JOURNAL OF AGRICULTURE & SOCIAL SCIENCES
ISSN Print: 1813–2235; ISSN Online: 1814–960X
08–032/MFA/2009/5–4–119–122
http://www.fspublishers.org

Full Length Article

Selection of Bread Wheat Genotypes against Heat and Drought Tolerance Based on Chlorophyll Content and Stem Reserves

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ABSTRACT

In order to compare some bread wheat cultivars against heat and drought tolerance stresses, two different experiments were done at Gachsaran Agricultural Research Station during, 2006-2007. In the first experiment, chlorophyll content was measured for 18 genotypes and in the second experiment, 5 genotypes desiccated with iodide potassium 0.4% at 10 days after anthesis. Both experiments laid out in complete randomized block design with 4 replications. Significant correlation between chlorophyll content and grain yield under heat and drought stresses can contribute to decrease of drought intensity damage due to reduction of chlorophyll content through light absorption. Stem reserves was obtained by comparing mean kernel weight under desiccation with mean kernel weight in the controls, for each tested genotype. Stem reserves, based on "Percent reduction in kernel weight", was from 15 to 36% in five cultivars. Meanwhile, there was high correlation between stem reserves with grain yield and plant height under dryland conditions. Hence, stem reserves is an important source of carbon for grain filling.

Key Words: Wheat; Heat; Drought; Stem reserves; Chlorophyll content

INTRODUCTION

In most wheat growing regions and especially in the Mediterranean climate, grain filling is subjected to several physical and biotic stresses. Grain filling often occurs, when temperatures are increasing and moisture supply is decreasing. Water deficit is the main environmental constraint limiting cereal yield worldwide and particularly within the Mediterranean basin, a problem likely to become even worse in the future. Cereal plants respond to drought through morphological, physiological and metabolic modifications occurring in all organs and therefore traits associated with improved performance under water limited conditions or improved survival to extremely low water availability are diverse (Slafer, 2005).

Heat stress during grain filling is also a major constraint to wheat (*Triticum aestivum* L.) yield in Iran. About 50% of wheat area in sub-tropical of Iran is planted after the optimum time and suffers heat stress, which causes a significant yield loss. To sustain wheat productivity under late planting, research emphasis has been given to develop heat tolerant genotypes. Field experiments were performed to evaluate the adaptation of some wheat genotypes and identification of some adapted traits under heat and drought stress environments. There is an average yield loss 1.7% per day, when sown beyond optimum time (Mohammadi, 2002). If our physiological understanding of yield is adequate, then the most likely traits to improve yields in a given environment can be identified.

Any genetic advance in yield in a dry environment is based on some physiological traits. The use of these traits as indirect selection criteria for yield in a breeding program will then depend on their relative importance (genetic correlation with yield), ease and cost of measurement, extent of genetic variation, heritability, genotype × environment interactions and whether they are associated with adverse pleiotropic effects or genetic linkage (Richards, 2002).

In most studies, in the small grains stems, some leaf sheaths with reserves were found. Small grains stems store carbohydrates in the form of glucose, fructose, sucrose and starch, but the main reserve is fructan (Lopatecki, 1962; Dubois, 1990; Wardlaw & Willenbrink, 1994).

Improving the capacity for supporting grain filling by stem reserves is an important breeding target in cereals subjected to environmental and biotic stresses during grain filling. Blum (1983a & b) proposed the use of chemical desiccation of the canopy after flowering as means for inhibiting plant photosynthesis and thus revealing the capacity for grain filling by stem reserves. The treatment does not simulate drought stress, but simulates the effect of stress by inhibiting current assimilation.

The use of physiological traits in a breeding program, either by direct selection or through a surrogate, such as

To cite this paper: Mohammadi, M., R.A. Karimizadeh and M.R. Naghavi, 2009. Selection of bread wheat genotypes against heat and drought tolerance on the base of chlorophyll content and stem reserves. *J. Agric. Soc. Sci.*, 5: 119–122

molecular markers, can then result in more precise targeting of factors limiting yield or may result in faster rates of yield improvement. It can also result in a broadening of the genetic base.

