POSTHARVEST RESPIRATION RATE AND SUCROSE CONCENTRATION OF RHIZOCTONIA-INFECTED SUGARBEET ROOTS

Larry Campbell[1], Carol Windels[2], Karen Fugate[1], and Jason Brantner[2]
[1]USDA-ARS Northern Crop Science Laboratory, Fargo, ND
[2]University of Minnesota, Northwest Research and Outreach Center, Crookston, MN

Rhizoctonia crown and root rot (RCRR) of sugarbeet, caused by Rhizoctonia solani AG 2-2, is increasing in Minnesota and North Dakota. As the disease increases in prevalence and severity, more diseased roots are being stored in piles where they affect storability and postharvest quality. In a preliminary study in the fall of 2009, Rhizoctonia-infected roots in several disease categories were collected from an inoculated experiment at the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston. Roots rated as "1" (healthy, slight scarring) and "5" (more than 50% root surface rotted) had 15.9 and 14.2% sucrose content, respectively, and after 30 days in storage, respiration rates were 3.46 and 9.34 mg CO_2 kg^{-1} $hour^{-1}$, respectively. The proportion of sugarbeet roots with RCRR that are mixed with healthy beets during harvest also is important (Lumley and Poindexter, 2008). In Michigan in 2008, healthy and diseased roots were mixed in proportions of 0, 10, 20, 40, 60, 80, and 100% of roots with RCRR – and BEFORE storage, sucrose concentrations averaged 18.3, 17.0, 16.6, 15.6, 14.3, 13.7, and 11.6%, respectively.

Other sugarbeet root diseases, such as Aphanomyces root rot, Beet necrotic yellow vein virus (Rhizomania), and Fusarium yellows, increase postharvest respiration rate, sucrose losses, and invert sugar accumulation during storage (Campbell and Klotz, 2006a; Campbell et al., 2008; Campbell et al., 2011; Klotz and Campbell, 2009). Harvested roots, if not frozen, respire constantly to provide the energy and products needed to maintain the integrity of the root, heal wounds incurred during harvest and piling, and protect against pathogens. Respiration typically accounts for as much as 80% of the sugar lost during storage (Campbell and Klotz, 2006b). Invert sugar is a product of sucrose breakdown. Elevated invert sugar concentrations increase the sodium carbonate required to maintain proper juice acidity, increase evaporator scaling, and increase juice color which hinders the production of white sugar (Dutton and Huijbregts, 2006). Even small differences in sucrose losses and changes in processing quality during storage have significant economic impact. Although reducing disease severity by planting resistant varieties will reduce postharvest losses, the industry needs additional information to develop strategies that minimize losses during storage of diseased roots and to determine when fields should be abandoned.

OBJECTIVE

The objective was to determine the impact of RCRR on postharvest respiration rate, sucrose concentration, and processing quality of sugarbeet varieties when roots were grouped into distinct disease categories ranging from healthy to severe.

MATERIALS AND METHODS

Three commercial varieties of sugarbeet (susceptible, moderately resistant, and most resistant to RCRR) were planted on 10 May 2010 in a trial at the University of Minnesota, NWROC. The same three varieties plus a second moderately resistant variety were planted at NWROC on 17 May 2011 and on 30 April 2012. Seed spacing was 2.4-inches in rows 30 ft long and 22 inches apart. The experimental design was a split-plot with four replicates. Inoculation times were the main plots and varieties the subplots. Each experimental unit consisted of 6-rows. Varieties were inoculated with ground barley grain inoculum of R. solani by application over the row into crowns with a Gandy applicator at 7, 9, and 11 weeks after planting (28, 40, and 40 g per 30 ft row, respectively) in 2010, and 7 and 9 weeks after planting (28 g per 30 ft row) in 2011 and 2012; a non-inoculated control was included for each variety in each year. The multiple inoculations were to ensure a range of disease severity ratings at harvest (Brantner and Windels, 2008; Engelkes and Windels, 1996). After inoculation, plots were cultivated to throw soil

into crowns to favor infection by R. solani (Schneider et al., 1982). In all years, the trial was fertilized and managed for optimal yield and quality.

