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EVALUATION OF STEM RESERVE UTILIZATION IN PAKISTANI WHEAT GENOTYPES UNDER POST ANTHESIS CHEMICAL DESICCATION STRESS

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Abstract

Pre-anthesis assimilation of stem reserves is considered as an important source for grain filling during post anthesis abiotic stresses that inhibit photosynthesis. Twenty one Pakistani wheat genotypes were evaluated for stem reserve utilization (SRU) using potassium iodide (0.4%) induced desiccation stress 14 days after anthesis. Evaluated genotypes differed significantly ($p<0.01$) for percent reduction in kernel weight under chemical desiccation stress. Percent reduction in kernel weight ranged from 26.19% to 50.72%. Minimum reduction was observed in C-271 (26.19%) showing highest stem reserve utilization while maximum reduction in kernel weight was recorded in Maxi-Pak (50.72%) presenting least SRU. A significant negative correlation ($R^2=0.452$) between percent reduction in kernel weight and plant height was observed. In conclusion, tested genotypes vary considerably in stem reserve utilization when subjected to post-anthesis chemical desiccation inhibiting the photosynthesis. The genotypes with better SRU based kernel growth in the absence of photosynthesis may also provide relative tolerance to drought. This technique therefore, can be used to indirectly screen the wheat genotypes for better performance under terminal drought conditions.

Introduction

Wheat is one of the dominant grains of the world and a staple food for in excess of half the world's population. Wheat grain contains close to 12% water, 60 to 80% carbohydrates (mainly starch), 8 to 15% proteins, 1.5 to 2% fats, 1.5 to 2% minerals, and about 2% vitamins and crude fibers. The development and growth of grain depends mainly on current assimilates that are directly translocated to the grains, but carbohydrate assimilated after anthesis and temporarily stored in the stem, before being mobilized to the grains, also play important role. The third source of carbohydrates to grains, very important for grain filling under stress, is the carbohydrate synthesized before anthesis accumulated mainly in the stem and mobilized to developing kernel (Ehdaie *et al.,* 2006). Wheat crops often experience heat stress and water deficit during the growth and development of grain, limiting the productivity (Ehdaie *et al.,* 1988). However, response of wheat genotypes varies under different levels of water deficit (Hameed *et al*., 2011). The common end result of these stresses is kernel shriveling, reduction in test weight and decrease in grain yield. These stresses are permanent constraint to agricultural productivity in many developing countries while in developed ones these stresses cause occasional losses in agricultural produce. (Ceccarelli & Grando, 1996).

Usually at the time of grain filling for wheat crop temperature show increasing trend while the moisture levels are decreasing. Even under mild conditions, readily available assimilates could be a limiting factor in normal grain filling. Current source of carbon assimilates depend on the active green surfaces of the plant that intercepts light for photosynthesis. Effect of various stresses and natural senescence reduce the rate of photosynthesis at the terminal stage, whereas at this stage the need by the growing kernel increases. In this situation, stem reserves are a vital source for grain filling and wheat crops in dry land areas may depend more on stem reserves than on current photosynthesis for proper grain filling (Ehdaie *et al.,* 2006).

In wheat, improving the capacity to support grain filling by stem and spike reserves is an important physiological trait and breeding target (Blum, 1998). A good capacity for stem reserve and its remobilization has been proposed as a drought adaptive trait in a theoretical model for drought tolerance (Reynolds *et al.,* 1999). There are several reports which validate that when severe drought stress occurs at the time of grain filling the desiccation of leaves greatly reduces photosynthesis and grain filling mainly depends on mobilized stem reserves (Bidinger *et al.,* 1977; Davidson & Birch, 1978; Hunt, 1979; Blum, 1988).

