ETHYLENE PRODUCTION AND ITS EFFECT ON STORAGE RESPIRATION RATE IN WOUNDED AND UNWOUNDED SUGARBEET ROOTS

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Ethylene is a natural plant hormone that induces respiration in most plant tissues and organs. Ethylene is produced endogenously by most postharvest plant organs and exogenously by many bacterial and fungal pathogens (Fukuda et al., 1993; Kay, 1997; Qadir et al.,1997). Endogenous ethylene production is controlled by developmental cues and, in many plant tissues, is strongly stimulated by mechanical injury and other stresses including chilling and low oxygen conditions (Yang and Hoffman, 1984). Although it is expected that sugarbeet roots produce measurable quantities of ethylene and that their respiration rate is induced by ethylene, ethylene production and its effect on respiration rate in postharvest sugarbeet roots has not been previously quantified. Here, we describe a series of experiments that were conducted to (1) quantify ethylene production in wounded, unwounded and conventionally harvested sugarbeet roots, (2) determine the effect of ethylene on storage respiration rate, and (3) determine the effect of ethylene synthesis and response inhibitors on basal and wound-induced respiration.

Ethylene production by sugarbeet roots

Unwounded sugarbeet roots produce low levels of ethylene (Fig. 1a). During the four days after harvest, gently hand-harvested roots produced, on average, 0.17 nmol kg^{-1} h^{-1} ethylene. Severe injury to roots induced a 4 to 6-fold increase in ethylene production in the four days following wounding. Concurrent with the increase in ethylene in wounded roots, root respiration rate was elevated (Fig 1b). Respiration rate in wounded roots was elevated 1.5 and 2.0-fold 72 and 96 h after wounding, relative to unwounded roots.

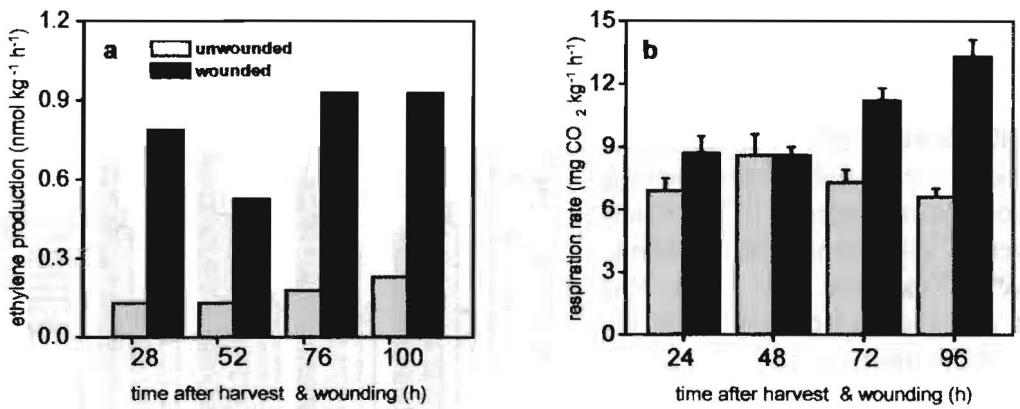


Figure 1. Ethylene production (a) and respiration (b) of greenhouse-grown roots, harvested 17 wk after planting, at 10°C. Following harvest, roots were severely wounded by tumbling 30 min in a pilot scale beet washer, causing bruising and surface abrasions. Error bars = SE of the mean. n = 2 and n = 6 for ethylene and respiration measurements, respectively.

In commercial sugarbeet piles, ethylene concentrations were less than 2 ppb during the first 21 d after piling in both a ventilated and a nonventilated pile (Fig. 2). Despite root injury due to harvest and piling operations, conventionally harvested and piled roots produced ethylene at a rate similar to the unwounded roots described above (data not shown). Beginning 31 and 67 d after piling, ethylene levels increased in the nonventilated and ventilated piles, respectively. The source of elevated ethylene levels after storage for 1-2 months is unknown, but may be due to ethylene production by pathogens.

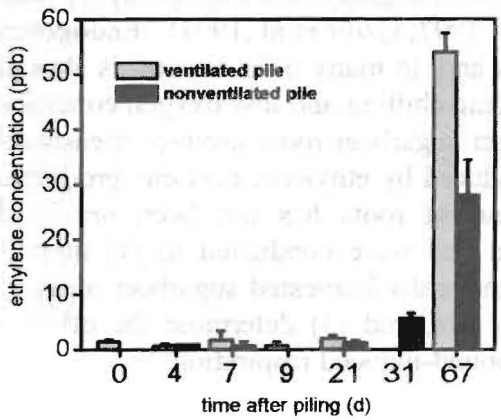
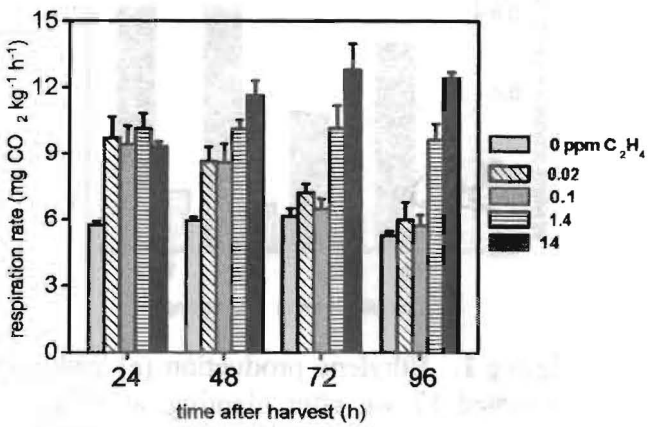


Figure 2. Ethylene concentrations in air samples collected at a depth of 1.5 m from a ventilated, 32 ft (9.8 m) pile and a nonventilated 18 ft pile (5.5 m) in Moorhead, MN. No data was collected for the nonventilated pile 0 and 9 d after piling. Ethylene concentrations in the ventilated pile 31 d after piling were below limits of detection. Data are mean ± SE of the mean (n = 3).