The trials were harvested on 16 September 2010, 14 September 2011, and 10 September 2012. Roots of each variety were rated for disease following a standard RCRR rating scale of 0 to 7 (Ruppel et al., 1979). A rating of 0 = root surface clean with no visible lesions; 1 = superficial, scattered non-active lesions; 2 = shallow, dry rot cankers on $\leq$ 5% of root surface; 3 = deep dry rot cankers at crown or extensive lateral lesions affecting 6-25% root surface; 4 = extensive rot affecting 26-50% of root, with cracks and cankers up to 5 mm deep; 5 = $\geq$ 50 of root blackened with rot extending into interior; 6 = entire root blackened except extreme tip; and 7 = root 100% rotted and foliage is dead. Then, roots of each variety were grouped into five distinct categories: 0 + 1 combined, 2, 3, 4, and 5 (30 roots per disease category and replicate). Roots in categories 6 and 7 were not used because they typically would not be harvested and placed in storage piles. Because of an insufficient number of roots with a rating of 5, the most resistant variety was not included in the 2011 and 2012 analyses.

Harvested roots were promptly transported to Fargo, ND, washed, and placed in perforated plastic bags. The bags were placed on shelves in a room maintained at 40°F and 90-95% relative humidity. Respiration rate was measured 30 and 90 days after harvest (DAH). Sucrose and extractable sucrose concentrations were determined 30 DAH. Invert sugar concentrations were determined 90 DAH. The respiration rate of 10-root samples was determined using an infrared carbon dioxide gas analyzer (LICOR LI-6252) and an open system with continuous airflow over the roots (Campbell et al., 2011). Sucrose concentration and purity were used to calculate extractable sucrose concentration. Sucrose was measured polarimetrically. Purity was determined using the procedures described by Dexter et al. (1967). Invert sugar (glucose + fructose) concentrations were determined colorimetrically using end point, enzyme-coupled assays (Klotz and Martins, 2007) and expressed as grams per 100 grams of sucrose.

RESULTS

Significant variety X disease rating interactions were infrequent. Differences among the varieties were relatively small, compared to the differences associated with disease severity. This suggests that the response of roots with a given disease rating, relative to healthy roots of the same variety, is not influenced by the resistance level of a variety. The results presented in this report are averages of three varieties; only the disease rating main effects are discussed.

Sucrose concentration in roots 30 DAH decreased from 17.3% to 14.3% in 2010, from 17.6% to 13.8% in 2011, and from 18.7% to 13.7% in 2012 as disease ratings increased from 0-1 to 5 (Fig. 1). Differences among sucrose concentrations of roots in categories 0-1 to 3 were relatively small, ranging from 17.3% to 16.9%, from 17.6% to 16.9%, and from 18.7% to 18.5% in 2010, 2011, and 2012, respectively. Roots with a disease rating of 4 had sucrose concentrations (16.2% in 2010, 15.7% in 2011, and 16.7% in 2012) that were less than roots with a 2 or lower disease rating and greater than roots with a disease rating of 5. The response pattern for extractable sugar closely resembled that observed for sucrose concentration. Extractable sugar concentration was impacted by both the decrease in sucrose concentration associated with increasing disease severity and a corresponding decrease in the juice purity values used to calculate extractable sugar. Extractable sugar ranged from 307 pounds ton^{-1} to 241 pounds ton^{-1} (Fig. 1) in 2010, from 310 pounds ton^{-1} to 214 pounds ton^{-1} in 2011, and from 327 pounds ton to 215 pounds ton in 2012. Disease categories 0-1 to 3 ranged from 307 pounds ton^{-1} to 296 pounds ton^{-1}, from 310 pounds ton^{-1} to 294 pounds ton^{-1} and from 327 pounds ton^{-1} to 322 pounds ton^{-1} in 2010, 2011, and 2012, respectively. In 2010, roots with a disease rating of 4 had 276 pounds of extractable sugar per ton while roots with a rating of 5 had 241 pounds ton^{-1}, 66 pounds per ton less extractable sugar than the healthy roots. Roots harvested in 2011 with a disease rating of 4 had 265 pounds ton^{-1} while roots with a rating of 5 had 214 pounds ton^{-1}, 96 pounds per ton less extractable sugar than roots with a 0-1 disease rating. The greatest difference between healthy roots and roots with a disease rating of 4 or 5 occurred in 2012. Roots with a disease rating of 4 had 280 pounds extractable sugar per ton, roots with a 5 rating had only 215 pounds ton^{-1}, 112 pounds ton^{-1} less than roots with a 0-1 rating.