Different indices that can be useful to differentiate between drought tolerance and susceptibility in wheat have been tested (Hameed *et al.,* 2010). Chemical desiccation method applied at the time of grain filling reveals genotypic differences of varieties in utilization of stem reserves in the absence of active photosynthesis (Blum *et al.,* 1983a; 1983b; 1990). A chemical contact-desiccant, Potassium iodide (KI), has been reported useful for disrupting photosynthesis and assessing grain filling by mobilization of stem reserves (Blum *et al.,* 1983a, 1983b; Blum & Pnuel, 1990; Hossain *et al.,* 1990; Nicholas & Turner, 1993). This treatment does not replicate drought stress but it creates the effect of stress by inhibiting photosynthesis. The observed outcome of potassium iodide treatment is similar to those reported in plants under water stress. Improvement of drought tolerance is one of the most desirable breeding objectives of recent times. (Keim & Kronstad, 1979; Blum, 1983b).

In the above view, present investigation was carried out to assess the genetic differences, among Pakistani wheat genotypes, for stem reserve utilization by developing grains under post anthesis chemical desiccation stress. Other objective was to asses the possible utilization of this technique for indirect screening for drought tolerance in wheat.

Materials and Methods

Twenty one Pakistani wheat genotypes were planted in randomized complete block design with 3 replications at Nuclear Institute for Agricultural & Biology, Faisalabad, Pakistan. Planting of materials was performed in two plots one as control (with out spray) and other as treated (sprayed with 0.4% w/v potassium iodide on canopy, including the ears) following the method described by Blum (1998). Rows were spaced 30 cm apart so that the lower parts of the canopy also receive proper amount of spray. The treatment was applied at linear growth phase of developing kernel which starts at about fourteen days after anthesis. Time of anthesis was determined when 50% of the spikes had extruded anthers. All the recommended agricultural practices were followed up to harvest. At maturity, data for plant height was also recorded. For each treated and non-treated rows 1000-grain weight was estimated separately. Finally, the magnitude of stem reserve was estimated as percent reduction in kernel weigh, due to chemical desiccation, by comparing mean kernel weights of desiccated and control genotypes (Blum, 1998).

Statistical analysis: All the data were subjected to statistical analysis through MSTAT-C. Correlation analysis was performed to examine associations between characters and DMR test was applied to compare the mean values.

Results and Discussions

Highly significant differences ($p<0.01$) were revealed (Table 1) by analysis of variance for percent reduction in kernel weight due to chemical desiccation. The differences among the genotypes for plant height were also significant. Previously, Regan *et al*., (1993) have reported significant differences in the response of genotypes to desiccation treatment. Genetic variability among genotypes for tested traits may be helpful for yield improvement.

Table 1. Analysis of variance of wheat genotypes.

Source of variance	df	Mean squares	
		Reduction in kernel weight (%)	Plant height (cm)
Replications	2	41.60	53.0229
Genotypes	20	113.096**	127.53**
Error	62	40.771	42.452

** Highly significant

Chemical desiccants are reported to simulate drought stress in the field enabling the selection for postanthesis drought stress tolerance (Haley & Quick, 1993). Grain filling mainly depends on the carbon source resulting from the current assimilation consequential to the viable green surfaces that intercept light after anthesis stage. In our experiment spray with chemical desiccant (0.4% K.I) resulted in leaf desiccation of tested genotypes within 3 to 4 days after treatment. The induced desiccation resulted in complete yellowing of leaves similar to the natural senescence as an effect of various stresses. Stem reserve mobilization capacity of the plant, in the absence of photosynthesis, is estimated as variation in 1000 grain weight because all yield components apart from kernel weight have already been determined, at the time of treatment (Blum *et al.,* 1983a; 1983b; 1991). Percent reduction in kernel weight by chemical desiccation displayed the differential response of Pakistani wheat genotypes to imposed stress condition. The mean values for percent reduction (%) in kernel weight ranged from 26.19% to 50.72% with an average of 38.46% (Table 2). The minimum reduction was observed in C-271 (26.19%) followed by Sandal (28.85%) while maximum reduction in kernel weight was recorded in Maxi-Pak (50.72%) followed by HD-2329 50.38% (Table 2). The rate of reduction was in the range of 5 to 50% in the tested wheat germplasm which is comparable to previous findings of Blum *et al.,* (1983a; 1983b).

