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RESPONSES OF GROWTH, WATER RELATION AND SOLUTE ACCUMULATION IN WHEAT GENOTYPES UNDER WATER DEFICIT

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Abstract

Eight wheat (*Triticum aestivum* L.) genotypes viz., Chakwal-86, M-154, DS-4, Rohtas, Lu-26, Sindh-81, DS-17 and Pasban were raised in soil under normal and water stress conditions. Stress was imposed by withholding water when the plants were 50 days old and growth parameters determined at 10 and 20 days after the imposed stress. Leaf water relation and solutes concentration were also determined. A wide range of differences in growth under increasing water deficit was observed between genotypes. Drought tolerant genotypes maintained turgor by decreasing osmotic potential at lower leaf water potential and they showed higher osmotic adjustment. Sugar and K^+ were the major osmotic contributor. Sugar played a major role in increasing osmotic concentration under water deficit.

Introduction

Plants subjected to water deficit are known to have the ability to uptake water from soil by decreasing osmotic potential in their cells. The lowered osmotic potential by net increase in intracellular metabolically compatible cytoplasmic solutes is now considered as a major component of drought tolerance mechanisms (Borowitzka & Brown, 1974). It allows to maintain turgor at low water status which in turn enables plants to maintain cell enlargement and stomatal opening.

Osmotic adjustment is considered to influence a wide range of physiological processes. It maintains stomatal opening and photosynthesis at lower leaf water potentials (Turner, 1986; Jones & Rawson, 1979), defers leaf rolling and leaf death at lower leaf water potentials (Hsiao *et al.*, 1984) and maintains root growth at lower soil water potential (Turner, 1986). Morgan (1984) showed that yields were higher in genotypes or lines which were capable of adjusting osmotically under water deficit, and higher yields were associated with higher root length densities and higher water uptake. In addition osmotic adjustment of leaves maintains transpiration at lower leaf water potentials (Turner, 1986).

The compound involved in osmotic adjustment are mostly soluble sugars, K, organic acids, chloride and free amino acids (Turner & Jones, 1988). A wide range of compounds have been found to accumulate by different plant species subjected to water stress (Osmond, 1983; Begg & Turner, 1976; Ford & Wilson, 1981; Khan *et al.*, 1992a). The present report describes the growth, net assimilation rates, leaf water relations and accumulation of solutes in wheat affected by increasing water deficit.

Table 1. Relative growth rate (RGR) and net assimilation rate (NAR) for plants of eight wheat genotypes after 20 days of water-stressed treatment and control.

Genotypes	RGR ($gxg^{-3}x01^{-1}$)		Reduction under stress	NAR (g/m^2)		Reducation in NAR Under Stress
	Control	Treatment	%	Control	Treatment	%
Chakwal-86	0.911±0.19	0.797±0.15	13	0.653±0.03	584±0.05	10
M-154	1.004±0.15	0.910±0.16	9	0.447±0.02	0.388±0.05	13
DS-4	0.899±0.13	0.732±0.04	19	0.411±0.02	0.306±0.01	25
Rohtas	0.993±0.18	0.768±0.04	23	0.486±0.05	0.352±0.03	27
Lu-26	0.932±0.20	0.714±0.13	24	0.549±0.03	0.358±0.04	35
Sind-81	0.995±0.09	0.842±0.44	15	0.666±0.04	0.436±0.03	35
DS-17	0.882±0.08	0.567±0.07	36	0.699±0.03	0.388±0.06	45
Pasban	0.873±0.12	0.617±0.07	30	0.419±0.07	0.225±0.05	47

Table 2. Leaf water potential, osmotic potential and turgor potential of eight wheat genotypes at 10 and 20 days of water stressed treatment.

