Discovery & Development of a New Class of Potato Sprout Inhibitors

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Background

Sprout inhibition during long term storage of potatoes is required to preserve fresh weight, dry matter, processing quality, and consumer acceptability. In Washington State alone, an estimated 4.6 billion pounds of stored potato tubers are treated with sprout inhibitor annually. Currently, the most widely used and effective compound registered for this purpose is the carbamate herbicide, CIPC (isopropyl *N*-(3-chlorophenyl) carbamate). In recent years, the EPA has lowered tolerance levels for CIPC residue on potatoes and tolerance levels in many export markets are substantially lower than in the U.S., requiring more frequent applications of CIPC at lower concentrations to maintain sprout inhibition. Alternative inhibitors for prolonged sprout control are thus being investigated. Biological alternatives to CIPC, such as clove oil and 1,4-dimethylnaphthalene, are available; however, the duration of sprout control is relatively brief with these agents, requiring multiple applications to achieve season-long sprout control.

We have discovered a new chemistry (α,β-unsaturated carbonyl compounds) for the suppression of sprouting in potato tubers. Small scale studies have demonstrated that full season sprout control (7-9 months) can be effectively achieved with 2-3 applications of α,β-unsaturated carbonyl compounds having the general structure shown below (Fig. 1).

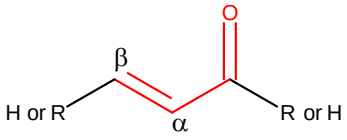

Fig. 1. General structure of an α,β-unsaturated carbonyl.

Many compounds containing this specific arrangement of functional groups are biological in origin. For example 6- to 10-carbon trans-2-aldehydes and ketones are components of the aroma and flavor of fruits, vegetables, and some mushrooms. Numerous compounds of this chemical family are approved for use as food flavoring additives in the U.S., Canada, EU, and Japan.

Efficacy

Research with the 9- and 10-carbon ketones has demonstrated that the duration of inhibition of sprouting depends on the timing of application, cultivar, and storage temperature. Maximum efficacy is achieved when applied after dormancy break when sprouts are peeping (Fig. 2). This is in contrast to CIPC, which must be applied prior to sprouting when tubers are dormant. Hence, the 'window of application' for the new inhibitors is narrower than for CIPC, demanding greater diligence to application timing for maximum efficacy. Using these compounds to control sprouting thus leverages the natural dormancy period of a particular cultivar.

The α,β-unsaturated carbonyls are volatile and can be fogged into commercial storages using conventional fogging equipment. Unlike CIPC and several other commercially available inhibitors, maintaining minimum residue levels is not important for efficacy of these compounds. Residue levels decline rapidly in tubers when ventilated with fresh air and residues are barely detectable three weeks after treatment. The precipitous decline in residue levels is due to high volatility of the compounds combined with their rapid metabolism to saturated aldehydes, ketones and ultimately alcohols.

