Maximizing Pre-harvest Sprouting in White- and Red-seeded Wheat

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Abstract

Seed dormancy is the main factor responsible for conferring pre-harvest sprouting tolerance to wheat grain. Recently, five common wheat germplasm lines (W98616, Line 211, CDC EMDR-4, CDC EMDR-9, and CDC EMDR-14) with deep seed dormancy levels and differing genetic backgrounds were released by the Crop Development Centre, University of Saskatchewan. The objective of this presentation is to give an overview of (1) the five CDC germplasm lines, (2) the two dormancy breaking methods that effectively overcome the deep seed dormancy levels in the five CDC germplasm lines, and (3) how the two dormancy breaking method can be used by breeders to improve sprouting tolerance within their breeding programs using the five CDC germplasm lines.

Introduction

In Saskatchewan, wheat usually ripens under warm, dry conditions that favor development of excellent grain for bread making. However, the ripe grain can sprout in the spike when moist conditions delay harvest and promote germination. Pre-harvest sprouting of physiologically mature grain can occur during wet harvest conditions. For the period of 1978-88, the economic losses attributed to pre-harvest sprouting in the Canadian red spring wheat crop were estimated at about $400 million (Derera 1990). Recently, a wetter than normal harvest in 2002 in Saskatchewan resulted in severe sprouting, and subsequently downgrading of wheat. In Western Canada, the Canadian Grain Commission grade tolerances protect the soundness of Nos. 1 and 2 Canada Western Red Spring (CWRS) grades, with total sprouted-kernel tolerances (%) set at 0.5, 1, and 3% for No. 1. CWRS, No. 2. CWRS, and No. 3. CWRS, respectively.

Pre-harvest sprouting causes processing problems because of high levels of the starch degrading enzyme alpha-amylase (α-amylase). The action of the enzyme during baking reduces the water holding capacity of the starch, resulting in lower baking absorption (i.e., lower bread yield) and handling problems due to sticky dough properties (i.e., a more open coarse crumb structure and gummy crumb). Gummy crumb causes build-up on slicer blades and interferes with effective bread slicing. Loaf volume often is not affected by sprout damage, and can actually increase due to more rapid gas production during fermentation. All of the effects of α-amylase are exaggerated for baking processes with long fermentation times because α-amylase continues to degrade starch during the fermentation stage. In years of wet harvest improper use of hot air dryers can damage gluten functionality and baking quality without visibly altering wheat appearance.

Seed dormancy is the main factor responsible for conferring pre-harvest sprouting tolerance to wheat grain. Seed dormancy is known as the temporary failure of a viable seed to germinate in a particular set of environmental conditions that later evoke germination when the restrictive state has been terminated. That is, dry, viable, and non-dormant seeds germinate readily when hydrated, but dormant seeds will not germinate. Incorporating seed dormancy into new red- and white-seeded wheat cultivars could reduce the economic losses associated with pre-harvest sprouting.

Currently, experimental line RL4137 is the source of elevated sprouting tolerance in a most CWRS wheat cvs. including Columbus and AC Domain. In 2004, CWRS cvs. (n=24) are described as having very good (21%), good (21%), fair (46%), or poor (13%) resistance to pre-harvest sprouting (Saskatchewan Agriculture, Food, and Rural Revitalization, 2004). All Hard White Spring wheat cvs. (n=2), Amber Durum cvs. (n=5), Extra Strong cvs. (n=5) have good, fair, and poor sprouting resistance, respectively. Canada Prairie Spring (red- and white seeded) cvs. (n=8) have fair (38%) or poor (62%) sprouting resistance. White-seeded genotypes have traditionally been considered more susceptible to pre-harvest sprouting damage than red-seeded genotypes, but with increased breeding efforts sprouting resistance within white-seeded cultivars can be improved. Recently, five common wheat germplasm lines (W98616, Line 211, CDC EMDR-4, CDC EMDR-9, and CDC EMDR-14) with differing genetic backgrounds were released possessing deep seed dormancy levels (Hucl and Matus-Cádiz 2002 a,b,c). The release of the five CDC germplasm lines with improved dormancy and sprouting resistance is expected to assist future breeding efforts in improving sprouting resistance in white- and red-seeded wheat.

