Effect of Drought Stress on Doubled Haploid Lines of Barley (Hordeum vulgare L.)

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ABSTRACT: In order to evaluate the effect of Water -Stress in cultivated spring barley, one hundred and fifteen (115) Doubled Haploid Lines developed from Steptoe and Morex (cultivars barley) with their two parents were tested in Yangling, China.

The objective of this study was to assess the effect of water stress on plant height in barley doubled haploids (DH) mapping populations. The field experiments were carried out in the Agricultural center of Northwest A&F University, Yangling (34°17′ Latitude, 108°4′ Longitude) during two barley growing seasons. The experimental design was a randomized complete block with two replications. Each experimental plot was 15 m long and 1.5 m wide with total area of 22.5 m². The plots were separated by a border of 0.25 m diameter. In each plot, each doubled haploid line and two parents were represented by two consecutive rows, with 1.5 m long and spaced by 0.3 m. Fertilizer 25 kg / mu or 374.98 kg / ha of Nitrogen and Phosphorus (N: P 1:1) were applied every year before sowing the crops. DH Lines and their two parents were tested in two different water regimes: regime1, rainfall (water stressed condition) and regime2, rainfall irrigation (non-water-stressed condition).

Irrigation was performed two times. The quantity of water supplied was the same for two seasons, 10 m³ / mu or 150 m³ / ha, (1 mu=666.7 m²).

The Analysis of results showed significant effects of water deficit on the variation and distribution of plant heights in DH Lines and its parents. In the water regime 1 (stressed conditions), the mean value of plant heights ranged from 77.0 cm to 121 cm for DH Lines, 67 cm to 90 cm for Steptoe and from 94 cm to 107 cm for Morex. While in the water regime2 (non-stressed conditions), plant heights varied from 90 cm to 143.3 cm for DH lines, 105 cm to 120 cm for Steptoe and from 113 cm to 128 cm for Morex.

The reduction of plant height in DH population is about 15 %, (21.6 cm), while it is 15 % and 29.1 % or it about 21 cm and 30 cm for Morex and Steptoe respectively in water-stressed conditions.

Keywords: Barley, Drought, Doubled Haploids Lines, Yangling.

I. INTRODUCTION

Stress is an altered physiological condition caused by factors that tend to disrupt the equilibrium. Strain is any physiological and chemical change produced by a stress (1). The term stress is used with various meanings, the physiological definition and appropriate term as responses in different situations. The flexibility of normal metabolism allows the response initiation to the environment changes, which fluctuate regularly and are predictable over daily and seasonal cycles.

In crop breeding, drought stress is considered to be a moderate loss of water, which leads to stomatal closure and limitation of gas exchange. Desiccation is much more extensive loss of water, which can potentially lead to gross disruption of metabolism and cell structure and eventually to the cessation of enzyme catalyzed reactions (2). Drought stress is characterized by reduction of water content, diminished leaf water potential and turgor loss, closure of stomata and decrease in cell enlargement and growth. Severe water stress may result in the arrest photosynthesis, disturbance of metabolism and finally the death of plant (3). Drought represents a major problem for agriculture in arid and semiarid areas. It can reduce significantly plant height and hence grain yield, and restricts latitudes and soils where economically important species can be grown. Water stress inhibits cell enlargement more than cell division. It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters (3), (4). In plant, a better understanding of the morpho-anatomical and physiological basis of change in water stress resistance could be used to select or create new varieties of crop to obtain a better productivity.
under water stress conditions (5). The reaction of plants to water stress differ significantly at various organizational levels depending upon intensity and duration of stress as well as plant species and its stage of growth (3). Understanding plant responses to drought is of great importance and also a fundamental part for making the stress tolerant (6). It has been established that drought stress is a very important limiting factor at the initial phase of plant growth and establishment. It affects both elongation and expansion growth (7).

In the past, when water was in sufficient for agricultural production, irrigation systems based on the construction of dams and canals had been put in place. However, the number of areas where new irrigation infrastructure economically viable is becoming limited. Concerns have also increased about the negative impacts on the environment. New approaches are especially needed for water-limited semi-arid and arid environments, as well as in other environments with unreliable rainfall and uncertain water viability for agriculture.

Development of drought tolerant genotypes and with higher efficiency in use of water is of global interest, due to continuous growth in global population and decrease of water resources destined to agriculture. Additionally, it will allow more safety to agriculture in marginal environments, which usually show high risks due to drought and high temperature stress (8).

