PLANT WATER RELATIONS, CANOPY TEMPERATURE, PHOTOSYNTHESIS AND GRAIN YIELD IN WHEAT GENOTYPES AS AFFECTED BY POST-ANTHESIS CHEMICAL DESICCATION

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SUMMARY

A field experiment was carried out during *rabi* (winter) season of 1996-97 at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar to study the plant water relations, canopy temperature and photosynthesis for screening wheat genotypes for post-anthesis moisture stress by chemical desiccant in normal irrigated field condition. Leaf water potential, osmotic potential, turgor potential, relative water content, photosynthetic rate and grain yield decreased, whereas canopy temperature increased under moisture stress condition. The reduction in these physiological characters and grain yield was much higher under desiccant sprayed treated plants than rainfed environment. Genotype UP 2338 maintained higher leaf water potential, turgor potential, relative water content, photosynthetic rate, grain yield and lower canopy temperature than other wheat genotypes under all the environments. Association between plant water relations, photosynthesis and grain yield was better at 12 days than six days after desiccant spray. This suggests that an inbuilt system of water economy in the cv. UP 2338 enables it to maintain vital physiological functions under adverse climatic condition to yield comparatively better.

***Key words*: Canopy temperature, leaf water potential, moisture stress, photosynthesis, potassium iodide, transpirational cooling.**

INTRODUCTION

Water deficit in plants influences various physiological processes, which are associated with the reduction in turgor such as stomatal behavior, photosynthesis and growth (Sullivan and Ross 1979). However, many crop species have evolved physiological and morphological adaptation to drought conditions. Positive associations were revealed between the maintenance to plant water potential or the capacity for osmotic adjustment and yield under water stress across wheat varieties (Kiem and Kronstad 1981). Leaf water potential was found to be a good parameter to calculate plant water stress in wheat (Singh and Singh 1984). The comparatively higher photosynthesis in wheat cultivars under stress condition was attributed to its maintenance of higher leaf water potential (Uprety and Sirohi 1985). Similarly, Richter and Wagner (1983) suggested that the maintenance of turgor permitted plants to resist the negative effect of water stress on photosynthesis. However, Schonfeld *et al.* (1988) observed that the RWC of leaves was higher in drought tolerant cultivars grown under rainfed condition. However, such studies are lacking in wheat genotypes subjected to moisture stress due to desiccant spray under field conditions (Hooda *et al.* 1996). Hence, this experiment was conducted to study the plant water

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relations, canopy temperature and photosynthesis in wheat genotypes subjected to post-anthesis moisture stress by chemical desiccant under normal irrigated field condition.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* (winter) season of 1996-97 at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar, India. The area has a semi-arid and sub-tropical climate with very hot and dry summers, cold winters and humid warm rainy season. The soil of experimental plots was sandy loam in texture with 0.4% organic carbon, slightly alkaline in reaction (pH 8.1), and medium in fertility (available nitrogen 184 kg/ha, available P 17 kg/ha and available K 325 kg/ha). The experiment was laid out in split plot design with three replications. The main plot treatments comprised of five environments, viz. (i) Rainfed (No post-sowing irrigation), (ii) Normal irrigated, (iii) Normal irrigated + spray of potassium iodide (KI) 0.1% solution on whole canopy at 1/3rd filled cavity of grains (IK_1), (iv) Normal irrigated + spray of potassium iodide (KI) 0.1% solution on whole canopy at 1/2 filled cavity of grains (IK_2) and (v) Normal irrigated + spray of potassium iodide (KI) 0.1% solution on vegetative parts (by escaping earheads) at 1/3rd filled cavity of grains (IK_3). The sub-plot treatments comprised of five genotypes, viz. WH 542, WH 533, WH 601, UP 2338 and Raj 3765. All agronomic practices were followed as per recommendations.