In previous reports significant correlation has been reported between the rate of reduction in grain weight by chemical desiccation and the rate of reduction by drought stress (Blum *et al.,* 1983b; Nicholas & Turner, 1993). In view of previous reports, tested genotypes were divided into three groups with high (< 30% reduction in kernel wt.), medium (31-41% reduction in kernel wt.) and Low (< 41% reduction in kernel wt.) stem reserve utilization during post anthesis chemical desiccation stress and the data was analyzed for any correlation with reported drought tolerance or susceptibility of these genotypes (Fig. 1). The genotypes having high utilization of stem reserves were considered relatively drought tolerant as compared to those with low utilization (drought susceptible). Theoretically, genotypes which accumulate a large amount of water soluble carbohydrates (WSC) in the stem may be able to relocate more carbohydrates to the grain than genotypes with less stem carbohydrate concentrations when the supply by photosynthesis is limited. The C-271 and Sandal fall in first group having minimum % reduction in kernel weight exhibiting high utilization of stem reserves under stressed conditions (Fig. 1). These genotypes also perform well under drought conditions. In previous reports wheat lines having low reductions in kernel weight after KI treatment also demonstrated stable kernel weight under drought stress (Nicolas & Turner, 1993). The second group (Medium) consisted of 24% of the genotypes namely, Sindh-81, Bakhtwar-92, Punjab-96, chackwal-86 and Nishter. These genotypes may be considered moderately drought tolerant as they utilized relatively less amount of stem reserves to compensate yield losses under the conditions of stress. Ahmad *et al*., (2003) have also reported Punjab-96 as relatively drought resistant genotype. The remaining genotypes (66%) of the third group (Low) exhibited the low utilization of stored reserves (Fig. 2) and considered susceptible. Such high reductions in kernel weight have also been reported by (Mohammadi *et al.,* 2009). The genotype Iqbal-91 with low stem reserve utilization in our study have been previously reported as relatively drought susceptible genotypes in post anthesis moisture stress (Ahmad *et al.,* 2003). The genotypes having low stem reserve utilization may not perform well in drought conditions as stem reserve utilization has been found to be effective yield sustaining mechanism under drought stress (Hossain *et al.,* 1990; Pheloung & Siddique, 1991; Gavuzzi *et al.,* 1997; Yang *et al.,* 2002; Asseng & Van Herwaarden, 2003; Plaut *et al.,* 2004).

Table 2. Plant height, seed weights and description of wheat genotypes.

S# No.	Variety/Accession	Origin	Year of release	Plant height (cm)	1000 Grain weight (treated)	1000 Grain weight (control)	Reduction in kernel weight (%)
1.	H.D-2009	INDIA	1985	91.67	1.81	3.18	42.79
2.	H.D-2329	INDIA	1973	86.90	1.88	3.79	50.38
3.	C-271	PUNJAB	1976	112.89	2.38	3.23	26.19
4.	MAXI-PAK-65	PUNJAB	1965	97.24	1.65	3.36	50.72
5.	PAK-81	PUNJAB	1981	89.39	1.83	3.31	44.56
6.	INQILAB-91	PUNJAB	1991	91.30	1.67	2.9	42.50
7.	CHACKWAL-86	SINDH	1986	90.83	2.04	3.48	40.71
8.	FD-83	PUNJAB	1983	92.66	2.01	3.46	41.85
9.	BHITAI	SINDH	2004	87.83	1.98	3.54	44.14
10.	RAWAL-87	PUNJAB	1987	88.10	1.91	3.79	49.72
11.	WIFAQ- 2001	PUNJAB	2001	100.00	2.08	3.77	44.63
12.	SINDH-81	SINDH	1981	97.28	2.15	3.33	35.47
13.	MEHRAN-89	SINDH	1991	88.17	1.96	3.43	42.72
14.	SOGHAT-90	SINDH	1991	90.78	1.82	3.47	46.48
15.	NISHTAR	NWFP	1995	84.78	1.64	2.87	40.50
16.	BAKHTAWAR-92	NWFP	1993	96.89	1.84	2.96	38.32
17.	FAKHR-E-SARHAD	NWFP	1998	92.66	1.92	3.46	45.00
18.	YECORA-70	PUNJAB	1975	97.22	1.96	3.68	46.15
19.	PUNJAB-96	PUNJAB	1996	92.55	1.98	3.30	39.93
20.	SANDAL	PUNJAB	1973	103.42	2.96	4.15	28.85
21.	ZARDANA	NWFP	1996	88.83	2.06	3.75	43.66

