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

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Rhizotonia 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 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 or 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 differing in resistance 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 with best resistance 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. Seed spacing was 2.4-inchs 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 40g per 30 ft row, respectively) in 2010 and 7 and 9 weeks after planting (28g per 30 ft row) in 2011; 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 both years, the trial was fertilized and managed for optimal yield and quality of sugarbeet.

The trials were harvested on 16 September 2010 and 14 September 2011. 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 disease was so severe that 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 analysis.

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^{o}F and 90-95% relative humidity. Respiration rate was measured 30, 60, and 90 days after harvest (DAH). Sucrose, and extractable sucrose concentrations were determined 30 DAH. Invert sugar concentrations were determined 30 DAH and 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.

We plan to continue this research in 2012. The results presented in this report are averages of the three varieties; only the disease rating main effects are discussed.

RESULTS

Respiration rates 30, 60, 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. 1). Respiration rates 30 days after the 2011 harvest followed a similar pattern; however, the difference 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. 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 both years. The magnitude of the respiration rates and differences among the disease groupings 60 DAH were similar to those observed 30 DAH in 2010. Roots with a disease rating of 0-1 had an average respiration rate of 3.64 mg CO_2 kg^{-1} $hour^{-1}$, compared to 6.02 mg CO_2 kg^{-1} $hour^{-1}$ for roots with a disease rating of 5. In 2011 the respiration rate of roots with a disease rating of 4 increased from 4.31 mg CO_2 kg^{-1} $hour^{-1}$ to 5.75 mg CO_2 kg^{-1} $hour^{-1}$ between 30 and 60 days after harvest while roots with a disease rating of 5 increased from 7.11 mg CO_2 kg^{-1} $hour^{-1}$ to 8.82 mg CO_2 kg^{-1} $hour^{-1}$. 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 and 8.82 mg CO_2 kg^{-1} $hour^{-1}$in 2011) than all other disease categories, 90 DAH. The respiration rate of roots with severe RCRR (disease rating = 5) was relatively high in both years, constant during the 90 days in storage in 2010, and increased between 30 and 60 days in storage in 2011.

Sucrose concentration in roots 30 DAH decreased from 17.3% to 14.3% in 2010 and from 17.6% to 13.8% in 2011 as disease rating increased from 0-1 to 5 (Fig. 2). Differences among sucrose concentrations of roots in categories 0-1 to 3 were relatively small, ranging from 17.3% to 16.9% and from 17.6% to 16.9% in 2010 and 2011, respectively. Roots with a disease rating of 4 had sucrose concentrations (16.2% in 2010 and 15.7% in 2011) that were less than roots with a 3 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

