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OSMOTIC ADJUSTMENT IN WHEAT– A RESPONSE TO WATER STRESS

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Growth, water relations and accumulation of two potentially involved solutes in osmotic adjustment were studied in four cultivars of wheat. Biomass and grain yield component data indicated two major groups (i) drought resistant and (ii) drought susceptible. Water potential (WP), solute potential (SP) and turgor potential (TP) were reduced under drought conditions, but the effect was much less in resistant cultivars. The relative water contents (RWC) of resistant cultivars were much higher than non-resistant under drought conditions, indicating osmotic adjustment in these cultivars. Accumulation of proline and betain was many fold greater in resistant than susceptible cultivars.

Key words: Wheat, Osmotic adjustment, Water stress.

Introduction

Wheat being a staple food is cultivated on a large area in Pakistan (7.085 million hacters). In order to feed the ever growing population more and more area needs to be brought under cultivation. Water stress or drought is one of the major limitation to growth in some area of the Punjab, sourthern part of Sindh, major portion of Baluchistan and some parts of NWFP of Pakistan.

A better understanding of the physiological mechanisms that are assoicated with drought resistance may lead to the development of wheats that are better adapted to these regions.

One potentially important mechanism of drought resistance is osmotic adjustment, accumulation of solutes in plant tissue in response to dehydration [1]. Osmotic adjustment results in the maintenance of turgor pressure to lower water potential. This machanism allows plants to extract more water from drying soils so that their physiological activities are maintained during the critical periods of crop growth [2]. Proline and betain accumulation in plants are frequently considered as adaptive reactions of plants to water deficit, which can be detected much earlier in the life cycle of plants [3-5].

In this experiment response of four cultivars of wheat to drought was done by studying the effect on water relations, the accumulation of proline and betain and yield components.

Materials and Methods

The experiment was conducted during Nov. 1989 to April 1990 in cemented tanks (3m x 3m x 3/4m) filled with medium textured soil (sandy clay loam) in a net house under natural conditions. Non-irrigated plants were covered with a transparent rain shelters constructed over a wooden frame work that ranged in height from 130 cm at upper end to 100 cm at the lower end to facilitate runoff of precipitation. Plastic side panels were installed on rainy days to prevent rainfall from entering through the side of shelters. There were four cultivars, i.e. Pak-15800, V-8001, Pak-15794, and Sarsabz, and two stress treatments i.e. T_0(Control), T_1(drought). Each treatment was replicated 4 times in a complete randomized block design. Before sowing, each tank was irrigated with 75mm/ha of water. Urea and single super phosphate (SSP) fertizers were applied at the rate of 100 kg/ha and 60 kg/ha respectively. The wheat was sowed in rows and the distance between rows was 30 cm with twenty plants spaced 10 cm apart within each row. The control plants were watered 5 times (75mm/ha per irrigation) during the growing season while the water for the other plants were withheld (droughted) after one irrigation (after vegetative stage).

Measurements. All measurment were made after 35 days from the start to treatment between 11 a.m. to 1 p.m. except grain yield and yield components.

Gravimetric soil water contents. Soil samples were collected by taking a soil core between 11. a.m. to 1. p.m after every week from the entire depth of soil. The soil samples were placed in paper bags, which were closed and weighed immediately. The samples were then dried over night at 100° in an oven and reweighed. Soil water contents are expressed as a percentage of dry weight.

Dry weight of plants. Dry weight of plants was taken after oven drying at 80° for 72 hrs.

Leaf water and osmotic potential. Fully expanded leaves were taken from plants of each cultivars and water potential was immediately measured by the pressure chamber technique [6]. Leaves of the same age and orientation were taken and osmotic potential was measured according to the method of Slavik [7] by Osmomett.

Relative water content. Twenty leaf discks measuring 0.24 cm² were taken from fully expanded leaves and ralative water contents were measured according to the method of Weatherly [8].

Concentrations of solute. The solute concentrations were measured in leaves, proline was measured according to the method of Bates *et al.* [3] and Betain by the method of Grieve and Graton [9].

Yield and yield components. Yield and yield components such as: 1000 grain weight, spikelets per head wer recorded after the final harvest of the plants.

Results and Discussion

Yield and yield components. The gravimetric soil water content at the time of measurement varied from 20% (irrigated) to 3.5% (non irrigated). The water stress significantly reduced biomass (dry weight/plant), plant height, number of tillers, grain yield per plant and 1000 grain weight, while the number of spikelets per head remained unaffected (Table 1). However, there were significant differences among the cultivars. The cultivars Pak-15800 and V- 8001 produced more biomass and grain yield per plant and were taller than the other cultivars. On the basis of these parameters these cultivars were considered drought tolerant. The maximum reduction in biomass (44-51 %) and yield (78-85) were noted in Sarsabz and Pak-15794 and these cultivars were catagorized as susceptable.