Plant breeders typically use greenhouse grow-outs to advance their most promising populations one or two generations during the winter season. Greenhouse grow-outs often require planting pre-germinated seed into small pots; however, dormant seeds fail to germinate under a broad set of environmental conditions. Use of chilling with KNO_3 or heating with KNO_3 pre-treatments are effective dormancy-breaking methods that are not associated with abnormal seedling growth (Matus-Cádiz and Hucl 2003). These two methods may be of interest to breeders selecting for increased seed dormancy within populations before advancing selected lines in greenhouse grow-outs. The objective of this presentation is to give an overview of (1) the five CDC germplasm lines W98616, Line 211, and three CDC-EMDR lines recently released by the CDC-UofS, (2) the two dormancy breaking methods that effectively overcome the deep seed dormancy levels in the five CDC germplasm lines, and (3) how the methods can be applied by breeders to incorporate dormancy from W98616, Line 211, and the CDC-EMDR lines into their breeding programs.

W98616

Line W98616, selected from the cross AUS1408/RL4137, was developed at the Crop Development Centre, Department of Plant Sciences, University of Saskatchewan (Hucl and Matus-Cádiz 2002c). AUS 1408, a white-seeded wheat, and RL4137, a red-seeded wheat, are both considered good sources of pre-harvest sprouting resistance. RL4137 is the source of elevated sprouting resistance in a number of Western Canadian red spring wheat cultivars (e.g., Columbus, AC Domain, AC Majestic, Harvest). The white-seeded spring wheat germplasm line W98616 exhibits stronger seed dormancy than white-seeded cultivars AC Vista and Snowbird. W98616 has similar sprouting resistance relative to Columbus, a red-seeded sprouting resistant cultivar. The release of W98616 with improved dormancy and sprouting resistance should assist future plant breeding efforts in improving pre-harvest sprouting resistance in hard white wheat cultivars.

Line 211

Line 211, selected from cross AUS1408/RL4137//AUS1293/Park/3/Ford/Rongotea//Kleiber/Tordo, was developed at the Department of Plant Sciences, Crop Development Centre, University of Saskatchewan, Saskatoon, Saskatchewan (Hucl and Matus-Cádiz 2002b). Ford and Rongotea have moderate levels of sprouting resistance relative to RL4137 while the other ancestors are considered good sources of pre-harvest sprouting resistance. Red-seeded spring wheat germplasm Line 211 exhibits stronger seed dormancy and similar pre-harvest sprouting resistance to the red-seeded sprouting resistant cultivars RL4137 and Columbus. The release of Line 211 may assist future plant breeding efforts in reducing pre-harvest sprouting in red-seeded spring wheat cultivars.

CDC-EMDR lines

The three early-maturing spring wheat germplasm lines CDC EMDR-4, -9, and -14 with increased levels of seed dormancy were developed at the Department of Plant Sciences, Crop Development Centre, University of Saskatchewan, Saskatoon, Saskatchewan (Hucl and Matus-Cádiz 2002a). CDC EMDR-4 was selected from the cross AUS1293/Park. CDC EMDR-9 and -14 were selected from the cross AUS1408/Park. AUS1293 and AUS1408 are late-maturing, sprouting-resistant white-seeded wheat genotypes. Park is an early-maturing, moderately sprouting-resistant Canadian red spring-wheat cultivar. Early maturing red-seeded spring wheat germplasm lines CDC EMDR-4, -9 and -14 exhibit stronger seed dormancy and similar pre-harvest sprouting resistance relative to Columbus and AC Domain, two red-seeded sprouting resistant cultivars. These three lines had similar grain protein concentration and kernel hardness relative to the check cultivars, except CDC EMDR-4, which had a soft endosperm texture. The release of these three lines may assist future plant breeding efforts in reducing pre-harvest sprouting in spring wheat cultivars.