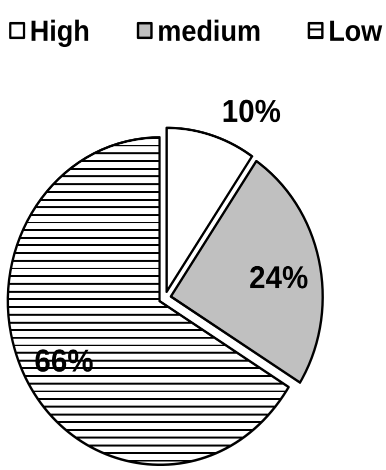

Fig. 1. Percentage of tested wheat genotypes showing high, medium and low stem reserve utilization.

It seems that plant height is an important component of grain yield in bread wheat. Longer stems and greater specific weight increases the storage capacity (Blum *et al.,* 1994). Our data elucidated significant negative correlation (r=0.453*) between plant height and percent reduction in kernel weight (Fig. 3). The genotypes having tall stature showed less reduction in kernel weight under stress conditions. However, the relatively dwarf genotypes were prone to high reduction in kernel weight suggesting the low contribution of stem reserves in stressed plants. In this connection, Borrell *et al*., (1993) reported that a 21% reduction in stem length may cause reduction in storage reserves by 35% and 39%, depending on the presence of dwarfing genes Rht-B1b and Rht-D1b of wheat respectively. Our results are also in line with the findings of Mohammadi *et al*., (2009) who mentioned significant correlation between plant height and stem reserve in chemically induced stress conditions. The high yielding technologies developed in Mexico during 1960's and 1970's helped revolutionize cereal production and resulted in what is known as green revolution. The use of dwarfing genes shaped a new plant type, the semi dwarf varieties with short stature, that were resistant to lodging under higher levels of fertilizers and irrigation. As mentioned above, dwarfing genes in the wheat had consequence of reduced storage capacity of the stem (Borrell *et al.*, 1993). It seems logical to infer that post green revolution semi dwarf wheats have lesser stem reserve utilization and drought tolerance. In this connection it is interesting to mention that wheat genotype C-271 showing highest stem reserve utilization (26.19%) in current study belongs to pre-green revolution era with comparatively taller stature. In the current scenario of decrease in irrigation water with every passing day breeding for drought tolerance is a major objective. In our opinion, shifting the breeding preference from semi dwarf to medium stature plant type in wheat may help in improving the drought tolerance of this crop.