Water relations. Water stress had marked effect on water relations of the wheat cultivars. A pronounced decrease in water potential was found in all the cultivars due to water stress (Table 2). The cultivars Pak-15800 and V-8001 had significantly lower water potential than Pak-15794 and Sarsabz under irrigated conditions. Turgor potential values, on the other hand were higher in Sarsabz and Pak-15794 (0.92 and 0.85 MPa) under irrigated conditions but were lower than Pak-15800 and V-8001 under non-irrigated conditions and these differnce were non- significant. Very small reduction (6%) in turgor potential in Pak-15800 was noted due to water stress where as it was 61% in Sarsabz 47% in Pak-15794 and 39% in V-8001.

The relative water content (RWC) of Pak-15800 and V-8001 did not change much under stress conditions (7 and 14% respectively). The cultivars Pak-15794 and Sarsabz had higher RWC under irrigated conditions. But under stress

TABLE 1. EFFECT OF WATER STRESS ON GROWTH YIELD AND YIELD COMPONENTS.

Treatment varieties	Dry wt./plant (gm)		Plant height (cm)		No. of tiller per plant		Grain yield/ plant (gm)		Spikelets per head		1000 grain weight (gm)	
	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated
Pak-15800	22.43	16.80	71.33	53.67	4.66	3.33	13.70	4.04	20.20	19.80	39.30	26.80
V-8001	25.83	19.10	74.33	46.67	4.00	3.00	15.49	3.70	25.10	24.70	43.10	23.20
Pak-15794	23.33	13.13	66.33	30.35	3.67	2.67	12.64	1.90	19.90	18.70	39.10	24.3
Sarsabz	29.80	14.63	70.00	40.00	4.33	2.67	12.79	2.80	22.40	21.80	41.50	21.40
Mean	25.35	15.91	70.50	42.67	4.16	2.92	13.66	3.11	21.90	21.25	40.75	23.93
L.S.D.at 5% for treatment	2.02	2.02	3.22	3.22	0.66	0.66	1.29	1.29	1.37	1.37	0.25	0.25
L.S.D. at 5% for varieties	2.86	2.86	4.55	4.55	0.94	0.94	1.83	1.83	1.93	1.93	0.35	0.35

TABLE 2. ACCUMULATION OF SOLUTES AND WATER STATUS IN WHEAT UNDER IRRIGATED AND STRESS CONDITIONS.

Treatment varieties	Proline (u mol/g F.wt.)		Betain (u mol/g Dd.wt.)		Water Potential ((-MPa)		Osmotic Potential (-MPa)		Turger Potential (MPa)		Relative water content (RWC)	
	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated	Irri-gated	Nonirri-gated
Pak-15800	4.28	36.75	10.65	38.47	1.04	2.41	1.54	2.88	0.50	0.47	60.59	56.51
V-8001	3.70	33.81	10.48	36.35	0.91	2.23	1.66	2.69	0.75	0.46	68.95	59.62
Pak-15794	3.25	33.10	14.58	31.01	0.61	2.11	1.47	2.56	0.85	0.45	76.12	47.44
Sarsabz	2.58	30.00	10.45	16.62	0.62	2.09	1.54	2.45	0.92	0.36	72.53	46.63
Mean	3.45	33.42	11.54	30.61	0.80	2.21	1.55	2.65	0.76	0.44	69.55	52.55
L.S.D.at 5% for treatment	0.87	0.87	1.70	1.70	0.14	0.14	0.15'	0.15	0.12	0.12	5.83	5.83
L.S.D. at 5% for varieties	1.22	1.22	2.51	2.51	0.21	0.21	0.22	0.22	0.17	0.17	8.25	8.25

conditions RWC decreased drastically (38 and 35 %). The relationship between yield componenets and water status are shown in Figs 1 - 4. As the culivars under irrigated conditions differed in all the parameters studied it was difficult to make a proper comparison. To overcome this we have therefore, used percentage increase or decrease in various values as a criterion for the effect of stress.

Although there was a reduction of 132 to 237% in water potential, the 1000 grain weight and tillers number remained uniform. The decrease in spikelets number and grain yield showed a concomitant percent reduction with decrease in water potential (Fig. 1). The relationship between osmotic potential and yield components (Fig.2) did not show a discernable trend. There was negative relationship between percent reduction in osmotic potential (OP) and 1000 grain weight (Fig. 2).The number of tillers did not change much. The turgor potential (TP) and number of tiller/plant showed positive association (Fig. 3), as did the 1000 grain weight. The relationship between RWC and spikelets number and grain yield was obvious and sharp (Fig. 4). In both cases a small decrease in RWC resulted in sharp decrease in yield and spikelets numbers. However, tiller numbers and thousand grain weight did not show such an effect (Fig. 4).

