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EVALUATION OF WHEAT GENOTYPES FOR TERMINAL HEAT TOLERANCE BY SIMPLE PHYSIOLOGICAL TRAITS

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SUMMARY

Four wheat genotypes were evaluated for terminal drought and heat tolerance by imposing three irrigation levels under timely and late planting. The physiological traits such as leaf relative water content (RWC), canopy temperature depression (CTD) and relative injury to cell membrane (RI) were measured during the reproductive growth period before and after desiccant spray (KI, potassium iodide) along with the grain yield and yield-attributes recorded after physiological maturity. RWC and CTD decreased while RI increased significantly in late planted crop. RWC and CTD were higher in irrigated (I_N) and I_N+KI spray than unirrigated environment (I_0). Grain yield was higher under timely than late sown condition and in irrigated than unirrigated and I_N+KI environments. Genotype PBW 343 showed higher RWC, CTD and grain yield than genotypes NIAW 34, Raj 3765 and WH 711. RWC and CTD showed positive while RI showed negative association with grain yield. RWC, CTD and RI were also correlated with each other. Therefore, these traits can be successfully used to screen wheat genotypes for terminal drought and high temperature stress caused by late planting.

Key words: **Canopy temperature depression, heat tolerance, relative injury, relative water content, wheat**

INTRODUCTION

The productivity of wheat is drastically reduced due to late planting in north western plain zone of India. Late planting of wheat has become a regular feature in this zone because of long duration preceding crops like rice and cotton, which causes delay in subsequent farm operations. One of the main reasons for reduced yield is the decrease in plant water status due to excessive water loss through rapid transpiration caused by high temperature and water deficit (Kumar *et al.* 2005). Exposure of late sown crop to high temperature and water deficit during reproductive growth stage also reduces grain filling period and remobilization of photosynthates to developing grains (Fisher 2007). In short term, adoption of agronomic practices like zero tillage can reduce the time of wheat planting, however, long term strategy requires the identification and development of late sown cultivars, which can withstand terminal drought or water deficit and high temperature after anthesis.

Plants exposed to high temperature and water stress have evolved a series of morphological and physiological adaptations, which confer tolerance to these stresses. However, the utility of a plant character as a selection criterion depends upon its rapid assessment and simplicity. Most physiological screening tests are too slow and complex to be suitable for large scale breeding programmes. The aim of the present study was to

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identify simple physiological traits which can be used to identify and screen wheat genotypes by assessing their association with grain yield.

MATERIALS AND METHODS

The study was conducted at CCS Haryana Agricultural University, Hisar (29°10'N latitude, 75°48'E longitude and 215 m altitude) during the winter season of 2002-03. The experiment was laid out in a split plot design with two dates of sowing (timely, 21^{st} November and late, 22^{nd} December) and three irrigation environments (normal irrigated, 3 irrigations at 31, 55 and 119 DAS to the timely sown and at 25, 50 and 83 DAS to the late sown crop (I_N), I_N + potassium iodide (KI) spray, 0.2% concentration at $1/3^{rd}$ seed fill cavity (I_N+KI) and no post-sowing irrigation (I_0) in the main plots and four wheat genotypes (NIAW 34, PBW 343, Raj 3765 and WH 711) in the sub- plots with three replications. Other agronomic practices and plant protection measures were followed as per standard recommendations for the timely and late sown wheat.

Physiological traits like relative water content, RWC (as described by Kumar *et al.* 1984), canopy temperature depression, CTD (by infrared thermometer, Telatemp. AG 42) and relative injury (RI) to cell membrane were measured concurrently on the flag leaf during midday hours before and 7 days after KI spray after spike emergence. RI which represented electrolyte leakage was determined by the method described by Blum and Embercon (1992). The extent of injury was estimated as RI using the following equation:

$$RI\ (\%) = 1- [\{1/ (T_1/T_2)\} / \{1- (C_1/C_2)\}] \times 100$$

T and C referred to conductance for treatment and control vials, respectively and subscripts 1 and 2 are initial and final conductance, respectively. Grain yield and yield-attributes were recorded after harvest.

