POSTHARVEST RESPIRATION RATE AND SUCROSE CONTENT 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 14.15% sucrose content, respectively and after 30 days in storage, respiration rates were 3.46 and 9.34 mg CO^2/kg/hour, 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 (Aphanomyces root rot, *Beet necrotic yellow vein virus* = Rhizomania, 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 degrade to colored compounds which hinder 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 addition information to develop strategies that minimize losses during storage of diseased roots or determine when fields should be abandoned.

OBJECTIVES

Research objectives were to determine the impact of RCRR on postharvest respiration rate, sucrose concentration, and processing quality of three sugarbeet varieties differing in resistance when roots were: 1**)** grouped into distinct disease categories ranging from healthy to severe, and 2) mixed in various proportions of healthy and diseased roots.

MATERIALS AND METHODS

Three commercial sugarbeet varieties (susceptible, moderately resistant, and most RCRR resistant variety available) were planted on May 10, 2010 in a trial at the University of Minnesota, NWROC. Seed was sown at a 2.4-inch spacing in rows 30 ft long and 22 inches apart. Plots were thinned to the equivalent of 175 plants per 100-ft row on June 7. The experiment was arranged in a split plot design, with variety as a main plot and times of inoculation as subplots; each treatment consisted of 6-rows and was replicated 4 times. Varieties were inoculated with *R. solani*-infected ground barley grain applied 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); a non-inoculated control was included for each variety. The various times of inoculation were done 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*. The trial was fertilized and managed for optimal yield and quality of sugarbeet.

The trial was harvested on September 16th. 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 dead. Roots of each variety from a single replicate were grouped into five distinct categories: 0 and 1 combined 2, 3, 4, and 5 (30 roots per sample). Roots in categories 6 and 7 were excluded because they typically would not be harvested. For each variety, healthy and diseased roots also were combined in various proportions of 0, 10, 20, 40, 60, 80 and 100% diseased. The healthy category combined roots rated as 0 and 1 and the diseased category combined roots rated as 3, 4, and 5 (10 roots per sample).

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, extractable sucrose, and invert sugar concentrations were determined 30 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-coupled assays (Klotz and Martins, 2007) and expressed as grams per 100 grams of sucrose.

Sucrose, extractable sucrose, and invert sugar concentration data for 90 DAH were not available at the time this report was prepared, but will be included in subsequent reports. Repetition of this research in 2011, and possibly in 2012 is also planned. Because the results summarized in this preliminary report are from a single trial and the data for 90 DAH is incomplete, the results presented in this report are averages of the three varieties; only the disease rating main effects are discussed in detail.

RESULTS

Disease Categories:

Respiration rates 30, 60, and 90 DAH increased as disease severity increased. Respiration rates of roots with a disease rating of 4 were slightly elevated and differences among roots with ratings of 3 or lower were relatively small. The respiration rate of roots with severe RCRR (disease rating = 5) was relatively high and constant during the 90 days in storage. Thirty days after harvest, healthy roots (disease rating = 0 – 1) had a respiration rate of 3.54 mg CO_2 kg^{-1} $hour^{-1}$, compared to a respiration rate of 6.27 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). The magnitude of the respiration rates and differences among the disease groupings 60 DAH were similar to those observed 30 DAH. 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. By 90 DAH the respiration rate of roots with disease ratings of 0-1 to 4 had increased. The increased respiration rate as disease ratings increased from 2 to 4 and differences among roots with a 0-1 rating and roots with disease ratings less than 5 were not significant. Roots with a disease rating of 5 had higher respiration rates (6.33 mg CO_2 kg^{-1} $hour^{-1}$) than all other disease categories, 90 DAH.

Sucrose concentration 30 DAH decreased from 17.3% to 14.3% as disease rating increased from 0-1 to 5 (Fig. 1). Differences among sucrose concentrations of roots in categories 0-1 to 3 were not significant and ranged from 17.3% to 16.9%. Roots with a disease rating of 4 had a sucrose concentration (16.2%) that was less than roots with a 3 or lower disease rating and higher 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 impact 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). Disease categories 0-1 to 3 ranged from 307 to 296 pounds ton^{-1}. 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.

