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Selection of Winter Wheat Mutant Lines Resistant to Drought Stress

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ABSTRACT

Mutated winter wheat lines were screened for improved drought resistance compared to the wildtype by withholding water for 3 weeks after 9 weeks of normal growth, and noting their responses upon re-watering. Of the 146 mutants grown, 73% were either killed due to water stress or showed poor recovery, while 27% recovered better than the wildtype line. This experiment enabled the selection of candidates for further investigation to better understand the genetic basis of drought tolerance in winter wheat.

INTRODUCTION

As both population pressure on the earth's resources and desertification due to global climate change continue to accelerate, the need for agricultural utilization of traditionally inarable land will likely become necessary. In order for production on marginal land to be a viable part of the solution, improved lines of staple crops must be identified and developed. These improved lines must grow and provide appreciable yields under conditions of stress not conducive to the cultivation of current lines of these crops.

Wheat is the third most widely cultivated crop in the world (by weight), behind maize and rice, and its continued production is essential to adequately supply global food systems [1]. However, as with other crops, many problems for their continued growth are on the horizon, and have already begun to surface. These problems include reduced rainfall in many places as a result of global warming, overgrazing that results in soil erosion and accelerates desertification, intensified human water usage, and soil acidification, salinization, or heavy metal contamination through poor management practices, industrial processes, or a combination of the two.

In China, the world's most populous country and leading wheat producer, drought frequency and intensity has been increasing over the past 5 decades in the nation's main wheat-producing areas, with the most severe occurring in late 2008 through early 2009 [2][3][4]. Fortunately, a massive crop failure has been averted this growing season due to both significant government-directed irrigation programs and sufficient rainfall resuming again in mid-February through March in most of the afflicted areas [5]. This disturbing phenomenon is not only unique to China; drought conditions have been increasing throughout the world over the past several decades [3].

Short-term water deficiency can be counteracted by increasing cellular solute concentration in order to lower osmotic potential, and thus retain water within the plant's cells. However, this mechanism is not sufficient to account for survival amid prolonged water stress [6]. This study was undertaken to screen and select for drought resistant winter wheat in order to provide winter wheat breeders with drought resistant cultivars, as well as allow for the molecular analysis of drought resistance. Observations of plant turgor and color were made throughout the experiment, specifically noting the extent of recovery among drought resistant mutants.

MATERIALS & METHODS

Plant material

Seeds of 146 hard red winter wheat mutants derived from the Winoka wildtype, a cultivar bred in South Dakota.

Growth Conditions

Five seeds of each mutant and the wildtype were planted 2-2.5 cm deep in a hexagon arrangement 3-4 cm from the side of plastic pots having a top diameter of 19 cm, a bottom diameter of 15 cm, and a height of 18.5 cm, using approximately 2.75 L of soil per pot; a teaspoon of extended release fertilizer pellets was mixed into the bottom half of the soil in each pot. The plants were watered as needed for the first 9 weeks, before completely withholding water for a 3-week period. Regular watering was then resumed for the next 10 days and observations were made regarding responsiveness.

RESULTS

As represented by the depiction in Figure A, all 146 mutant plants showed healthy growth for the initial 9-week period.

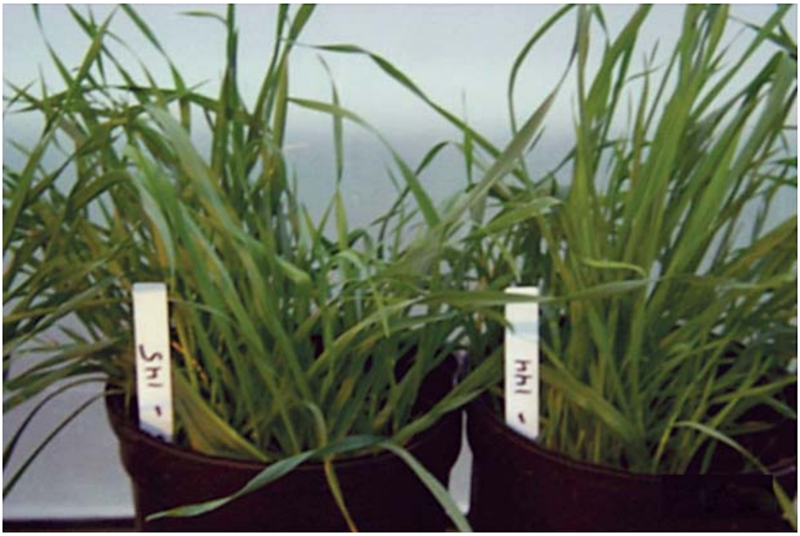

Figure A. Healthy plants prior to drought stress

During the 22-day drought, the plants responded by losing either a majority or virtually all of their turgor and green pigmentation, as seen in Figure B.

Figure B. Plants during drought stress

Upon re-watering more than a quarter of the mutants began to regain turgor and green pigmentation in at least some of their leaves, with some lines displaying impressive recovery within a week. Figure C reveals the differential extent of recovery that occurred amongst these lines, while Figure D underscores that most mutants, however, did not survive the drought.

Figure C. Gradient of drought recovery (WT in the middle).

Figure D. Drought susceptible mutants that did not recover.

The proportion of mutants showing either no drought recovery upon re-watering, or that recovered but to a lesser extent than the wildtype, compared to the number of mutants that displayed greater drought tolerance than the wildtype is documented in Chart 1.

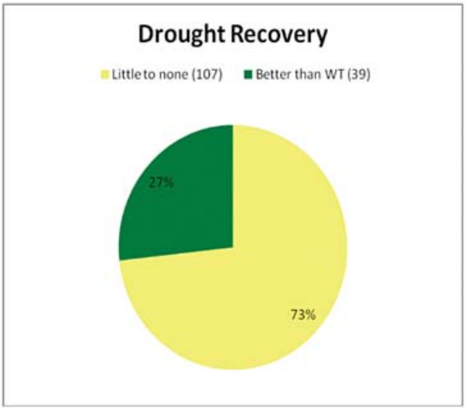

Chart 1. Drought recovery classifications for mutant lines

The most drought resistant mutant, which regained color and turgor in 50-60% of the leaves, is shown in Figure E, next to the control at the same age, in Figure F, having experienced no water stress at any time during its growth.

Figure E. Most drought resistant mutant

Figure F. Unstressed control

DISCUSSION AND CONCLUSIONS

Seed mutagenesis of the wildtype cultivar resulted in 39 lines of hard red winter wheat plants that demonstrated greater drought tolerance than the wildtype cultivar. The four mutant varieties judged by the experimenters to be the most drought resistant, as well as a few from the drought susceptible and those displaying an intermediate response, have been replanted to validate the results of this experiment. If confirmed, an analysis of differential gene expression will be undertaken in order to understand the molecular basis for the observed gradient of drought resistance. Candidates for improved drought resistance can also be identified and developed as single seed descent lines.

ACKNOWLEDGEMENTS

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