RESULTS AND DISCUSSION

The development of water stress was faster under late than timely sown crop as indicated by the decrease in soil moisture content (Fig. 1) and RWC (Table 1) which was 6.4% in late and 4.8% in timely sown crop after 7 days. The crop under timely sowing maintained cooler canopy than late sown crop. Plants in irrigated environment maintained cooler canopy than the plants in I_0 and I_N+KI. Desiccant sprayed plants remained warmer due to dehydration and complete loss of chlorophyll. On the other side, higher leaf conductance in I_N due to more water availability (Fig. 1), and perhaps presence of comparatively higher green leaf area in I_0 than I_N+KI might have led to greater leaf transpiration and therefore, greater cooling effect (higher CTD) in the former than in the latter environment (Reynolds *et al.* 2004). Wheat genotypes PBW 343 and Raj 3765 maintained cooler canopy than genotypes NIAW 34 and WH 711. Higher RWC might have resulted in increased leaf transpiration and cooler effect in the former than the latter genotypes. Similar genotypic differences in CTD due to differences in RWC were also reported in wheat (Reynolds *et al.* 2004).

Fig. 1. Changes in soil moisture content (SMC, volume/volume basis) under timely (a and b) and late sown (c and d) wheat. Irrigation was applied on 31, 55 and 119 DAS in timely and on 25, 50 and 83 DAS in late sown crop. Values in parenthesis represent standard deviation of mean of the three observations.

Relative injury (RI) to cell membrane (electrolyte leakage) was greater under late than timely sown crop. Higher ambient air temperature and vapor pressure deficit increased plant water deficit, which reduced RWC causing dehydration of cellular membranes and thereby increasing RI in the late than timely sown crop. RI increased many folds in desiccant spray plants

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Table 1. Effect of different treatments on canopy temperature depression (CTD), relative water content (RWC) and relation injury (RI) in wheat.

Treatment	CTD (°C)		RWC		RI (%)	
	Before KI spray	7d after KI spray	Before KI spray	7d after KI spray	Before KI spray	7d after KI spray
Date of sowing						
Timely (21 November)	7.84	3.20	0.83	0.79	4.97	8.31
Late (22 December)	4.32	2.97	0.78	0.73	9.92	17.72
lsd (P=0.05)	0.11	0.17	0.02	0.01	0.21	0.21
Irrigation levels						
Irrigated (I_N)	5.84	5.42	0.82	0.80	7.26	7.78
I_N+KI	5.86	0.70	0.81	0.71	7.31	28.0
I_0	3.32	2.97	0.78	0.72	9.64	10.75
lsd (P=0.05)	0.11	0.20	0.02	0.05	0.21	0.25
Genotypes						
NIAW 34	4.38	2.96	0.81	0.77	8.40	15.88
PBW 343	5.00	3.35	0.80	0.76	7.60	11.78
Raj 3765	4.92	3.37	0.79	0.75	8.60	16.41
WH 711	4.03	2.45	0.80	0.75	9.20	18.00
lsd (P=0.05)	0.30	0.23	0.01	0.09	0.16	0.26

I_N= Irrigated, KI= Potassium iodide spray (0.2% conc.), I_0= No post sowing irrigation

because of rapid dehydration of leaves (Sawhney and Singh 2002). Wheat genotype PBW 343 showed lowest RI indicating greater tolerance to high temperature and water stress, which occurred at terminal growth stages. RI was also lower in genotype NIAW 34 as compared to genotypes Raj 3765 and WH 711. Genotype NIAW 34 is a recommended late sown variety and therefore, genetically may have greater tolerance to high temperature at terminal growth stages, whereas genotypes Raj 3765 and WH 711 are evolved for timely sown conditions.