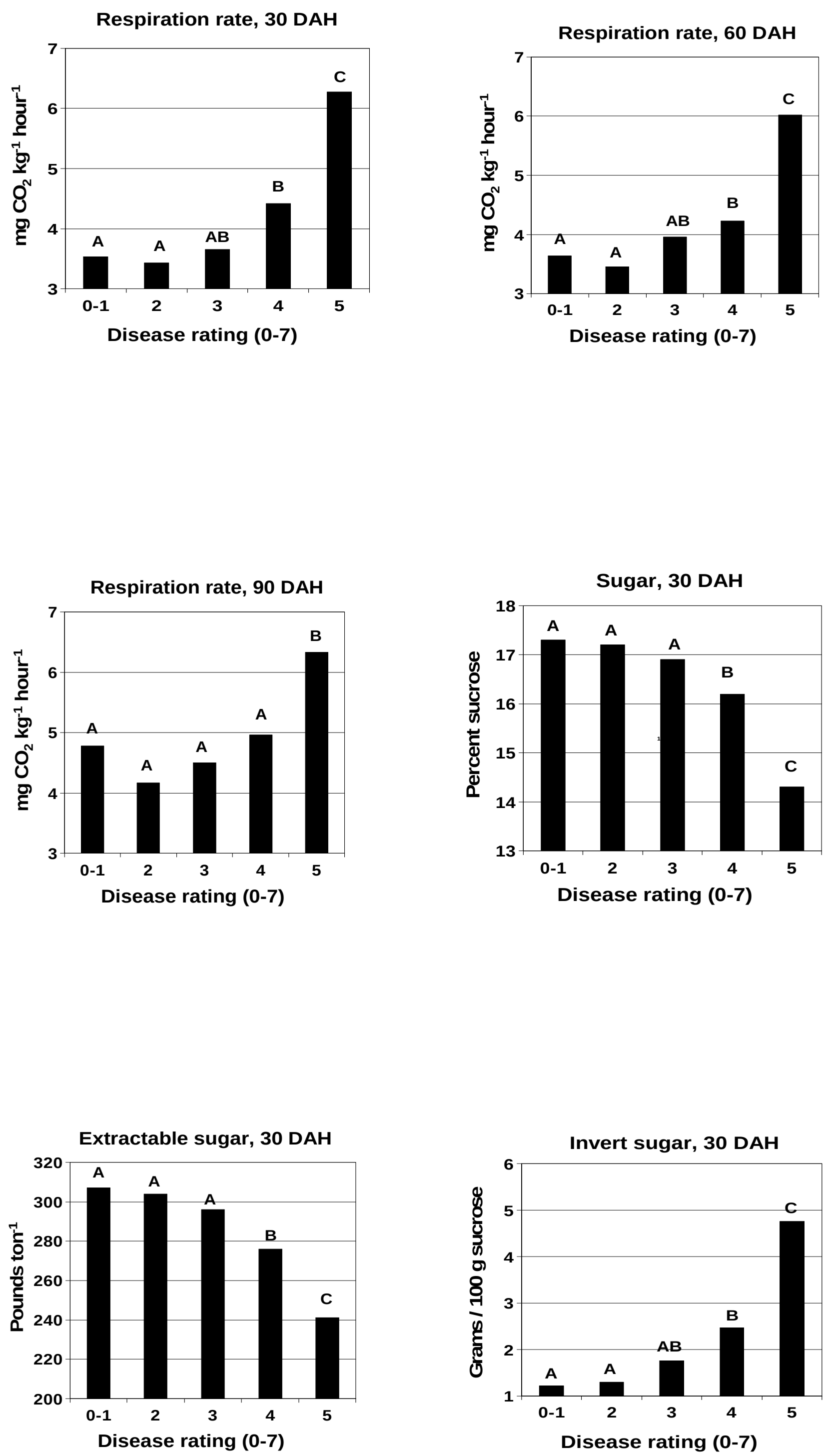

Fig. 1. Respiration rate 30, 60, and 90 days after harvest (DAH) and, sucrose, extractable sugar, and invert sugar concentration 30 DAH of roots with Rhizoctonia crown and root rot from Crookston, MN, 2010.