Barley (Hordeum vulgare L.) is considered as a model species for physiological, agronomical and genetic surveys due to several reasons: 1) it is an important crop worldwide (fourth among the cereals in worldwide production); 2) it shows high degree of self-pollination and its crossbreeding is compatible with species within primary pool of genes; 3) it is annual species with a short lifecycle; 4) it is diploid with only seven pairs of chromosomes; 5) it shows a wide range of physiological, morphological and genetic diversity; 6) there is a wide genetic reserve; and 7) there are well defined genetic map (9).

Haploids plants were regenerated from single microspores or macrospores which carry only one set of alleles on each locus. In barley the first doubled haploids lines were developed by Ciba Geigy Seeds Ltd., Ontario in 1979, only five years after its parental lines were crossed. The Steptoe / Morex doubled haploid barley mapping population was the first product of the North American Barley Genome Mapping Project and was developed from the F1 hybrid by the Hordeum bulbosum.

The two parents differ for number of inherited traits such as a plant height (morex higher than steptoe), seed dormancy (higher in Steptoe, absent in morex), reaction to drought (morex is very susceptible and Steptoe is resistant) and productivity (Steptoe more productive than morex). The seeds for this study were obtained from the Department of Crop and Soil Science, Oregon State University, Corvallis, OR 97331. Steptoe: is a high yielding, broadly adapted six –row coast-type feed barley selected from the cross of “WA 3564”/ “Unitan.”

Morex: a Midwestern six-rowed cultivar used as the American malting industry standard derived from Manchurian barley. It was developed from the cross of “Cree”/ “Bonanza”.

II. MATERIAL AND METHODS

2.1 Plant materials

One hundred and fifteen (115) doubled haploid Lines (DHLs) barley mapping population and their two parents (Steptoe and Morex) were used in this study. The Steptoe / Morex doubled haploid barley mapping population was the first product of the North American Barley Genome Mapping Project and was developed from the F1 hybrid by the Hordeum bulbosum.

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2.2 Field experiment

The field experiments were carried out in the Agricultural center of Northwest A&F University, Yangling (34°17′ Latitude,
108°4′ Longitude) during two barley growing seasons; from October 2008 to June 2009, and October 2009 to June 2010. The average rainfalls for the experimental seasons was 525.8 mm and 565.7 mm for two seasons respectively but lower than 663.9 mm average rainfall of last ten years.

A total of 115 DH Lines and their two parents were grown in two different water regimes, regime1: rainfall (water-stressed conditions) and regime2: rainfall irrigation (non-stressed conditions).

The experimental design was a randomized complete block with two replications. Each experimental plot was 15 m long and 1.5 m wide with total area of 22.5 m². The experimental plots were separated by a border of 0.25 m diameter. Fertilizers at the rate of 374.98 kg / ha of Nitrogen and Phosphorus (1:1) respectively were applied every year before sowing of plants. Sowing was done in mid of October, 2008 and 2009. In each plot, each DH line and parent were represented by two consecutive rows, with 1.5 m long and spaced by 0.3 m. The growth seasons were characterized by a totally low rainfall. In the first season the rainfall was 525.8 mm and in the second season 565.7 mm. For two experimental years, the rainfall was below the average of last 10 years.

Irrigation was performed twice: First after 3 months of sowing and the next one 2 months later. The quantity of water supplied was the same for two seasons, 10 m³ / mu or 150 m³ / ha (1 mu=666.7 m²).

Plants were harvested after maturity at the same day.

2.3 Data collection

Plant height of five plants for each DH Lines and each parent per treatment and per replication was recorded from the base of the culm to the tip of the spike without awn of the main culm.

3.4 Data analysis

Results were statistically analyzed for variance using SAS system. When analysis showed significant treatment effects, Duncan’s multiple range tests were applied to compare the means at p<0.05.

Reduction (R) of plant height was calculated by the following formula as well as for DH Lines and for two parents

\[ R = \frac{H_{i,\text{max}}}{H_{s,\text{max}}} \]

Where, \( R \) represents the mean values of the reduction of plant heights; \( H_{i,\text{max}} \) and \( H_{s,\text{max}} \) represents respectively the maximum of the mean values of plant heights in the non-stressed and in the stressed conditions.