Grain yield was decreased by 28.1% due to late sowing (Table 2). Yield decreased by 44.4 and 21.2% due to KI spray and no post-sowing irrigation as compared to normally irrigated crop. The differences in grain yield between the treatments were due to similar differences in number of spikes, grains spike^{-1} and 1000-grain weight (Table 3). Among the yield attributes, numbers of spikes were affected most by date of sowing and 1000-seed weight by irrigation application (Reynolds *et al*. 2007). In desiccant spray environment, the decrease in grain yield was mainly due to reduced seed size (15.5% compared to normal irrigation), which was triggered by higher electrolyte leakage due to greater RI. Desiccant spray is reported to result in cessation of current photosynthesis as well as their translocation to different plant organs (Kumar *et al.* 1994). Whereas greater soil moisture availability (Fig 1a, c) improved plant water status resulting to lower RI, which might have improved the rates of photosynthesis and their translocation to developing seeds (Parry *et al.* 2007).

Table 2. Effect of different treatments on grain yield of wheat.

Genotype	Grain yield (kg/ha)					
	Irrigation levels				Sowing time	
	I_N	I_N+KI	I_o	Mean	Timely	Late
NIAW 34	4140	2407	2613	3053	3435	2672
PBW 343	4043	2157	3622	3274	3707	2841
Raj 3765	3972	2108	3481	2998	3697	2677
WH 711	3864	2225	2906	3187	3721	2275
Mean	4005	2224	3156		3640	2616
lsd (P=0.05)						
Sowing time		238				
Irrigation levels		291				
Genotypes		NS				
Genotypes × irrigation levels		546				
Genotypes × Sowing time		NS				

I_N= Irrigated, KI= Potassium iodide spray (0.2%), I_0= No post sowing irrigation

Table 3. Effect of different treatments on yield-attributes of wheat.

Treatment	Spikes/m^2	Grains/spike	1000-seed weight (g)
Date of sowing			
Timely (21 November)	414.2	47.0	38.8
Late (22 December)	374.7	42.0	36.4
lsd (P=0.05)	17.8	4.6	NS
Irrigation levels			
Irrigated (I_N)	383.6	47.3	40.8
I_N + KI	402.2	45.2	34.5
Unirrigated (I_0)	353.3	41.0	39.0
lsd (P=0.05)	21.8	5.7	4.2
Genotypes			
NIAW 34	385.8	43.0	37.9
PBW 343	410.2	47.7	38.5
Raj 3765	384.4	42.5	39.7
WH 711	397.3	44.8	37.8
lsd (P=0.05)	18.7	4.5	2.4

I_N= Irrigated, KI= Potassium iodide spray (0.2% conc.), I_0= No post sowing irrigation

Among wheat genotypes, PBW 343 significantly out yielded genotypes WH 711, Raj 3765 and NIAW 34 due to similar differences yield forming characters. The

Fig. 2. Relationship of relative injury (RI) with canopy temperature depression (CTD, canopy minus air temperature) and leaf relative water content (RWC). Flag leaf was used for the measurements of RI and RWC. Data of three irrigation treatments were used to establish the relationships

formation of yield attributes is determined by the supply of photosynthates and the growing environment. In conclusion, water and high temperature stress influence plant water status which in turn adversely affects the physiological traits, i.e. RWC and RI. Low RWC and high RI decrease current photosynthesis and increase the electrolyte leakage thereby reducing translocation and remobilization of assimilates and finally lower grain yield. In this study, significant and negative associations were found between RI and CTD and RI and RWC (Fig. 2a and b). Higher CTD and RWC resulted in lower RI and vice-versa. Grain yield was negatively related to RI (Fig. 3a) showing that higher RI resulted in lower yields. On the other hand, higher RWC and CTD were positively related to grain yield (Fig. 3b and c).

Fig. 3. Relationship of grain yield with relative injury (RI), leaf relative water content (RWC) and canopy temperature depression (CTD, canopy minus air temperature). Flag leaf was used for the measurements of RI and RWC. Data of three irrigation treatments were used to establish the relationships

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