The main goals of this research were: Chlorophyll content comparisons among eighteen wheat lines, correlation of this trait with drought based on grain yield production and comparing of mean kernel weight under desiccation with mean kernel weight in the controls.

MATERIALS AND METHODS

The trial included eighteen bread wheat genotypes and it was laid out in randomized complete block design with 4 replications in Gachsaran Agricultural Research Station. Fertilizers were applied 60-60 kg NP kg/ha. Seeds were sown 300 kernel per square meter in unit plots of 5 m long 6 rows at 30 cm apart. Chlorophyll content (green color intensity) was measured at 10 days interval from anthesis date. Measurements were made on flag leaves per plot with a self calibrating chlorophyll meter (model CL-0, Hanseatech instruments).

Chemical desiccation. The test is planted under non-stress conditions to avoid any reductions in kernel weight in the controls. In a special nursery that include five bread wheat genotypes under well watered and disease free (controlled), meanwhile under dryland conditions (medium water stress) with recommended package of practices, considered lines were chemical desiccated in a randomized complete block design with four replications (Mackill, 2003). The spray consisted of solutions of potassium iodide, all at 0.4% active ingredient (Blum, 1998). Planting of materials for chemical desiccation performed in rows spaced 30 cm apart in nursery rows (for evaluating advanced lines). Such spacing would allow the spray to reach the lower parts of the canopy. Spray treatment is generally applied to each genotype at 10 days after heading. The spray is applied manually (usually with a back-sprayer) to the whole plant to full wetting, including the ears. Stem reserves estimated based on percent reduction of thousand kernel weight for each genotype. "Percent reduction in kernel weight" by chemical desiccation was obtained by comparing mean kernel weight under desiccation with mean kernel weight in the controls, for each tested genotype (Blum, 1998).

RESULTS AND DISCUSSION

The result of variance analysis showed significant difference among wheat genotypes in view of grain yield and chlorophyll content (Table I). The correlation across diverse genetic materials between the chlorophyll content and the grain yield under heat and drought stresses was found to be negatively significant and reasonably high (r = -0.62**).

Obtained results from experiments, which were done by Havaux and Tardy (1999) reported that low chlorophyll of Syrian barley landraces have correlation with stomata conductance and therefore adapt to drought conditions. Low leaf chlorophyll causes reduction light absorption and decreases of heat damages.

Yang (2002) reported that chlorophyll content, grain filling duration, yield and kernel weight were highly negatively correlated with heat susceptibility index (HSI) of the hexaploid amphiploids at 30/25^{o}C, but grain yield was positively correlated with HSI at 20/15^{o}C. Present results support these findings. Moreover, field studies in warm environments in Mexico have shown that photosynthetic rates and leaf chlorophyll content measured grain filling were positively associated with yield in irrigated conditions (Reynolds, 1994).

It seems that the occurrence of high temperature along with drought stress in Gachsaran Agricultural Research Station is a main cause of low chlorophyll content, which decreases drought intensity damage through reduction of light absorption. In arid, high temperature the heat load received by the leaf under high light conditions can be reduced by increasing leaf reflectance. This leads to lower leaf temperatures and leaf-air vapor pressure deficits. As a result water loss decreases (Johnson, 1983).