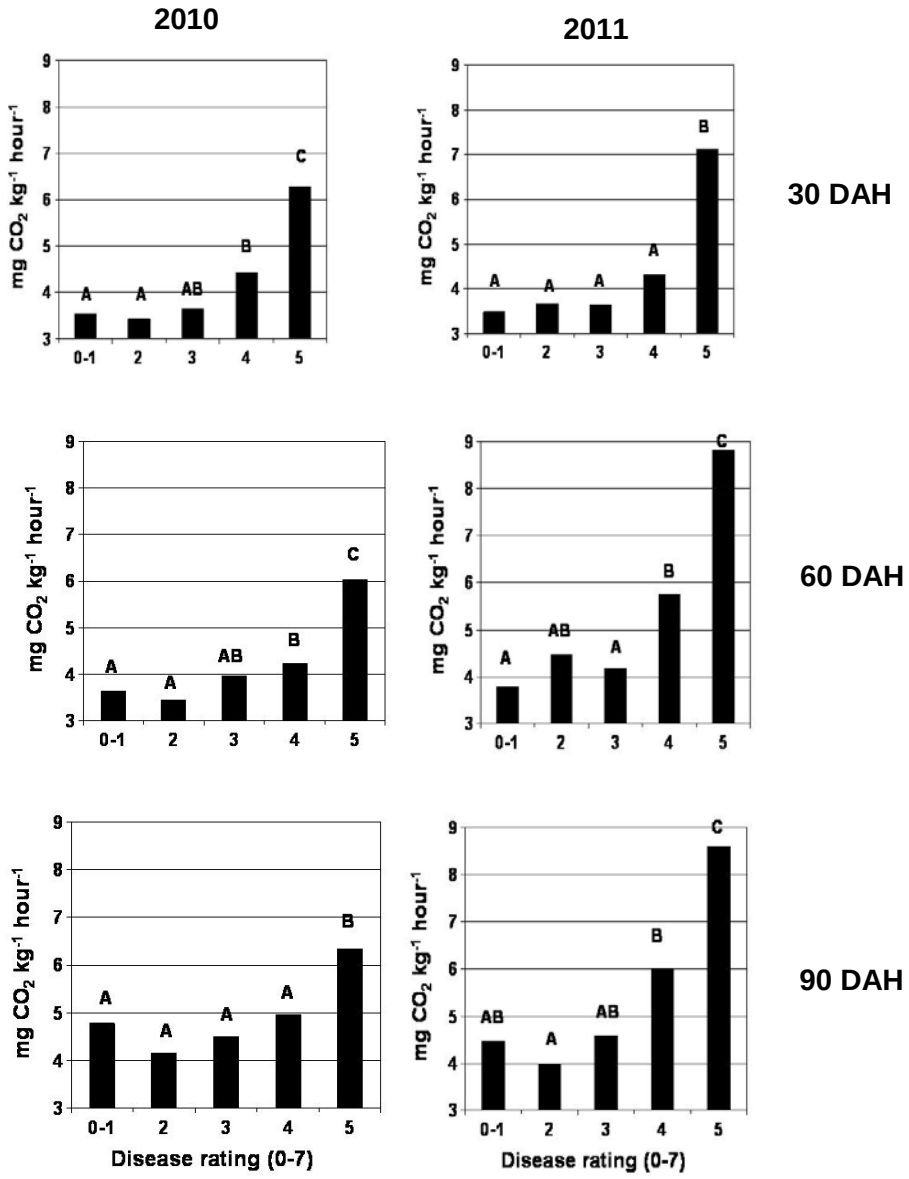

Fig. 1. Respiration rate 30, 60, and 90 days after harvest (DAH) of roots with Rhizoctonia crown and root rot from Crookston, MN, 2010 and 2011.