Roots with a 0-1 or 2 rating had invert sugar concentrations of 1.23 and 1.30 g/100 g sucrose, respectively (Fig. 1). 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).

Significant variety X disease rating interactions were indicated for respiration rate 60 DAH and sucrose, extractable sugar, and invert sugar concentrations 30 DAH. Differences among the varieties were relatively small for healthy roots, compared to the corresponding differences when roots with high disease ratings were examined. In general, roots of the susceptible variety with a disease rating of five tended to have higher respiration rates and invert sugar concentrations and lower sucrose and extractable sugar concentrations than roots with a rating of 5 from the resistant variety. With the limited data available at this time, all interactions should be considered tentative until confirmed by additional trials and with a different set of resistant and susceptible varieties.

Healthy / diseased root mixtures.

Extractable sugar concentration decreased and invert sugar concentration increased as the frequency of diseased roots increased. Each percentage increase in the frequency of diseased roots in a sample was accompanied by a 0.43 pound ton^{-1} decrease in extractable sucrose and a 0.01 g/100 g sucrose increase in invert sugar, 30 DAH (Fig. 2). As expected, the samples with all healthy roots (0% diseased) had extractable sucrose and invert sugar concentrations very similar to roots in the 0-1 disease category when roots were grouped by disease severity (Fig. 1). Roots with ratings of 3 to 5 were randomly selected to produce the desired ratios of healthy to diseased roots, so the observations for 100% diseased roots are not as extreme as those reported for roots with a disease rating of 5.

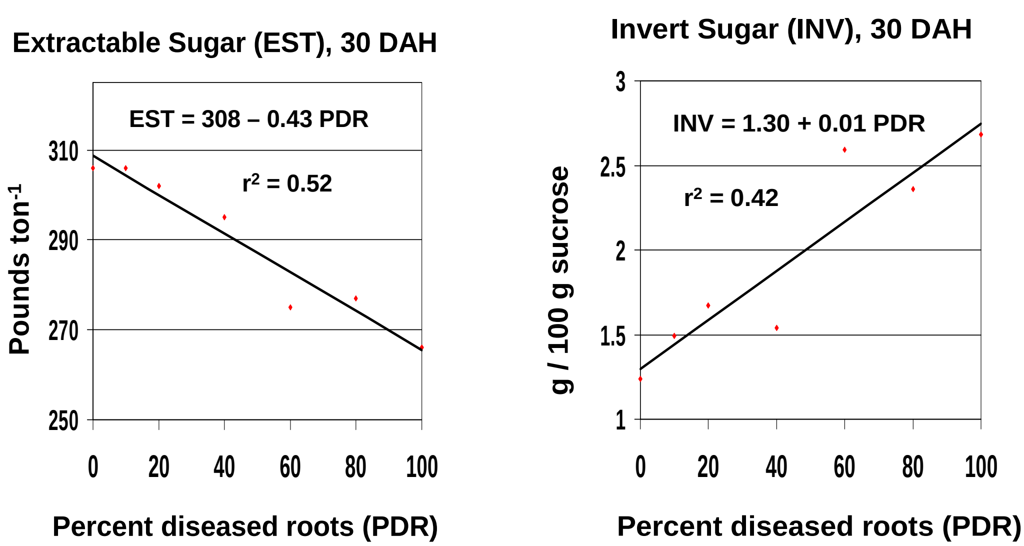

Fig. 2. Extractable sugar and invert sugar concentration of mixtures of healthy and diseased (Rhizoctonia crown and root rot) roots 30 DAH, Crookston, MN, 2010.