Testing of various germination methods to overcome seed dormancy in W98616, Line 211, and CDC-EMDR lines

An effective dormancy-breaking method may be of interest to wheat (*Triticum aestivum* L.) breeders selecting for increased seed dormancy prior to advancing their populations via greenhouse grow-outs (Matus-Cádiz and Hucl 2003). The objective of this study was to identify an effective pre-treatment for breaking dormancy in wheat that did not result in seedling etiolation. In 2000, eight dormant (W98616, Line 211, EMDR-4, EMDR-9, EMDR-14, RL4137, Columbus, and AC Domain) and one non-dormant line (Roblin) were grown at two locations in Saskatchewan. Seeds were: (i) stored for zero to 21 weeks at 24±C before incubating at 20±C for 7d; (ii) incubated at 5, 10, 15, 20, and 25±C for 14d; and (iii) treated with GA_3 (0.0006 and 0.0014 M), KNO_3 (0.01 and 0.02 M), chilling, heating, chilling with 0.01 M KNO_3, and heating with 0.01 M KNO_3 before incubating at 10±C for 14d. Seedling growth was observed in a duplicated growth chamber experiment. Seedling length, first inter-node length, and biomass yield data were collected from plants grown from seeds treated with four effective pre-treatments. Data were subjected to an ANOVA. Six to 18 weeks of storage at 24±C were required to break the dormancy (≥95 % germination) in dormant genotypes. Incubation at 10±C was the most effective temperature for promoting germination in dormant seeds after 10d of testing. Four pre-treatments including 0.0006 M GA_3, 0.0014 M GA_3, chilling with 0.01 M KNO_3, and heating with 0.01 M KNO_3 led to ≥ 95 % germination within 10d of testing. Only GA_3 treatments were associated with etiolated seedling growth. Heating with 0.01 M KNO_3 or chilling with 0.01 M KNO_3, applied before incubating at 10±C in darkness, may be of interest to breeders selecting for increased dormancy before advancing breeding populations in greenhouse grow-outs.

Two recommended dormancy-breaking methods

The use of chilling with 0.01 M KNO_3 or heating with 0.01 M KNO_3 may be of interest to breeders selecting for increased seed dormancy within populations before advancing selected lines in greenhouse grow-outs (Matus-Cádiz and Hucl 2003). This can be accomplished by (1) harvesting single spikes from the upper canopies of a field or greenhouse grown population at ZGS 92, (2) air-drying samples at 24±C for 7d, (3) threshing single spikes, (4) storing them at –20±C until needed, and (5) using only a portion of each sample in germination tests (Hucl and Matus-Cádiz 2002 a, b, c). Samples can be germinated in petri-dishes, containing one filter paper (5 mL de-ionized water per plate), at 22 to 24±C in darkness for 7d. The dormancy of the most promising seed samples can be overcome as follows: (1) remove any excess water from each petri-dish; (2) add one to 1.5-mL of a 0.01 M KNO_3 solution per petri-dish; and (3) incubate at 5±C (in darkness) for 5d followed by an incubation at 10±C (in darkness) for at least 10d. If the reserved or non-hydrated portion of threshed seed samples is used, the dormancy of the most promising seed samples can be overcome as follows: (1) incubate samples at 35±C for 6d; (2) add one to 1.5-mL of a 0.01 M KNO_3 solution per petri-dish; and (3) incubate at 10±C (in darkness) for at least 4d. Pre-germinated seeds can be greenhouse grown in small pots containing a soil mixture. The seedling growth of the most promising lines pre-treated with heating with 0.01 M KNO_3 or chilling with 0.01 M KNO_3 will not be associated with abnormal growth. The use of chilling with KNO_3 or heating with KNO_3 will be of particular interest to breeders using backcrossing techniques to improve pre-harvest sprouting tolerance within their programs.

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