Genotypes	Leaf water potneial (MPa)		Osmotic potnetial (MPa)		Turgor potential (MPa)	
	Control	Treatment	Control	Treatment	Control	Treatment
At 10 days						
Chakwal-86	1.32±0.13	2.35±0.29	2.53±0.13	2.89±0.14	1.21±0.06	0.54±0.02
M-154	1.29±0.13	2.34±0.28	2.31±0.12	2.68±0.13	1.02±0.05	0.34±0.06
DS-4	1.20±0.12	2.31±0.12	2.22±0.11	2.64±0.13	1.02±0.05	0.33±0.06
Rohtas	1.19±0.07	2.28±0.11	2.21±0.09	2.61±0.13	1.02±0.06	0.33±0.02
Lu-26	1.16±0.06	2.18±0.11	1.98±0.09	2.46±0.12	0.82±0.04	0.28±0.02
Sind-81	1.13±0.06	2.13±0.11	1.90±0.09	2.37±0.12	0.77±0.05	0.24±0.02
DS-17	1.13±0.09	1.98±0.09	1.76±0.08	2.19±0.11	0.63±0.03	0.21±0.03
Pasban	1.10±0.05	1.77±0.08	1.64±0.08	1.99±0.09	0.54±0.03	0.22±0.02
AT 20 days						
Chakwal-86	1.41±0.14	2.80±0.14	2.49±0.12	3.46±0.17	1.08±0.05	0.66±0.03
M-154	1.31±0.13	2.78±0.14	2.37±0.31	3.17±0.09	1.06±0.05	0.39±0.03
DS-4	1.29±0.07	2.72±0.13	2.33±0.12	3.11±0.15	1.04±0.05	0.39±0.03
Rohtas	1.26±0.11	2.58±0.12	2.31±0.07	2.95±0.14	1.05±0.05	0.37±0.02
Lu-26	1.26±0.13	2.45±0.12	2.29±0.07	2.78±0.14	1.03±0.05	0.33±0.02
Sind-81	1.25±0.13	2.45±0.31	2.12±0.08	2.60±0.13	0.87±0.04	0.15±0.06
DS-17	1.23±0.12	2.39±0.12	2.26±0.11	2.51±0.13	1.03±0.05	0.12±0.06
Pasban	1.19±0.07	2.29±0.12	2.22±0.11	2.53±0.11	1.03±0.04	0.24±0.02

Material and Methods

Eight wheat genotypes (*Triticum aestivum* L.) viz., Chakwal-86, M-154,DS-4, Rohtas, Lu-26, Sind-81, DS-17 and Pasban were grown in irrigated sandy clay loam soil filled in two cemented tanks (10'x10' and 3'depth). Randomized block design with three replications consisting of O.5 m long rows spaced O.25 m apart with .06 m spacing between plants was used. Plants were covered with a portable polyvinyle roof to prevent contact with rain water.

A basic dose of fertilizer mixture was applied as urea and diammonium phosphate (7O kg N, 35 kg PO_2O_5/ha). Plants in one tank were subjected to water stress treatment by withholding irrigation water 50 days after sowing whereas they received normal irrigation water in the second tank (75 mm). The experiment was terminated after another 20 days growth of plants.

Measurement of growth parameter: Three representative plants were sampled from each genotype from three replications at the beginning of treatments, 10 and 20 days after treatment. Total leaf area, fresh weight of leaf (excluding sheath) and stem were recorded. Plant material was dried at 70°C for 48 hr and the dry weight of the samples was noted. Relative growth rate and net assimilation rate were calculated according to the method described by Wilson (1966)

Leaf water potential and osmotic potential: Three fully expanded leaves from each of the three replications were taken for measuring leaf water and osmotic potentials. Leaf water potential was measured using pressure chamber technique and osmotic potential by measuring osmolality of extracted leaf sap using a calibrated micro-osmometer (Khan *et al.*, 1992a). The turgor potential was calculated as the difference between leaf water and osmotic potential.

Nutrient analysis of cell sap: Extracted sap from fully expanded leaf were used for the analysis of sugars, Na, K, Ca, Mg and P concentrations. Sugars were determined by the anthrone method (Yoshida *et al.*, 1972), The ions were measured using flame photometer for sodium and potassium (Jenway PFP 7). Spectrophotometer for Mg and Ca (Hitachi), and the total phosphorus was determined by molybdenum blue method (Yoshida *et al.*, 1972).