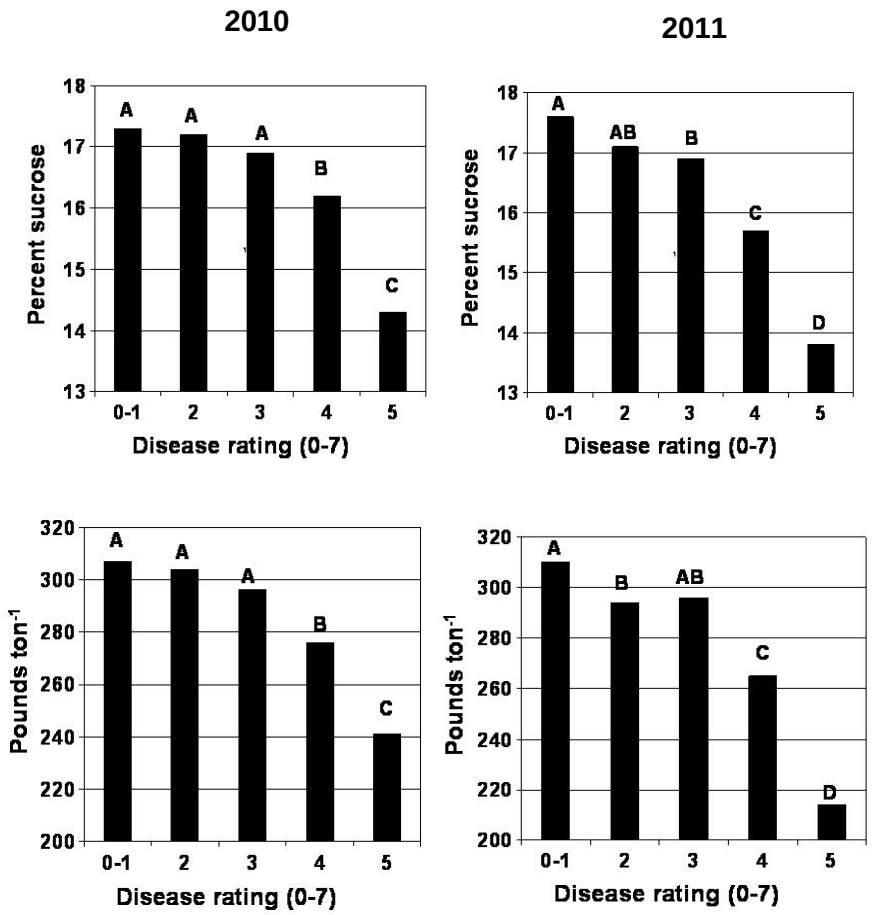

Fig. 2. Sucrose concentration (top) and extractable sugar per ton (bottom) 30 DAH of roots with Rhizoctonia crown and root rot from Crookston MN,2010 and 2011.

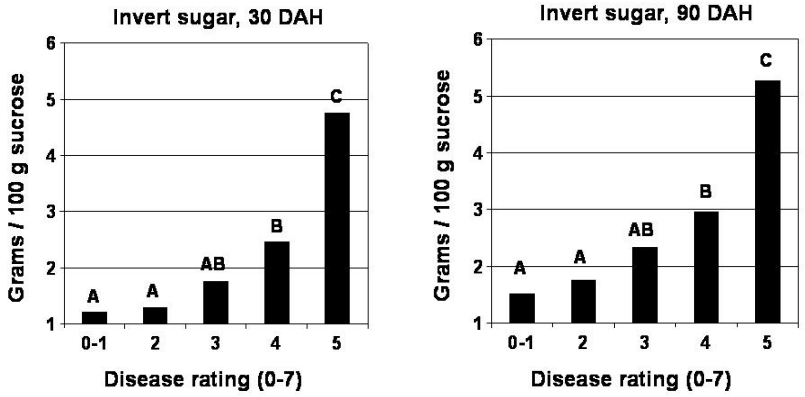

Fig. 3. Invert sugar concentration 30 and 90 days after harvest (DAH) of roots with Rhizoctoni crown and root rot from Crookston, MN, 2010.

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. 2) in 2010 and from 310 pounds ton^{-1} to 214 pounds ton^{-1} in 2011 Disease categories 0-1 to 3 ranged from 307 pounds ton^{-1} to 296 pounds ton^{-1} and from 310 pounds ton^{-1} to 294 pounds ton^{-1} in 2010 and 2011, respectively. In 2010, roots with a disease rating of 4 had 276 pounds of sugar per ton while roots with a rating of 5 had 241 pounds ton^{-1}, 66 pounds 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 less extractable sugar than roots with a 0-1 disease rating.

Thirty days after the 2010 harvest, roots with a 0-1 or 2 rating had invert sugar concentrations of 1.23 and 1.30 g/100 g sucrose, respectively (Fig. 3). Invert sugar concentrations increased to 1.76 for roots with a disease rating of 3. The average invert sugar concentrations of roots with a disease rating of 4 was approximately twice (2.47 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 4.76 g /100 g sucrose, which was 3.8 times the invert sugar concentration of healthy roots (0-1 disease rating). The invert sugar concentration of all disease groups increased during storage, but the relationships between the groups was similar to that observed 30 DAH. After 90 days in storage, roots with a 0-1 disease rating had an invert concentration of 1.52 g /100 g sucrose, compared to an invert sugar concentration or 5.26 g /100 g sucrose for roots with a disease rating of 5. Invert sugar data for the roots harvested in 2011 were not available at the time this report was prepared.

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.

CONCLUSIONS

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 quality of the 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. Thus planting resistant varieties is an effective strategy for reducing postharvest storage losses from severe RCRR infection.

The results presented in this report are preliminary, so caution should be exercised when making decisions based upon these results. Additional data are needed to determine the extent environmental conditions during the growing season may influence the results. Also, it is not known if 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.

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