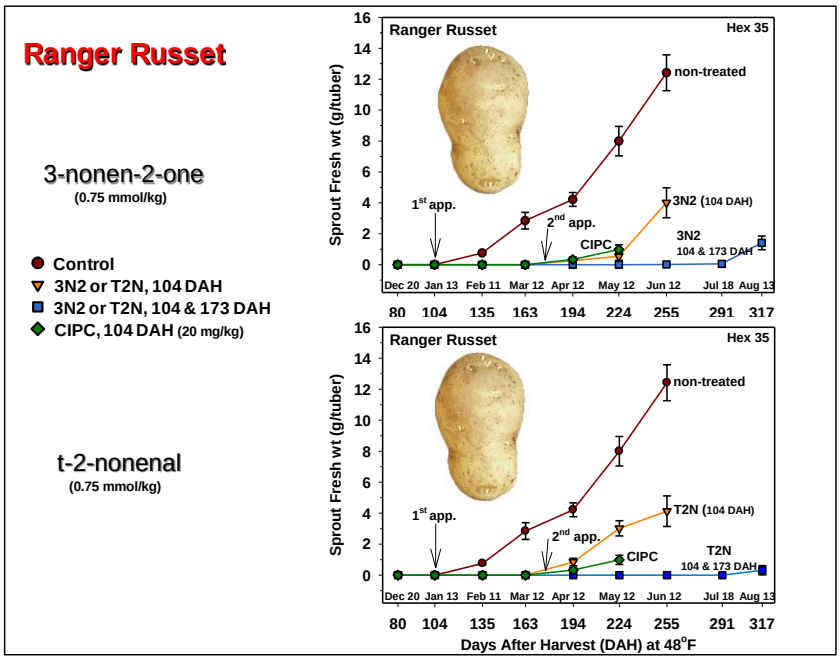

Fig. 2. Effects of single and dual applications of 3N2 (top) and T2N (bottom) on sprouting of Ranger Russet potatoes. Tubers were grown at Othello, WA and harvested October 1. Tubers were wound healed for ~10 days at 55°F and subsequently held at 48°F for the duration of storage. Timing of the first and second applications of sprout inhibitors were 104 and 173 days after harvest (DAH), respectively (arrows). CIPC was applied in a single application only. Tubers were treated for 24 h. Inset tubers show the extent of sprout development at the time of treatment.

Physiological Responses & Mode of Action

Meristematic tissues (buds) are most sensitive to being injured by the α,β-unsaturated carbonyl compounds. Sprouting tubers respond to treatment with a concentration-dependent transitory increase in respiration rate; a response that likely reflects injury to the developing sprouts. Tuber respiration rate then decreases progressively to pre-treatment levels within 7 to 10 days. Cells within sprouts experience a rapid loss of membrane integrity and increased peroxidation of membrane lipids, which results in oxidative stress. The metabolic pathways responsible for neutralizing reactive oxygen species and controlling cellular redox potential (e.g. glutathione system) are directly compromised by these compounds. The loss of membrane function, rapid water loss, and reduced ability to neutralize reactive oxygen species and modulate cellular redox potential collectively leads to unabated oxidative stress, cell death and tissue necrosis. Sprouts thus exhibit a "burnt out" appearance within 24 h of exposure to α,β-unsaturated carbonyl compounds (Fig. 3).

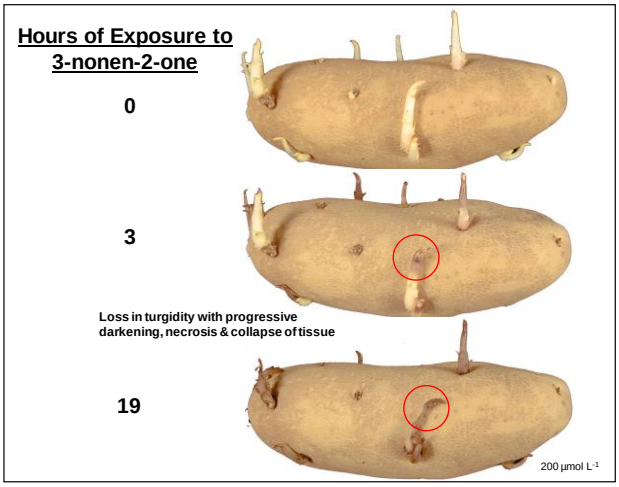

Fig. 3. Visible symptoms of the toxicity of 3-nonen-2-one (3N2) to sprouts. A sprouting tuber was exposed to 3N2 vapors for 19 h. Sprouts begin to darken within 3 h of exposure with accompanying loss of turgidity, starting at the sprout apex and moving downward. The progressive loss in turgidity results in collapse of tissue by 19 h. These symptoms are a primary consequence of reduced membrane integrity.

Current Status of Commercialization

WSU licensed the sprout inhibitor technology to AMVAC Chemical Corporation in 2005. Many compounds were screened for efficacy and ease of manufacture from 2005-07. Proof of concept studies were completed for the 10-carbon ketone (3 decen-2-one) in 2007 and a manufacturing method has been optimized. This compound, originally coded as AMV-1018, has been trademarked for commercial use as SmartBlock™. U.S. and Canadian registrations are pending. Registrations in Japan and the EU are being pursued. The following treatment strategy is based on results of trials in the U.S., France, Germany, Japan and the UK:

- Make first application as a thermal fog when potatoes show signs of breaking dormancy.
- 75% "peeping" is the preferred timing window.
- Recirculation should be for 24 hrs.
- Meristematic sprout tissue is destroyed & the initial effect lasts 2-3 months, depending on variety & temperature.
- Typically 2-3 applications will be required over a 7- to 9-month storage season.
- Sprouts up to 1 inch can be destroyed; hence, SmartBlock™ can be used to restore marketability (i.e. "rescue") sprouted tubers (Fig. 4).

Fig. 4. Sprouted Russet Burbank tubers were treated with 115 ppm SmartBlock™ for 24 h. Photo was taken 12 days after treatment. Tubers were stored at 61°F.