Results and Discussion

Relative growth rate and net assimilation rate decreased under soil drought and significant genotypic dependent differences were observed (Table 1). The reduction of percentages were similar for relative growth rate and net assimilation rate under water stress treatment except for genotype Chakwal-86 and M-154, since their leaf area ratio did not differ considerably. Genotypes Chakwal-86 and M-154 were capable of maintaining photosynthetic production hence their relative growth rate and net assimilation rate was not decreased considerably under stress treatment and they are considered tolerant. On the other hand drought tolerance of genotypes DS-17 and Pasban, seem to be poor, since their relative growth rate and net assimilation rate decreased markedly under stress treatment. The result at 10 days after treatment (not presented) were similar.

The leaf water potential was lower during treatment and decreased with increasing water deficit at 20 days compared to 10 days (Table 2). Osmotic potential of the leaf tissue decreased under water stress in order to maintain turgor at low leaf water potential condition. Osmotic potential was lower at 20 days than 10 days with increasing water deficit.Turgor potential was lower during treatment than in control. These results indicate adaptation to water stress via osmotic adjustment and turgor maintenance under low leaf water potential condition. Stomata responsed by closing, with consequent reduction in transpiration as well as assimilation (Bradford & Hsiao, 1982). Leaf rolling occur in minimizing evapotranspiration water loss during water deficit (Hsiao *et al.*, 1984).

Genotype with the ability to maintain turgor at low water status are tolerant to drought. The turgor potential was higher in genotypes Chakwal-86, M-154, during treatment at 10 and 20 days. Osmotic adjustment was higher in genotype Chakwal-86 and M-154 (0.97, 0.80 MPa) respectively, whereas it was lower in DS-17 and Pasban at 0.25, 0.31 MPa at 20 days water stress treatment. Drought tolerance of these genotypes evaluated by percentage reduction in relative growth rate is comparable to these results.

Table 3. Solute contribution to osmotic potential in eight wheat genotypes at 10 and 20 days of water stressed treatment.

Genotypes	Concentration of solutes in cell sap (m. mol/L)					
	Total sugar		Na^+		K^+	
	Control	Treatment	Control	Treatment	Control	Treatment
At 10 days						
Chakwal-86	7.08±0.05	16.51±0.04	1.24±0.01	1.35±0.00	164.00±2.31	178.00±2.08
M-154	6.82±0.03	16.48±0.03	1.21±0.01	1.29±0.00	155.00±4.51	168.00±3.06
DS-4	6.59±0.05	15.85±0.03	1.20±0.01	1.28±0.00	148.00±0.57	161.00±0.57
Rohtas	6.32±0.03	12.96±0.03	1.17±0.01	1.23±0.06	145.00±1.15	158.00±1.73
Lu-26	5.83±0.04	12.90±0.04	1.15±0.01	1.20±0.00	140.00±1.15	154.00±2.08
Sind-81	5.77±0.07	12.27±0.05	1.14±0.01	1.17±0.06	139.00±2.52	148.00±1.99
DS-17	5.72±0.05	10.82±0.05	1.12±0.01	1.15±0.06	132.00±1.55	140.00±1.15
Pasban	5.63±0.05	10.22±0.12	1.06±0.01	1.10±0.06	130.00±2.31	135.00±0.99
At 20 days						
Chakwal-86	9.11±0.21	21.06±0.11	1.09±0.00	1.29±0.00	175.00±2.08	184.00±1.99
M-154	8.48±0.03	20.64±0.05	1.04±0.00	1.14±0.00	169.00±2.31	180.00±2.52
DS-4	8.32±0.03	20.58±0.03	0.91±0.00	0.98±0.00	166.00±1.15	178.00±2.52
Rohtas	8.16±0.05	16.45±0.04	0.89±0.00	0.94±0.00	155.00±0.99	170.00±1.15
Lu-26S	7.65±0.07	16.21±0.03	0.83±0.00	0.88±0.00	150.00±2.08	164.00±2.88
Sid-81	7.50±0.05	15.81±0.08	0.77±0.06	0.80±0.00	145.00±2.52	160.00±2.08
DS-17	7.46±0.04	12.76±0.04	0.73±0.06	0.76±0.06	141.00±1.53	153.00±2.31
Pasban	7.45±0.07	12.50±0.07	0.69±0.00	0.73±0.00	138.00±3.05	147.00±1.15

Table 4. Solute contribution to osmotic potnetial in eight wheat genotypes at 10 and 20 days of water-stressed treatment.

