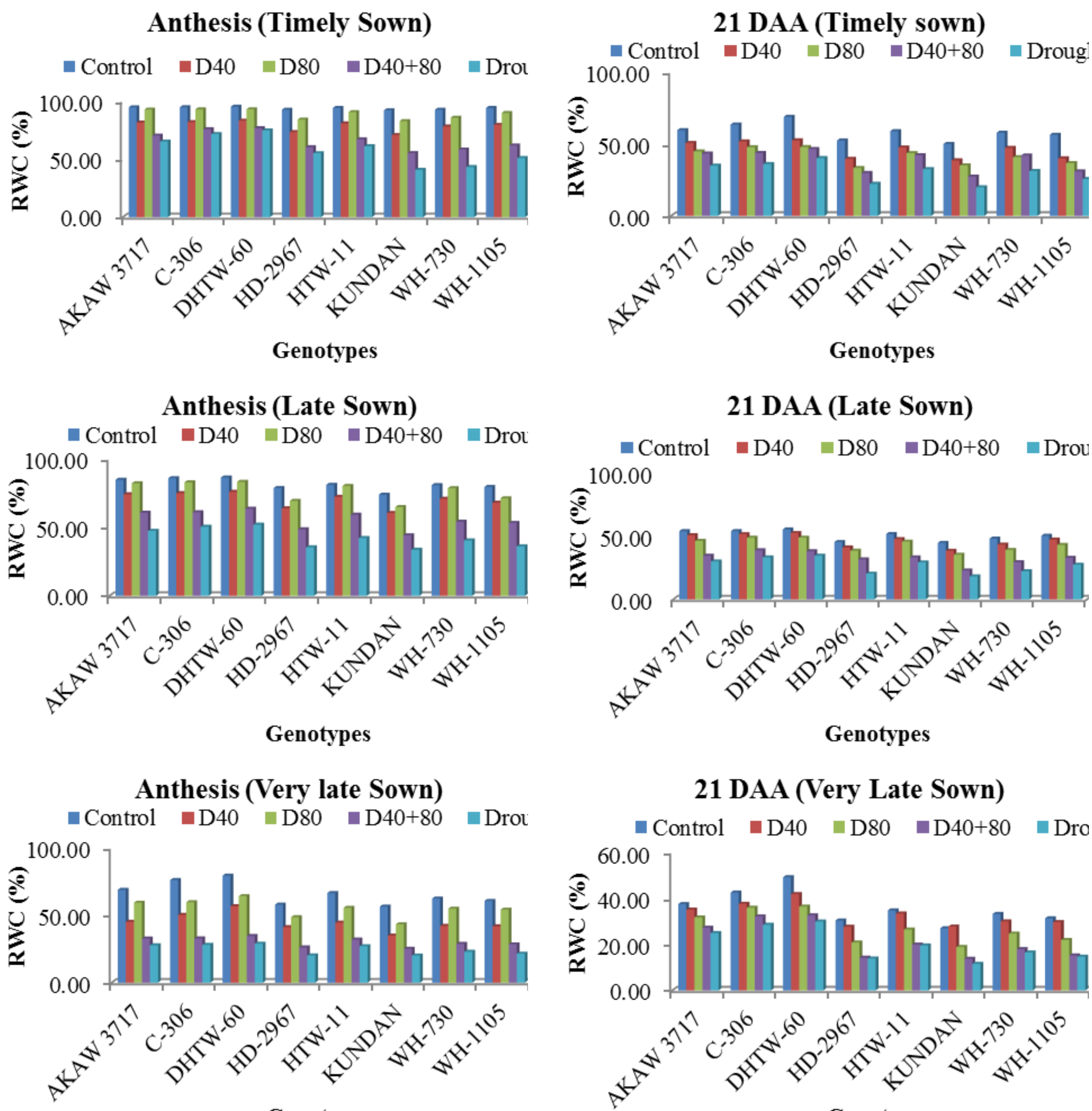
IR- Irrigated, **D40**- Drought at 40 days after sowing (DAS), **D80**- Drought at 80 DAS, **D40+80**- Drought at 40+80 DAS, **CD**- Complete drought, **TS**-Timely Sown, **LS**-Late sown and **VLS**- Very Late Sown

Fig.2b Water potential (-MPa) in wheat genotypes at 21 days after anthesis under timely, late and very late sown conditions