III. RESULTS AND DISCUSSIONS

The results showed in this study are the mean values of plant heights for two our experimental years. The results showed a continuous distribution of plant height in DH Lines that exceeded the range between those of the parents. Some of DH Lines were significantly shorter than Morex (i.e. DH-6 and DH-137 with plant heights 77 cm and 78 cm respectively), but all DH Lines were higher than Steptoe in stressed conditions; The plant height of DH Lines in stressed conditions varied from 77.0 cm to 121 cm; while for Steptoe and morex they ranged from 67 cm to 90 cm and 94 cm to 107 cm respectively (Table 1). The distribution of the values of plant height as follows: 78.11 cm for 12 lines, 89.90 cm for 47 lines, 101.68 cm for 41 lines and 113.46 cm for 15 lines (see Figure 1).

In non-stressed conditions, the value of plant heights ranged from 90.0 cm to 143.3 cm in the DH Lines population and from 105 cm - 128 cm for Steptoe, from 113 cm - 128 cm for Morex. The plant heights distribution for DH Lines as follows: 89.90 cm for 9 lines, 101.68 cm for 41 lines and 113.46 cm for 41 lines and 113.46 cm for 15 lines (see Figure 1).

In general, in stressed and non-stressed conditions, the higher plants were found in DHLs compared to their two parents and also by plant height distribution, results revealed that about 55 lines (either 47.82 %) of DHLs population were higher than Morex that is the highest among the parents.
The results in table 1 showed that water-stress reduced plant height of DH Lines population and of their two parents. Compared with non-stressed conditions (or control), plant heights were significantly reduced. The reduction of plant height in DH population is about 15 %, (21.6 cm), while it is 15 % and 29.1 % or 21 cm and 30 cm for Morex and Steptoe respectively in water-stressed conditions.

Similar results were found with Zahra et al. (10) who found 30 % reduction in plant height in severe water stressed conditions in barley. The result indicates also, that rainfall (525.8 mm to 565.7 mm) in Yangling during the experimental period was not sufficient for optimal growth for spring barley (DHLs) that has a negative impact on the plant height and consequently on grain yields because grain yield in spring barley is positively correlated to plant height (11).

The reduction of plant height may be explained by inhibition of length of cells or cell division due to water deficit. Water stress inhibits cell enlargement more than cell division. It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters (4).
Table 1: Plant height of DH Lines, Steptoe and Morex

<table>
<thead>
<tr>
<th>Variety</th>
<th>Rainfall</th>
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<th>Rainfall Irrigation</th>
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<tbody>
<tr>
<td></td>
<td>Minimum (cm)</td>
<td>Maximum (cm)</td>
<td>Mean (cm)</td>
<td>Minimum (cm)</td>
<td>Maximum (cm)</td>
<td>Mean (cm)</td>
<td></td>
</tr>
<tr>
<td>DHLs</td>
<td>77.00</td>
<td>121.00</td>
<td>101.58</td>
<td>90.0</td>
<td>143.3</td>
<td>113.56</td>
<td></td>
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<tr>
<td>Steptoe</td>
<td>67.00</td>
<td>90.0</td>
<td>80.0</td>
<td>105.0</td>
<td>120.0</td>
<td>115.0</td>
<td></td>
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<tr>
<td>Morex</td>
<td>94.0</td>
<td>107.0</td>
<td>103.4</td>
<td>113.0</td>
<td>128.0</td>
<td>122.4</td>
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IV. CONCLUSION AND SUGGESTIONS

Water is essential at every stage of plant growth. Thus water stress during the vegetative stage reduced plant height significantly (upon 15%) in DHLs at our study. Water stress causes deceleration of cell enlargement and thus reduces stem length by inhibiting internodes elongation (12).

On the other hand, the results of this study confirm hypothesis that Morex is taller than Steptoe in irrigation and non-irrigation conditions (Table 1). In general, in stressed and non-stressed condition, the higher plants were found in DHLs (DH-122, with 143.33 cm) compared to their two parents and also by distribution of plant height, results revealed that about 55 lines (either 47.82 %) of DHLs population were higher than Morex that is the highest among parents.

According the results of the present study we recommend one or two times irrigation as supplementary for rainfall during the vegetative period for optimal growth of DH Lines (spring barley) at three or four month after seedling time in the experimental region, and the optimum quantity of water to be applied is about 150 m$^3$ per hectare.

The drought tolerant varieties are needed to increase yields, not only in semiarid zones, but also in temperate areas with temporary drought occurrences. In semiarid areas, water unavailability is frequently happened so the presence of drought resistant varieties in Third World countries must reduce frequent harvest failures and eliminates the need of grain import. These varieties will represent an important economic advantage for these countries of semiarid zones for grain and forage production.

REFERENCES