Measurements of components of water potential were made concurrently on the fully expanded flag leaf of wheat plant during mid-day hours (12-14 h). These measurements were made before KI spray, 6 and 12 days after KI spray. The leaf water potential (ψ_L) was measured by a pressure chamber apparatus (Scholander *et al.* 1965) and leaf osmotic potential (ψ_π) with the help of vapour pressure osteter-model 5100-B (Pannu and Singh 1993). The (ψ_L) and (ψ_π) measured concurrently on flag leaves were used to determine turgor potential (ψ_p) from the equation: $(\psi_p) = (\psi_L - \psi_\pi)$. Corrections were made for apoplastic water by multiplying each value of (ψ_π) with 0.09 as factor. Relative water content (RWC) was calculated as described by Weatherley (1970). A steady state photosynthetic apparatus (Portable infrared gas analyzer, CIRAS-1, PP System, U.K.) was used to measure photosynthetic rate of fully expanded flag leaves between 11-13 h of day before KI spray, 6 and 12 days after KI spray. The canopy temperature (Tc) and transpiration cooling (Tc-Ta) were measured with the help of infrared thermometers (Telatemp AG 42).

RESULTS AND DISCUSSION

The various components of water potential, viz. leaf water potential (ψ_L), osmotic potential (ψ_π), turgor potential (ψ_p) and relative water content (RWC) were decreased under moisture stress than normal irrigated conditions (Tables 1and 2) owing to lesser availability of water in the soil profile (0-120 cm) under dry (18.7% v/v) than normal irrigated (20.9% v/v) condition at anthesis. Similar results were also reported by Hooda (1995). The decrease in ψ_L, ψ_π, ψ_p and RWC was higher in desiccant sprayed plants as compared to rainfed environment. This could be attributed to rapid leaf senescence (yellowing) because of increased dehydration in leaf due to desiccant spray. These results are in conformity with those reported by Blum *et al.* (1983) and Turner *et al.* (1989).

Wheat genotypes differed significantly in osmotic potential, turgor potential and RWC. However, leaf water potential did not differ significantly among wheat genotypes, except before KI spray where it was significantly higher in cv. UP 2338 and lower in cv. WH 601. The turgor potential and RWC were highest in cv. UP 2338 and lowest in cv. WH 601 (Table 1). This might be due to the differences in genetic constitution of these genotypes. Similar genotypic variations in the water potentials of wheat grown under moisture stress condition were also reported by Kiem and Kronstad (1981) and Uprety and Sirohi (1985).

The canopy temperature (Tc) was higher in moisture stress condition as compared to normal irrigated condition (Table 2). This may be due to higher stomatal conductance and greater transpirational cooling (Tc-Ta) under normal irrigated than unirrigated conditions. These results are in close conformity to those reported by Singh *et al.* (1993). The Tc further increased under desiccant treated plants as compared to rainfed environment. This may be due to rapid leaf senescence, which caused greater stomatal

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Table 1. Effect of different treatments on leaf water potential (ψ_L), leaf osmotic potential (ψ_π), leaf turgor potential (ψ_P) and relative water content (RWC) in wheat genotypes.

Treatments	Before desiccant spray				6 days after desiccant spray				12 days after desiccant spray			
	ψ_L (MPa)	ψ_π (MPa)	ψ_P (MPa)	RWC (%)	ψ_L (MPa)	ψ_π (MPa)	ψ_P (MPa)	RWC (%)	ψ_L (MPa)	ψ_π (MPa)	ψ_P (MPa)	RWC (%)
Environments												
Rainfed	-1.65	-2.34	0.70	70	-1.77	-2.39	0.62	66	-2.11	-2.60	0.49	58
Normal Irrigated	-1.36	-2.16	0.80	76	-1.42	-2.18	0.76	74	-1.65	-2.35	0.70	69
IK_1	-1.34	-2.14	0.80	76	-2.63	-3.13	0.51	47	-3.25	-3.27	0.02	29
IK_2	-1.34	-2.14	0.80	77	-2.63	-3.14	0.51	45	-3.25	-3.27	0.02	30
IK_3	-1.34	-2.13	0.80	77	-2.62	-3.13	0.51	46	-3.25	-3.27	0.02	30
CD at 5%	0.13	0.15	0.03	2	0.16	0.17	0.08	4	0.22	0.18	0.10	3
Genotypes												
WH 542	-1.40	-2.26	0.86	77	-2.19	-2.79	0.60	56	-2.69	-2.99	0.30	44
WH 533	-1.39	-2.18	0.79	73	-2.19	-2.80	0.61	54	-2.69	-2.92	0.23	42
WH 601	-1.48	-2.10	0.62	71	-2.35	-2.84	0.49	51	-2.85	-3.02	0.17	41
UP 2338	-1.32	-2.25	0.93	78	-2.15	-2.82	0.68	61	-2.63	-2.94	0.31	45
Raj 3765	-1.42	-2.11	0.70	77	-2.20	-2.72	0.52	54	-2.66	-2.89	0.23	44
CD at 5%	0.11	NS	0.14	2	NS	0.08	0.06	2	NS	0.05	0.05	3

Table 2. Effect of different treatments on canopy temperature (Tc), transpirational cooling (Tc-Ta) and photosynthetic rate (g CO_2 m^{-2} h^{-1})* of wheat genotypes.