Solutes accumulation. Under the conditions of stress both proline and betain contents were significantly higher than under irrrigated conditions (Table 2). The increase in proline was much higher than betain. Only in case of betain under non-irrigated condition there was a significant difference between a tolerant and non-tolerant cultivars.

From most of the yield components, Sarsabz and Pak-15794 were more susceptible to drought with values that were lower than for Pak-15800 and V-8001, which are comparatively more tolerant cultivars. Even when allowence was made for performance differences under irrigated condition, by using percentage reduction under non-irrigated condition the tolerant cultivars had higer values. Similar results have been reported by Ashraf and Khan [10] and Richard and Smith [11] in wheat, Peacock *et al.* [12] in sorghum and Ashraf and Mehmood [13] in brassica.

The values for both water and osmotic potential were lower in the two tolerant cultivars under non-irrigated condition. However, only Pak-15800 had significant lower values. In the present study, Pak-15800 and V-8001, interestingly, had lower water potential (WP) even under irrigated conditions. In terms of percentage reduction in water potential, the cultivars that showed the greatest percent reduction behaved poorly in terms of yield and spikelets number/head (Fig. 1). In these cultivars it seems that more of the metabolites were retained for the maintenance of water potential (WP). The differences in osmotic potenital (OP) were not significant under irrigated condition, which were reflected in higher turgor potential in Pak 15794 and Sarsabz. The reduction in water and osmotic potential (OP) is considered to be an important adaptive mechanism for drought tolerance particularly when active accumulation of organic and in-organic solutes takes place as a result of water stress and leads to maintenance of turgor

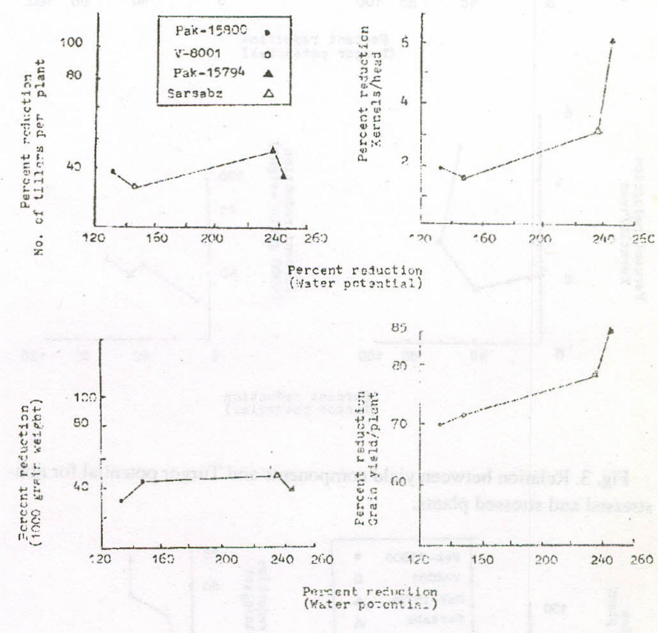

Fig. 1. Relations between yield components and water potential for non-stressed and stressed plants.

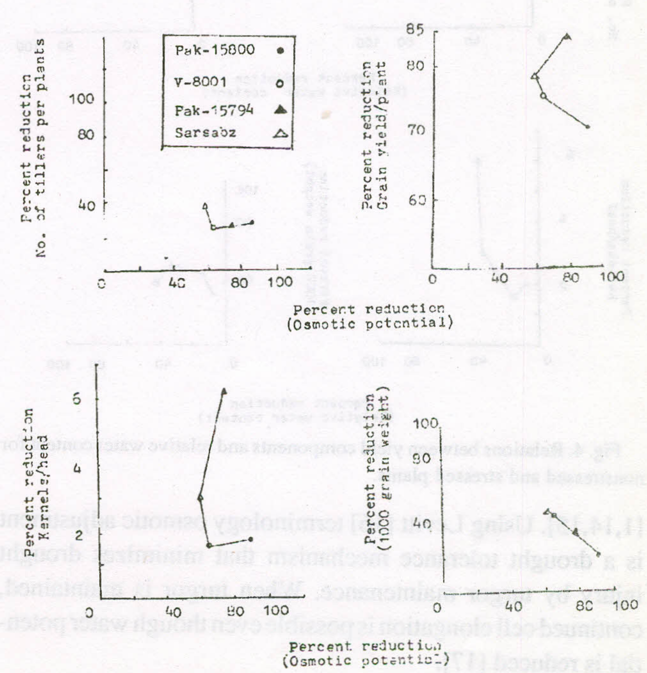

Fig. 2. Relation between yield components and Osmotic potential for stressed and nonstressed plants.