Respiration rates 30 and 90 DAH increased as disease severity increased. In 2010, healthy roots (disease rating = 0 – 1) had a respiration rate of 3.54 mg CO_2 kg^{-1} $hour^{-1}$ 30 days after harvest compared to a respiration rate of 6.27 mg CO_2 kg^{-1} $hour^{-1}$ for roots with a disease rating of 5 and 4.42 mg CO_2 kg^{-1} $hour^{-1}$ for roots with a disease rating of 4 (Fig. 2). Respiration rates 30 days after the 2011 harvest followed a similar pattern; however, the difference

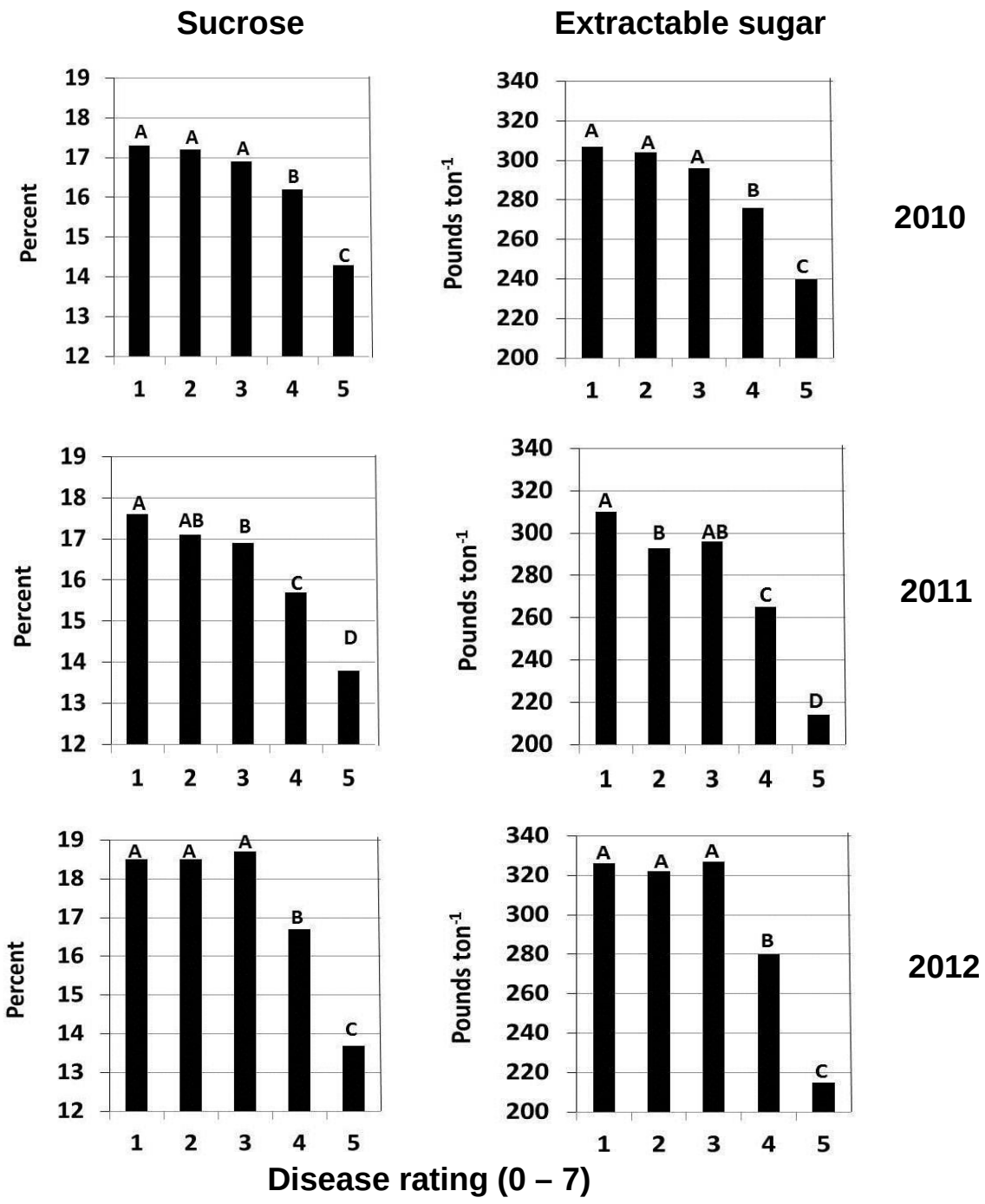

Fig. 1. Sucrose and extractable sugar concentration of roots with Rhizoctonia crown and root rot 30 days after harvest from Crookston, MN, 2010 – 2012. Differences between bars with a common letter are not significant, based upon LSD (P = 0.10).