IR- Irrigated, **D40**- Drought at 40 days after sowing (DAS), **D80**- Drought at 80 DAS, **D40+80**- Drought at 40+80 DAS, **CD**- Complete drought, **TS**-Timely Sown, **LS**-Late sown and **VLS**- Very Late Sown

Fig.3 Relative water content (%) in wheat genotypes at anthesis and 21 days after anthesis under timely, late and very late sown conditions



Control- Irrigated, **D40**- Drought at 40 days after sowing (DAS), **D80**- Drought at 80 DAS, **D40+80**- Drought at 40+80 DAS and **Drought**- Complete drought

Drought stress at anthesis (Fig. 2a) showed mean water potential value was -1.63 MPa in irrigated environment (timely sown), -1.69 MPa (late sown) and -1.80 MPa in (very late sown), combine effects of drought and heat showed mean water potential value was -1.75 MPa in irrigated environment (timely sown), -1.84 MPa (late sown) and -1.98 MPa in whereas, at 21 days after anthesis (Fig. 2b) showed mean water potential value was -1.68 MPa in irrigated environment (timely sown), -1.75 MPa (late sown) and -1.98 MPa in (very late sown), combine effects of drought and heat showed mean water potential value was -1.91 MPa in irrigated environment (timely sown), -1.97 MPa (late sown) and -2.42 MPa in. All through there were significant difference in water potential among the genotype and treatments, the interaction between genotype and treatment were significant in all three environments. Our results are in agreement with those of Abebe *et al.*, (2003) in wheat, Behbahanizadeh *et al.*, (2014) in barley genotypes water potential reduced in contrast to control condition and cultivars had a significant difference together in water relation traits.

Relative water content (RWC)

Relative water content indicated the relative amount of water present in the tissues, and is a measure of turgor in leaf tissue. All genotypes show higher RWC under timely sown irrigated conditions compared to late and very late sown stress condition in figure 3. Compared to 21 days after anthesis the relative water content was found higher at anthesis stage in tolerant and susceptible genotypes. As the duration of temperature and drought treatment increased the relative water content decreased in all genotypes at anthesis and 21 days after anthesis. Drought stress at anthesis showed mean relative water content value was 93.9% in irrigated environment (timely sown), 81.4% (late sown) and 66.0% in (very late sown). Combine effects of drought and heat showed mean relative water content value was 58.3% irrigated environment (timely sown), 50.6% (late sown) and 35.8% whereas, at 21 days after anthesis shows mean relative water content value was -57.9% in irrigated environment (timely sown), 42.3% (late sown) and 24.5% in (very late sown), combine effects of drought and heat showed mean relative water content value was 30.3% irrigated environment (timely sown), 27.0% (late sown) and 19.9%. Genotype DHTW-60 and C-306 has sown high RWC as compare to other genotype under late and very late sown environment with drought condition. Decrease in RWC in response to abiotic stress has been documented in a wide variety of plants by Almeselmani *et al.*, (2012); Saxena *et al.*, (2014) and Ramani *et al.*, (2017).

Yield

Overall average mean grain yield per plot was higher in DHTW-60 and C-306, followed by HTW-11 (Table 1). High temperature and drought led to a decrease in mean grain yield per plot, respectively. Interaction of genotype and treatments resulted in significant decrease of grain yield per plot, however maximum decline was observed at drought 40+80 days after sowing and complete drought in late and very late sown condition. A greater decline in grain yield per plot was observed in AKAW-3717 followed by HD-2967, due to interactive effects of combine stresses than DHTW-60 in relation to control in all environment. Our results are in agreement with those of Lopes *et al.*, (2012) and Hossain (2012) in wheat found reduction in yield on the onset of stress. Under drought and heat stress conditions in cereal crops grain yield was positively correlated with RWC, WP and OP Behbahanizadeh *et al.,* (2014).

In conclusion, from the above results and discussion, it may be concluded that the combined effect of high temperature and drought is more destructive than stress alone. Relative water content, osmotic potential and water potential decreased in wheat genotype under combine effects of drought and high temperature. Genotypes DHTW-60, C-306 and HTW-11 showed maximum water retention capacity and yield in all environment (timely sown, late sown and very late sown) and all treatments (drought at 40 DAS, drought at 80 DAS, Drought at 40+80 DAS and complete drought) conditions. Genotype was found promising and may be exploited in future breeding programme in order to improve water status and ultimately yield in wheat crop.

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