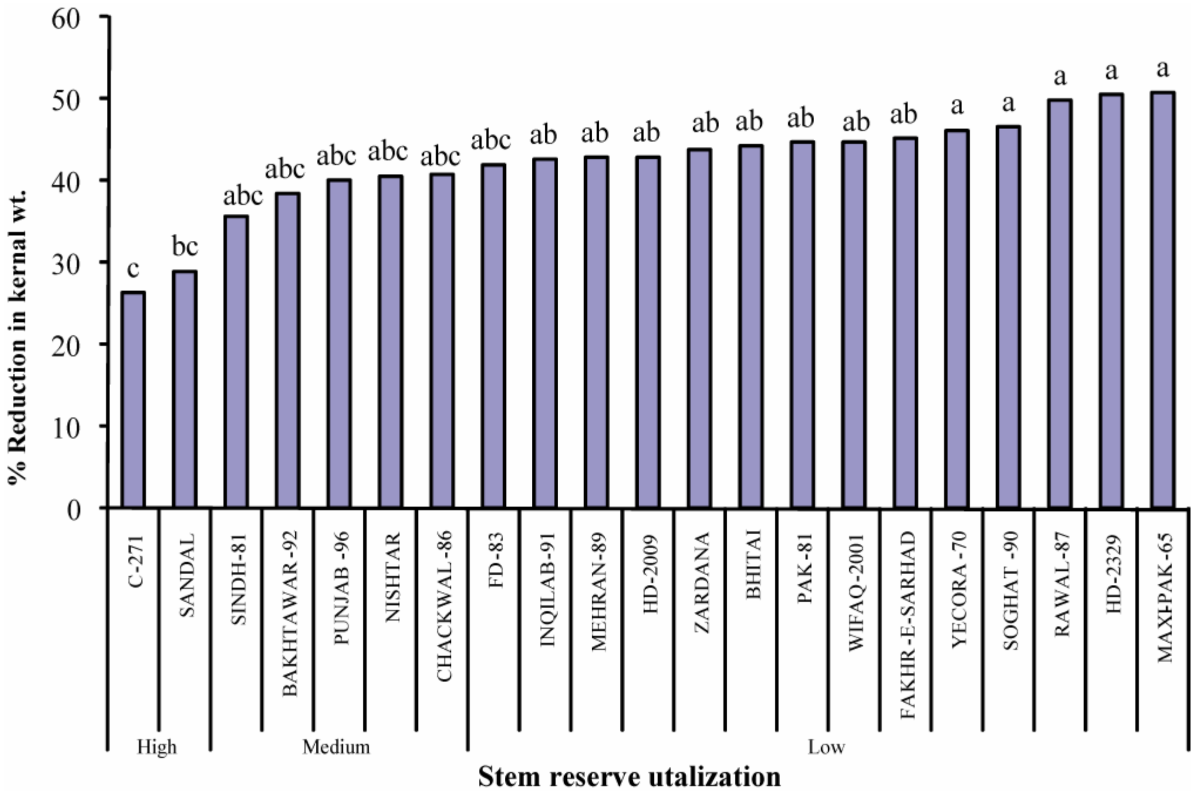

Fig. 2. variation in stem reserve utilization by different wheat genotypes under chemicaly induced desication stress.

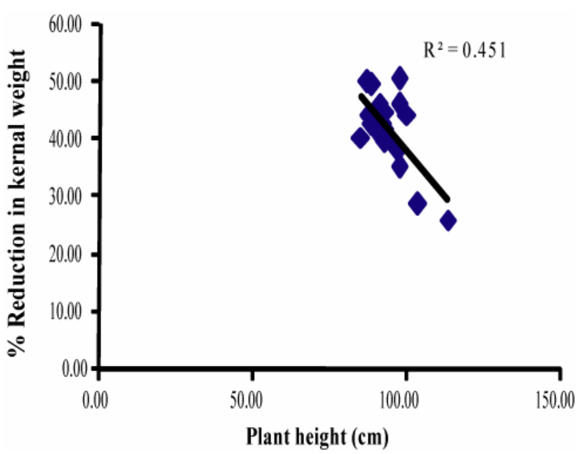

Fig. 3. correlation between plant height and percent reduction in kernel weight under chemical desiccation stress.

Conclusion

It can be concluded that stem reserves mobilization supports kernel growth in cereal crop when subjected to post-anthesis stress relative to transient photosynthesis. The deployment of post-anthesis chemical desiccation stress experiments may provide probable base for selection of relatively drought tolerant genotypes. Genetic variation for stem reserves utilization could be used for further improvement to develop wheat varieties that are more adapted to stressed environments. We need to change our breeding preferences according to the continued change in environment.

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