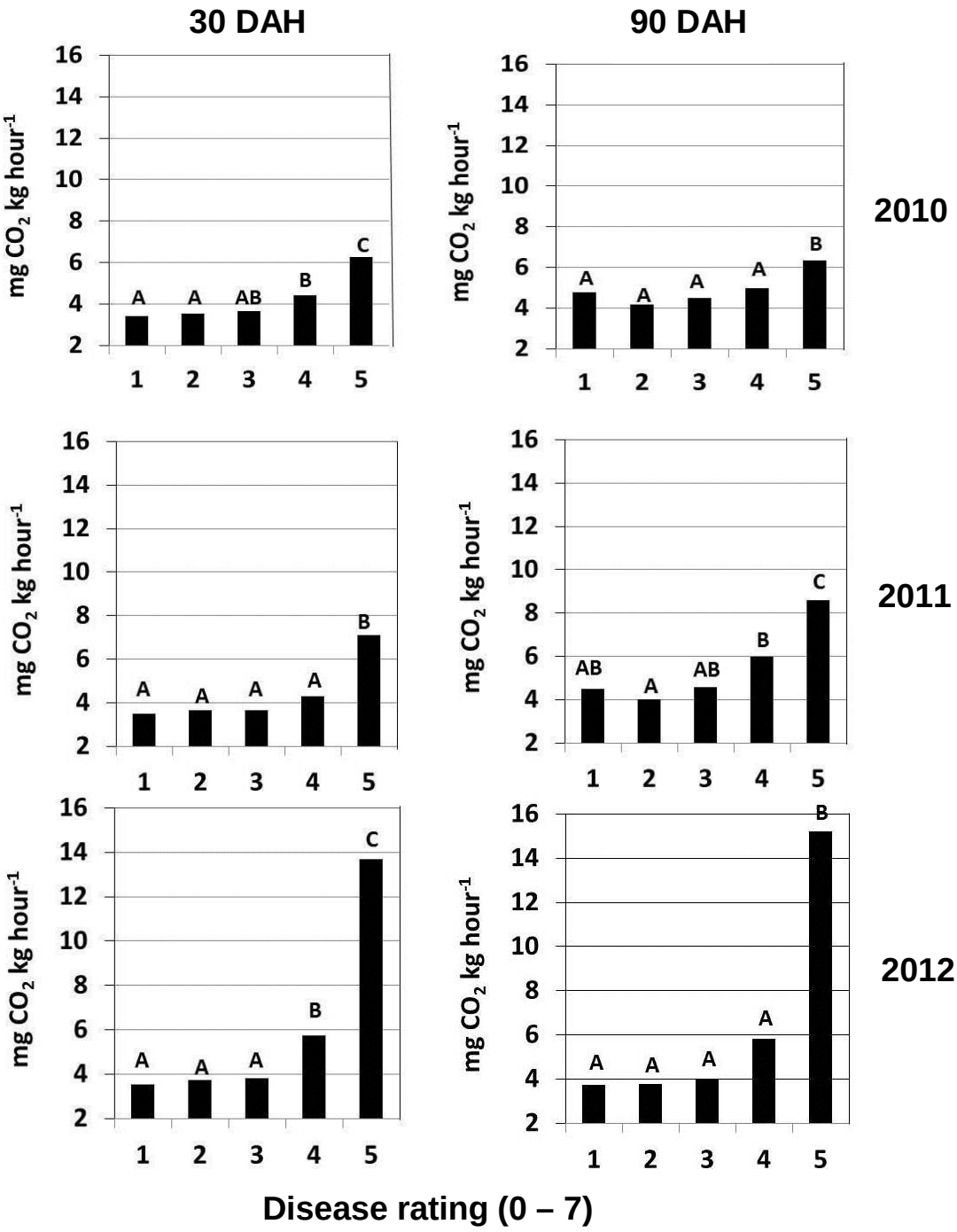

Fig. 2. Respiration rate of roots with Rhizoctonia crown and root rot 30 and 90 days after harvest (DAH) from Crookston, MN, 2010 -2012. Differences among bars with a common letter are not significant, based upon LSD (P = 0.10).

between the healthy roots (3.49 mg CO_2 kg^{-1} $hour^{-1}$) and roots with a disease rating of 5 (7.11 mg CO_2 kg^{-1} $hour^{-1}$) was greater than in 2010. In 2012, the contrast between the respiration rate (3.54 mg CO_2 kg^{-1} $hour^{-1}$) 30 DAH of healthy roots (0-1 rating) and roots with a disease rating of 5 (13.69 mg CO_2 kg^{-1} $hour^{-1}$) was greater than that observed in 2010 or 2011. Respiration rates of roots with a disease rating of 4 were slightly elevated. Differences among roots with ratings of 3 or lower were relatively small 30 DAH in all three years. By 90 DAH, the respiration rate of roots with all disease ratings had increased. Roots with a disease rating of 5 had higher respiration rates (6.33 kg^{-1} $hour^{-1}$ in 2010, 8.82 mg CO_2 kg^{-1} $hour^{-1}$in 2011, and 15.22 mg CO_2 kg^{-1} $hour^{-1}$ in 2012) than all other disease categories, 90 DAH. While the respiration rate of roots with severe RCRR (disease rating = 5) was relatively high compared to roots with no or mild symptoms in all years, it was constant during the 90 days in storage in 2010, and increased slightly between 30 and 90 days in storage in 2011 and 2012. The contrast between relatively healthy roots and roots with severe symptoms was greatest in 2012.