Effect of exogenous ethylene on root respiration rate

To determine whether ethylene increases storage respiration in postharvest sugarbeet roots, gently hand-harvested sugarbeet roots were exposed to ethylene at concentrations of 0 to 14 ppm (Fig. 3). Ethylene concentrations of 0.02 and 0.1 ppm caused a transient, 60% increase in respiration rate after 24 and 48 h of exposure to ethylene. Ethylene concentrations of 1.4 and 14 ppm elevated root respiration rate for at least 4 d. On average, respiration rate was elevated 73% by 1.4 ppm ethylene and 100% by 14 ppm ethylene.

Figure 3. Respiration rate of greenhouse-grown roots exposed to varying concentrations of ethylene, at 10°C. Roots were harvested 18 wks after planting. Roots were exposed to ethylene throughout the 4 d experiment. Data are mean ± SE of the mean (n = 3).



Effect of ethylene synthesis and response inhibitors on wound respiration

To determine the role of ethylene in wound-induced respiration in postharvest roots, respiration rates were determined in wounded and unwounded roots after treatment with ethylene synthesis and response inhibitors, and compared to that of untreated wounded and unwounded roots. The ethylene synthesis inhibitor, aminoethyoxyvinylglycine (AVG) prevented ethylene production in wounded roots (Fig. 4a) and attenuated the increase in wound-induced respiration by 38, 54 and 58% after 48, 72, and 96 hours after harvest and wounding (Fig. 4b). The reduction, but not the elimination of a respiratory increase due to wounding, suggests that ethylene has a role in the increase in respiration due to wounding, but is not solely responsible for the respiratory increase.

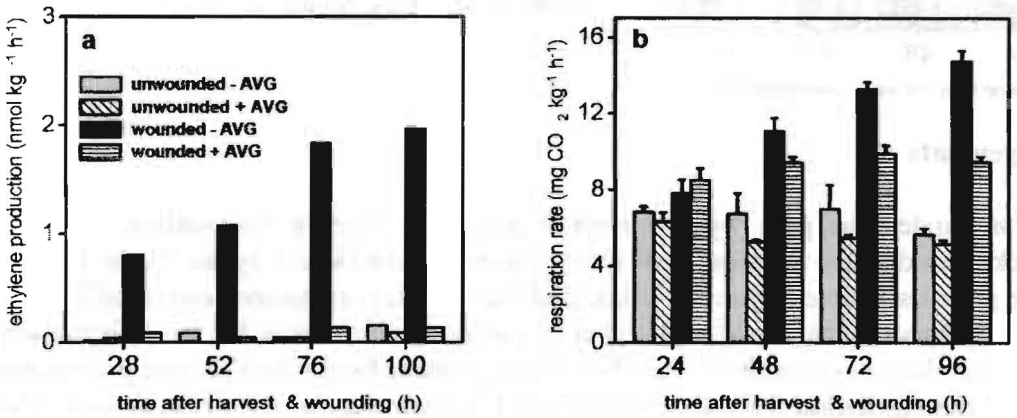


Figure 4. Ethylene production (a) and respiration rate (b) at 10°C of wounded and unwounded greenhouse-grown roots, 18 wk after planting, with and without treatment with 50 µM aminoethoxyvinylglycine (AVG). Wounded roots were severely bruised and abraded by tumbling 30 min in a pilot scale beet washer. Inhibitor treatments were administered after wounding by submerging roots for 1 h in aerated water or AVG solution. Error bars = SE of the mean. n = 2 and n = 3 for ethylene and respiration measurements, respectively.

Similar to AVG, the ethylene response inhibitor, silver thiosulfate (STS), attenuated the increase in respiration due to wounding (Fig. 5). Wound-induced respiration was reduced 60% by STS treatment 72 and 96 h after harvest and wounding. Similar experiments were conducted with the ethylene response inhibitor, 1-methylcyclopropene (MCP). However, no consistent results could be obtained with this compound, despite repeated efforts.

Materials and methods

All experiments were conducted with sugarbeet hybrid Beta 6225. Respiration was determined with an infrared CO_2 gas analyzer (Haagenson et al., 2006). Ethylene was determined by GC analysis (Suttle, 2003). Details for individual experiments are described in figure captions. All

experiments described, except the measurement of ethylene levels in commercial piles, were repeated. In repeated experiments, similar results were obtained.

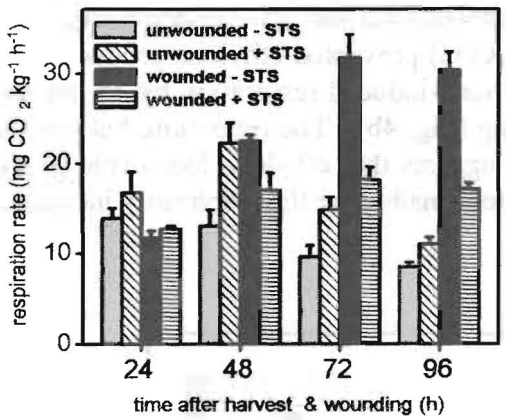


Figure 5. Respiration rates of wounded and unwounded greenhouse-grown roots, 18 wk after planting, with and without treatment with 4 mM silver thiosulfate (STS) at 10°C. Wounded roots were severely bruised and abraded by tumbling 30 min in a pilot scale beet washer. STS treatment was administered after wounding by briefly immersing root tissue in STS solution. Data are mean ± SE of the mean (n = 3).

Acknowledgements

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