DISCUSSION

In summary, it appears that the negative impact of RCRR on postharvest respiration, sugar concentration, and beet quality for roots with disease ratings of two or three are 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. Extractable sugar and invert sugar concentration of roots stored for 90 days will provide some insight into the relationship between RCRR severity and losses during storage. The 90 DAH results will be especially relevant for making decisions regarding long-term storage of roots with RCRR.

The results presented in this report are from a single trial so caution should be exercised when making decisions based upon these preliminary results. Additional observations are needed to determine if this year's results are unique due to specific environmental conditions or typical of what one would expect in most environments. 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.

ACKNOWLEDGEMENTS

We thank American Crystal, BetaSeed, and Hilleshog for providing seed; University of Minnesota, Northwest Research and Outreach Center, Crookston for providing land, equipment and other facilities; Todd Cymbaluk and Jeff Nielsen for plot maintenance; student workers Chloe Danielson, Katie Baird, and Chelsie Solheim for technical assistance; and Nyle Jonason, John Eide, and Joe Thompson for technical assistance with the respiration, sugar, and quality assessments.

LITERATURE CITED

Brantner, J.R. and C.E. Windels. 2008. Comparison of inoculation techniques for assessing sugarbeet variety resistance to Rhizoctonia root and crown rot. Sugarbeet Res. Ext. Rept. 38:266-271.

Campbell, L.G., K.K. Fugate, and W.S. Niehaus. 2011. Fusarium yellows affects postharvest respiration rate and sucrose concentration in sugar beet. J. Sugar Beet Res. 48: (In press).

Campbell, L.G. and K.L. Klotz, 2006a. Postharvest storage losses associated with Aphanomyces root rot in sugarbeet. J. Sugar Beet Res. 43:113-127.

Campbell, L.G. and K.L. Klotz, 2006b. Storage. p. 387-408. *In* A.P. Draycott (ed.) Sugar Beet. Blackwell Publishing. Ltd., Oxford, UK.

Campbell, L.G., K.L. Klotz, and L.J. Smith. 2008. Postharvest storage losses associated with rhizomania in sugar beet. Plant Dis. 92:575-580.

Dexter, S.T., M.G. Frakes, and F.W. Snyder. 1967. A rapid and practical method of determining extractable white sugar as may be applied to the evaluation of agronomic practices and grower deliveries in the sugar beet industry. J. Am. Soc. Sugar Beet Technol. 14: 433-454.

Dutton, J., and T. Huijbregts. 2006. Root quality and processing. p. 409-442. *In* A.P. Draycott (ed.) Sugar Beet. Blackwell Publishing. Ltd., Oxford, UK.

Engelkes, C.A., and Windels, C.E. 1996. Susceptibility of sugar beet and beans to *Rhizoctonia solani* AG-2-2 IIIB and AG-2-2 IV. Plant Dis. 80:1413-1417.

Klotz, K.L., and L.G. Campbell. 2009. Effects of Aphanomyces root rot on carbohydrate impurities and sucrose extractability in postharvest sugar beet. Plant Dis. 93:575-580.

Klotz, K.L., and D.N. Martins. 2007. Microplate assay for rapid determination of sucrose glucose, fructose, and raffinose. J. Sugar Beet Res. 44: 169-170.

Lumley, M. and S. Poindexter. 2008. 2008 Rhizoctonia quality experiment. p. 33-34. *In* Sugarbeet Advancement: On Farm Research and Demonstrations. Sugar Beet Growers, Michigan Sugar Growers, Michigan State University, Agribusiness.

Ruppel, E.G., C.L. Schneider, R.J. Hecker, and G.J. Hogaboam. 1979. Creating epiphytotics of Rhizoctonia root rot and evaluating for resistance to *Rhizoctonia solani* in sugarbeet field plots. Plant Dis. Rep. 63:518-522.