Ninety days after the 2010 harvest, roots with a 0-1 or 2 rating had invert sugar concentrations of 1.52 and 1.75 g/100 g sucrose, respectively (Fig. 3). Invert sugar concentrations increased to 2.34 g/100 g sucrose for roots with a disease rating of 3. The average invert sugar concentrations of roots with a disease rating of 4 was approximately twice (2.96 g/100 g sucrose) that observed for the 0-1 and 2 disease categories. Roots with a 5 disease rating had an average invert sugar concentration of 5.26 g /100 g sucrose, which was 3.5 times the invert sugar concentration of healthy roots (0-1 disease rating). Invert sugar concentrations in 2011 were higher for all disease categories than those observed in 2010 but followed a similar pattern (Fig. 3). Roots with a 0-1 or 2 rating had invert sugar concentrations of 2.86 and 2.28 g/100 g sucrose, respectively. Roots harvested in 2011 with a disease rating of 3 had an average invert sugar concentration of 3.69 g /100 g sucrose. The invert sugar concentration of roots with a four rating (5.05 g/100 g sucrose) was 1.8 times the concentration of roots with 0-1 ratings. Roots with a disease rating of 5 had an average invert sugar concentration of 16.16 g /100 g sucrose, which was 5.6 times the invert sugar concentration of healthy roots (0-1 disease rating). Invert sugar data for roots harvested in 2012 were not available at the time this report was prepared.