Tests of advanced lines for capacity of maintaining large storage in stems were evaluated under two treatments: desiccation and non-treated controls. With this method we applied a chemical desiccant (iodide potassium; 0.4% w/v) as a spray to the canopy, including the ears. The treatment was applied to each genotype at 10 days after heading, when kernel growth entered its linear phase. At maturity, kernel weight was compared between treated and non-treated (control) plants, calculating the rate of reduction in kernel weight caused by the treatment (Table II). The correlation across diverse genetic materials between the rate of reduction in kernel weight by chemical desiccation and the grain yield reduction by drought stress was found to be significant and reasonably high (r=65**). Hossain (1990) noted that winter wheat cultivars of stable kernel weight over years and locations sustained relatively less reduction under sodium chlorate desiccation of the canopy. Blum (1994) found a high correlation (r = 0.94**) across five wheat cultivars between the reduction in kernel weight by chemical desiccation and the reduction in kernel weight by heat stress (35/25^{o}C day/night temperatures) during grain filling. The rate of reduction in kernel weight under harsher heat stress conditions was well correlated across different wheat cultivars (r = 0.74**) with the reduction in kernel weight caused by post-anthesis defoliation and shading of plants under optimal temperatures (Fokar, 1998). Finally, the reduction in kernel weight by chemical desiccation was significantly correlated across different. The capacity for maintaining large storage in stems appears to be a genetically controlled constitutive trait (*e.g.,* Hunt, 1979; Blum, 1994).

Clarke (1984) demonstrated very well that simple relationship between stem reserve storage or remobilization and varietal drought tolerance in terms of yield (such as by the "stress susceptibility index") are not to be expected. The

Table I. Agronomic traits, grain yield and chlorophyll content of 18 bread wheat genotypes

Ent. No	Variety/Line	Days to heading	Plant height	Days to maturity	Thousand kernel weight	Yield	Chlorophyll content
1	V1	99	91	137	49.3	4091 e	21.4 abc
2	V2	101	88	138	42.9	4604 cde	19.3 defgh
3	V3	99	92	138	47.1	4806 bc	18.4 fgh
4	V4	100	96	138	47.5	5402 a	18.1 gh
5	V5	100	93	138	41.6	4574 cd	18.4 fgh
6	V6	100	95	139	45.2	4516 cd	18.1 gh
7	V7	100	87	137	45.7	5324 a	19.0 defgh
8	V8	99	98	139	43.6	4721 bc	18.6 efgh
9	V9	101	102	139	43.2	4598 cd	17.5 gh
10	V10	100	98	139	43.4	5082 ab	20.8 cde
11	V11	101	97	139	45.1	4208 de	21.4 abc
12	V12	100	103	138	43.3	4655 bcd	18.4 fgh
13	V13	101	99	140	45.6	4359 cde	21.7 abc
14	V14	99	85	138	46.1	4389 cde	19.5 cdefgh
15	V15	100	87	139	44.6	3979 e	23.1 a
16	V16	100	94	137	45.1	4180 de	22.1 ab
17	V17	99	88	140	42.7	4291 de	23.2 a
18	V18	101	95	139	45.6	4285 de	20.4 bcdef

Table II. Percent reduction in kernel weight (stem reserve) for five considered Bread wheat lines

Entry No	Variety/Line	PLH	TKW-1	TKW-2	Stem reserve (%)
14	GHK"S"BOW"S"//90 -ZHONG87	85	50	13.5	27
15	KATILA-11	87	49	7.4	15
16	NESTOR/3/HE1/3*CNO79//2*SERI CMSS92M00092S-015M-0Y-0Y-050M-25Y-2M-0Y	94	51	14.8	29
17	SERI82/SHUHA "S" ICW89-0018-7AP-0AP-1AP-0TS-0AP	88	47	10.8	23
18	KOUHDASHT	95	52	18.7	36

TKW-1: Thousand kernel weight without desiccation
TKW-2: Thousand kernel weight after desiccation same as above

impact of stem reserves should be evaluated only under stress conditions, which equally inhibit crop assimilation during grain filling in all materials tested.

An alternative way might be increasing the contribution of vegetative stem reserves to grain filling to raise yields under terminal stresses that severely inhibit actual photosynthesis (otherwise source limitation is likely; Boras, 2004). In these cases, augmenting the contribution of carbohydrates reserves accumulated during vegetative growth to grain filling may be worthwhile for improving harvest index (Loss & Siddique, 1994).

Stem reserves from pre-anthesis plant assimilation are being increasingly recognized as an important source of carbon for grain filling, when current photosynthesis is inhibited by drought, heat or disease stress during this stage.

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(Received 16 July 2008; Accepted Accepted 28 July 2009)