Treatments	Before desiccant spray			6 days after desiccant spray			12 days after desiccant spray		
	Tc (°C)	Tc-Ta (°C)	Photosynthetic rate	Tc (°C)	Tc-Ta (°C)	Photosynthetic rate	Tc (°C)	Tc-Ta (°C)	Photosynthetic rate
Environments									
Rainfed	23.7	-5.52	3.30	25.2	-4.82	3.02	26.7	-3.84	2.46
Normal Irrigated	22.3	-6.81	4.00	23.4	-6.61	3.74	25.1	-5.42	3.37
IK_1	22.4	-6.84	3.88	26.9	-3.23	1.31	29.8	-0.73	-0.07
IK_2	23.1	-6.71	3.91	27.3	-3.33	1.34	30.3	-0.81	-0.05
IK_3	22.3	-6.82	4.00	27.0	-3.14	1.30	29.9	-0.62	-0.04
CD at 5%	NS	0.46	0.39	1.3	0.43	0.57	1.2	0.31	1.07
Genotypes									
WH 542	22.2	-7.01	3.83	25.5	-4.62	2.25	28.6	-2.10	1.22
WH 533	21.9	-7.41	3.78	25.3	-5.01	2.22	28.0	-2.31	1.15
WH 601	23.5	-6.04	3.29	26.4	-3.94	1.78	28.7	-2.11	0.97
UP 2338	22.6	-6.83	4.47	25.9	-4.56	2.42	27.5	-3.10	1.52
Raj 3765	23.6	-5.66	3.72	26.6	-3.11	2.04	29.0	-1.60	1.13
CD at 5%	0.8	0.06	0.70	0.6	0.31	0.28	0.7	0.25	0.37

* Leaf area basis.

resistance and decreased transpiration rate in desiccant treated plants within 10-12 days after desiccant spray (Hooda 1995). The canopy of UP 2338 was coolest and significantly cooler than all other genotypes in irrigated and rainfed condition recorded 12 days after KI spray (Table 4). But the crop sprayed with KI did not differ significantly among the genotypes. This higher cooling of UP 2338 canopy was mainly due to longer stay green character. The crop canopy of Raj 3765 was significantly warmer than all other genotypes. This may be due to its slightly early maturity duration, which has caused slightly early senescence in this genotype. Similar genetic variation in Tc-Ta has also been reported by Hooda (1995) due to their genetic constitution. Whereas, narrow differences in genotypes under KI sprayed plants was due to desiccation of leaf tissues in all the genotypes.

The reduction in photosynthesis under moisture stress condition was mainly due to decline in turgor potential and increase in stomatal resistance as evident from reduced transpirational cooling, CO_2 intake and assimilation rates than under normal irrigated condition (Table 2). These results are in conformity with the findings of Uprety and Sirohi (1985) and Sairam *et al.* (1990). The reduction in photosynthesis was much higher in desiccant sprayed plants as compared to rainfed environment. This was mainly due to rapid leaf senescence (yellowing) within 10-12 days after desiccant spray. Similar results have also been reported by Turner *et al.* (1989). It was reported that within three days after desiccant spray, the photosynthetic rate was reduced by 85 and by 99% within seven days after desiccant spray in wheat. However, in our condition, the photosynthesis, reduced after six and 12 days of desiccant spray by 66.2 and 100% under IK_1, 65.7 and 100% under IK_2 and 67.5 and 100% under IK_3 treatments, respectively. Such variations for photosynthesis might be due to differences in the mediterranean and our climate. The higher photosynthetic rate in cv. UP 2338 could be attributed to its higher turgor potential leading to greater stomatal conductance and cooler canopy. The cv. UP 2338 maintained 36.0 and 55.0% higher flag leaf photosynthetic rate after six and 12 days of desiccant spray than cv. WH 601.