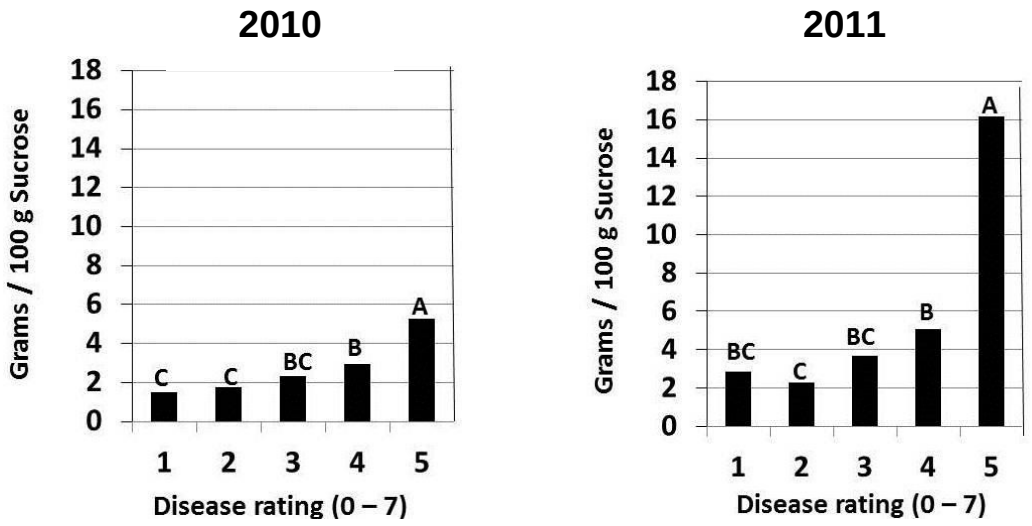

Fig. 3. Invert sugar concentration of roots with Rhizoctonia crown and root rot 90 days after harvest from Crookston, MN, 2010 and 2011. Differences among bars with a common letter are not significant, based upon LSD (P = 0.10).

DISCUSSION

It appears that the negative impact of RCRR on postharvest respiration, sugar concentration, and beet quality for roots with disease ratings of 2 or 3 is relatively small and would have only a small, and maybe immeasurable, effect on factory efficiency when mixed with healthy roots. A high frequency of roots with a disease rating of 5 will likely slow processing and reduce the quantity of sugar produced. The elevated respiration rate of roots with a disease rating of 5, and to a lesser extent 4, indicates that the sugar loss during storage will be relatively high and the temperature increase caused by the high respiration rate may increase losses in nearby healthy roots, if the heat is not dissipated.

The response of stored roots with a given disease rating, relative to healthy roots of the same variety, does not appear to be influenced by the resistance level of the variety. However, it is important to note that resistant varieties frequently will have considerably fewer roots with disease ratings of 4 or above than susceptible varieties, when conditions are favorable for disease development.

Differences in sucrose concentration, quality components, and respiration rates from year to year and differences in the magnitude of the contrast between healthy roots and roots with serve symptoms indicates that environmental conditions during the growing season influences the impact of Rhizoctonia crown and root rot on postharvest losses. It is not known to what extent the varieties included in this study are representative of the resistant and susceptible varieties available. Varietal differences in storage characteristics may be controlled by factors other than the level of RCRR resistance.

CONCLUSIONS

Planting resistant varieties will not only diminish the risk of substantial pre-harvest losses but also is an effective strategy for reducing postharvest storage losses from severe RCRR infection.

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