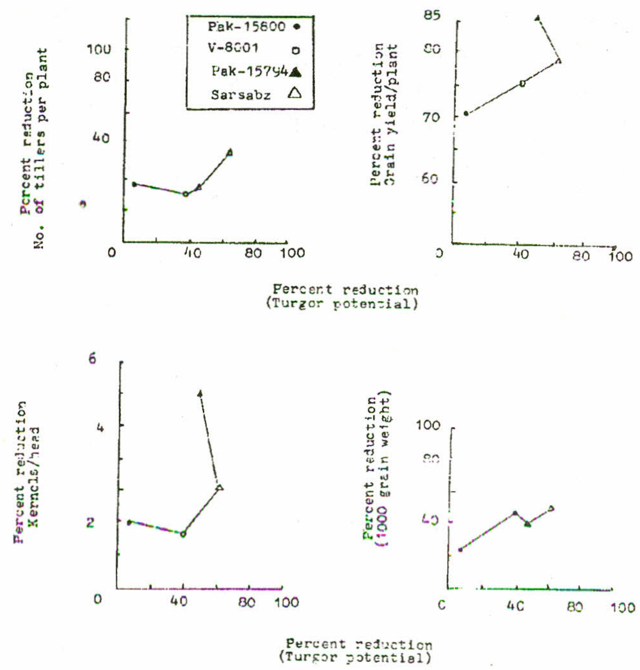

Fig. 3. Relation between yield components and Turgor potential for non-stressed and stressed plants.

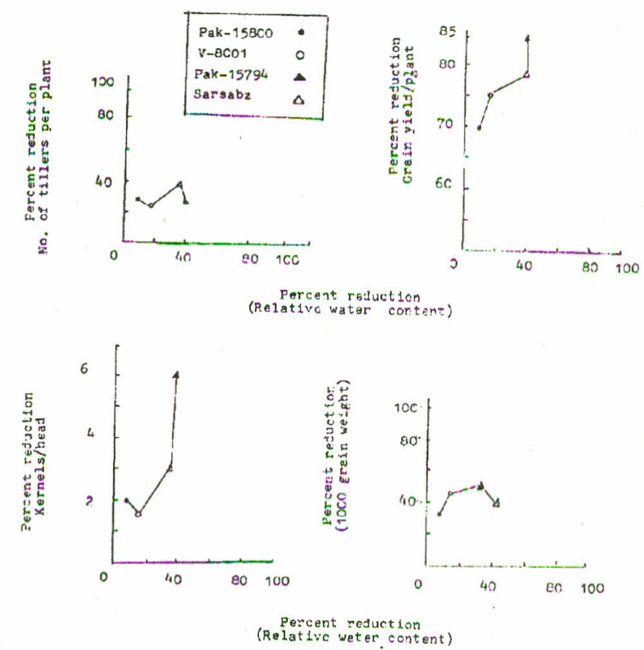

Fig. 4. Relations between yield components and relative water content for nonstressed and stressed plants.

[1,14,15]. Using Levitt [16] terminology osmotic adjustment is a drought tolerance mechanism that minimizes drought injury by turgor maintenance. When turgor is maintained, continued cell elongation is possible even though water potential is reduced [17].

Both proline and betain increased in the cultivars as a result of water stress. A pronounced accumulation of proline and betain was recorded in all the cultivars; in Pak-15800 and V-8001 it was higher than in Pak-15794 and Sarsabz (Table 2). The role of proline and betain in the osmotic adjustment as an ideal osmotica has been pointed out by Jones *et al.* [18]. Handa *et al.* [19] has suggested that solutes (proline and betain) make a substantial contribution towards osmotic adjustment and adaptation to stress and according to Wyn Jones and Storey [20] proline and glycine betain acts as cytoplasmic osmotica. Although there was more than 8 fold increase in proline and a 1.6 - 3.6 fold increase in betain, their calculated contribution towards total osmotic adjustment, was small. Johnson *et at.* [17] also made the calculation and found the contribution of total amino acids including proline to be only 7.1%. As pointed out their contribution in osmotic adjustment is negligible. If they play other important role it needs elucidation.

In the present study the cultivars which showed greatest percent reduction in leaf water potential gave least reduction in grain yield. The same was true for osmotic potential. Blum and Pnuel [21] concluded that osmotic adjustment plays the greatest part in drought tolerance.

Osmotic adjustment is also possible due to greater hydration or RWC [22]. In a cell, water volume and solute concentration combine to determine osmotic potential [23] therefore if leaves from different clutivars have the same osmotic potential but differ in RWC, it may be inferred that greater solute accumulation and osmotic adjustment occured in the cultivars with higher RWC [24], which was true for Pak-15800 and V-8001.

Osmotic adjustment and other drought resistant mechanism likely interpaly to facilitate the overall drought resistant mechanism. Additional research with large number of cultivars is necessary to determine the physiological marker or indicators for drought tolerance, which may provide the suitable selection criteria for breeding drought tolerant wheat cultivars.

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