Significantly lower grain yield under rainfed than normal irrigated environment could be attributed to reduced turgor and turgor driven processes such as stomatal conductance, photosynthesis and yield components. The moisture stress also enhanced maturity, reduced the duration of grain filling and affected grain number spike^{-1}, 1000-grain weight and grain yield. Similar results were also reported by Hooda (1995). The drastic reduction in gain yield under different desiccant treatments was due to reduction in number of grain spike^{-1} in IK_1 and IK_2 because of mortality of endosperm due to desiccation and reduction in 1000-grain weight (Table 3). The reduction in grain size under different desiccant treatments was mainly due to poor translocation of pre-anthesis assimilates to grains. The improvement of grain size in IK_3 (by escaping earheads) over IK_1 and IK_2 treatments was attributed to higher current photosynthesis by different organs of earhead namely lemma, palea and awns which resulted in higher kernel growth rate. Saghir *et al.* (1968) also reported 10-60% contribution of ear photosynthesis to grain growth in wheat.

Table 3. Effect of different treatments on yield attributes and grain yield in wheat genotypes.

Treatments	Number of grains spike^{-1}	1000-grain weight (g)
Environments		
Rainfed	49.5	32.1
Normal Irrigated	54.7	41.0
IK_1	40.4	18.8
IK_2	44.5	20.9
IK_3	52.3	27.0
CD at 5%	3.2	4.9
Genotypes		
WH 542	48.6	25.0
WH 533	50.5	26.8
WH 601	41.0	24.5
UP 2338	53.7	33.0
Raj 3765	47.7	30.8
CD at 5%	2.5	2.1

The interaction of genotypes and environments on grain yield of wheat indicated that genotype UP 2338 yielded significantly higher than all other genotypes under all the environments except in IK_1 and IK_2 where UP 2338, Raj 3765 and WH 533 were at par (Table 5).

Table 4. Interactional effect of different environments and genotypes on transpirational cooling (°C) in wheat 12 days after KI spray.

			Environment			
Genotypes	**Rainfed**	**Normal irrigated**	**IK_1**	**IK_2**	**IK_3**	**Mean**
WH 542	-3.5	-5.2	-0.7	-0.7	-0.5	-2.1
WH 533	-3.8	-5.7	-0.7	-0.8	-0.6	-2.3
WH 601	-3.3	-5.3	-0.7	-0.6	-0.6	-2.1
UP 2338	-5.5	-6.9	-0.9	-1.2	-1.1	-3.1
Raj 3765	-2.7	-3.8	-0.6	-0.7	-0.4	-1.6
Mean	-3.8	-5.4	-0.7	-0.8	-0.6	
CD at 5%	0.4					

Table 5. Interactional effect of different environments and genotypes on grain yield (kg ha^{-1}) in wheat.

			Environment			
Genotypes	**Rainfed**	**Normal irrigated**	**IK_1**	**IK_2**	**IK_3**	**Mean**
WH 542	3651	4629	1305	1551	2582	2744
WH 533	3986	5154	1479	1658	2814	3018
WH 601	3502	4468	1115	1487	2290	2572
UP 2338	4441	5872	1647	1877	3339	3435
Raj 3765	4072	5332	1485	1802	3014	3141
Mean	3930	5091	1406	1675	2808	
CD at 5%	306					

Whereas, genotype WH 601 yielded lowest and its performance was significantly inferior than all other genotypes under all the environments except in IK_1 and IK_2 where genotypes WH 542, WH 533 and WH 601 were non-significant among themselves. This variation in grain yield between genotypes can also be explained due to higher rate of leaf photosynthesis, better plant water relations and yield attributes in UP 2338 and significantly poor yield attibutes in WH 601 than all other genotypes (Table 3).

Grain yield was positively correlated with leaf water potential (r = 0.93, 0.93), leaf turgor potential (r = 0.83, 0.92), transpirational cooling (r = 0.80, 90) and photosynthesis (r = 0.86, 93) both at six and 12 days after desiccant spray. However, association was better at 12 days than six days after desiccant spray. Similar positive associations were also reported by Kiem and Kronstad (1981) in wheat.

The results showed a differential response of wheat genotypes to moisutre stress. Genotype UP 2338 had higher turgor potential, photosynthetic rate and lower canopy temperature under moisture stress than other genotypes of wheat. This suggests that an inbuilt system of water economy in the cv. UP 2338 enables it to maintain vital physiological functions under adverse climatic condition to yield comparatively more.

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