Genotypes	Concentration of solutes in cell sap (m. mol/L)					
	Ca^{++}		Mg^{++}		P	
	Control	Treatment	Control	Treatment	Control	Treatment
At 10 days						
Chakwal-86	35.80±0.31	34.20±0.12	13.40±0.23	13.50±0.17	10.70±0.12	9.50±0.12
M-154	34.20±0.23	33.60±0.15	13.30±0.17	13.00±0.06	10.40±0.25	9.40±0.15
DS-4	32.80±0.23	33.00±0.15	12.20±0.12	12.40±0.25	9.50±0.39	9.30±0.21
Rohtas	31.70±0.53	30.40±0.25	12.00±0.21	12.10±0.23	9.20±0.23	9.00±0.21
Lu-26	29.00±0.23	28.70±0.09	11.30±0.17	11.30±0.28	8.80±0.15	8.40±0.17
Sind-81	27.80±0.64	27.20±0.12	10.80±0.31	10.00±0.23	8.40±0.15	8.20±0.32
DS-17	26.70±0.26	26.50±0.21	9.50±0.28	9.30±0.09	7.60±0.06	7.20±0.33
Pasban	26.67±0.18	26.00±0.23	9.30±0.21	9.10±0.31	7.30±0.06	7.00±0.28
At 20 days						
Chakwal-86	34.90±0.06	32.70±0.17	13.50±0.15	12.70±0.25	10.20±0.12	9.30±0.35
M-154	34.60±0.23	32.20±0.21	13.10±0.43	12.20±0.21	10.00±0.15	9.00±0.53
DS-4	32.00±0.57	31.30±0.15	12.00±0.35	12.00±0.41	9.10±0.21	8.20±0.28
Rohtas	31.20±0.26	29.60±0.31	11.80±0.12	11.73±0.21	8.90±0.21	7.40±0.31
Lu-26	29.10±0.28	28.10±0.21	11.20±0.25	11.00±0.12	8.70±0.12	7.00±0.12
Sind-81	27.30±0.28	26.80±0.12	10.20±0.36	9.60±0.17	8.20±0.21	6.80±0.21
DS-17	26.80±0.23	26.00±0.41	9.10±0.26	8.90±0.15	7.40±0.26	4.80±0.15
Pasban	26.30±0.32	25.70±0.25	9.00±0.17	8.80±0.36	7.10±0.17	4.20±0.12

Sugars and K were the major osmotic contributor, sugars concentration was almost twice that of control both at 10 and 20 days after treatment. Potassium concentration increased at 10 days after treatment but a considerable increase was not seen at 20 days. Calcium, Mg, Na and P concentrations did not show any appreciable change under stress and control treatment both at 10 and 20 days. Potassium was the major osmotic contributor in well watered plants whereas sugars became the major osmotic contributor under increasing water deficit. These results suggest that sugar plays a major role in decreasing osmotic potential under water deficit conditions in wheat. Sugars have been known to accumulate in stress leaves of various crop plants. Munns & Weir (1981) reported that in tissue of wheat, increase in soluble sugars are an important adaptive response to water deficit. Seventy percent of change in solute concentration under drought conditions in soyabean are due to an increase in concentration of glucose, fructose and free amino acid (Boyer & Meyer, 1980).

Sugars and K were involved in osmotic adjustment by solute accumulation in drought tolerant genotypes (0.79 MPa in average) under increasing water deficit. Osmotic adjustment of 0.59 MPa (average of eight cultivars) was observed in water stress treatment of 20 days. Osmotic adjustment of plants exposed to water stress was

reported to be 0.5 MPa in Sorghum leaves (Jones & Rawson, 1979), 0.39 MPa to 0.86 MPa in tropical grasses (Wilson *et al.*, 1980), 0.44 MPa in mungbean (Zhao *et al.*, 1985) and 0.6 MPa in sunflower leaves (Turner *et al.*, 1980).

These results indicate the ability of drought tolerant plants to maintain turgor at low leaf water potential by decreasing osmotic potential. Osmotic adjustment was higher in drought tolerant plants under stress. Sugars and K were the major contributor in osmotic adjustment in wheat. Sugars seem to play a major role in increasing osmotic concentration under water deficit.

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