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ST 02: Efficacy of Potato Sprout Control Products to Minimize Sprout Production

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Contents

In response to a request by the NAPPO Potato Panel, the Potato Sprout Inhibitors (PSI) Technical Advisory Group (TAG) has prepared this science paper to examine potato sprout inhibitors according to terms of reference provided by the Panel (Appendix 1). This paper includes a compilation of the existing information about the sprout inhibition products and methods currently available in the three NAPPO nations as well as products known to be under development.

Introduction

Tubers of the potato (*Solanum tuberosum* L.) can remain suitable for consumption or processing through long periods of storage after harvest. Long storage life has helped to make potato tubers one of the most important foods worldwide, and enables the potato processing industry to operate year-round in locations where potatoes can only be produced during a favorable growing season. Botanically speaking, potato tubers are a perennation structure which becomes dormant to survive non-favorable (e.g. cold) growing conditions in order to produce a new plant and another crop of tubers when favorable weather returns.

The biological advantage for a dormancy period in a plant is survival of the species. The inherent dormancy of potatoes allows most varieties to survive winter (barring freezing conditions) and to resprout later, thereby reproducing and perpetuating the species. Tuber dormancy prevents sprouting, reducing chances of the potatoes being killed by unfavorable winter conditions. The tubers have apical and lateral buds or "eyes", comprised of meristematic tissue which can produce sprouts and grow into a new plant under favourable conditions. The tuber dormancy period allows many months of storage without application of a sprout control product.

There are three classes or types of dormancy that can be described in potatoes. "Endodormancy" occurs after harvest and is due to the internal or physiological status of the tuber. In this situation, even if tubers are placed in conditions favorable for sprout development, sprouting will not occur. "Ecodormancy" is when sprouting is prevented or delayed by environmental conditions, for example, potatoes stored at lower temperatures remain dormant longer than similar potatoes stored at warmer temperatures. "Paradormancy" is comparable to endodormancy although the physiological signal for dormancy originates in a different area of the plant than where the dormancy occurs. An example of this is apical dominance of a tuber—the apical meristem or dominant bud/eye impedes development of secondary bud or sprout development. Some varieties have stronger paradormancy than others. The growing season or pre-harvest conditions can also affect dormancy length as well as post-harvest conditions such as temperature and light.

At harvest, potato tubers are dormant, and remain dormant for several weeks or months depending on the cultivar. The tubers remain alive, i.e. the tuber tissues continue to respire and undergo various metabolic processes, but the eyes are temporarily unable to sprout. The progression from dormant to non-dormant during the storage term is part of the physiological ageing process. The rate of physiological ageing varies among varieties, and is more rapid at warm temperatures than at cooler temperatures. When tubers reach the non-dormant phase of their physiological age, they become capable of producing sprouts which can grow into a new potato plant and provide another crop of tubers to complete the growth cycle. If the natural duration of tuber dormancy is shorter than the desired period of storage, the tubers will sprout during storage. This reduces their quality for marketing, processing and consumption. Therefore several methods and product applications have been developed to delay or prevent sprouting.

In the potato industry, control of sprouting is usually focussed on "sprout inhibition" for some appropriate period of time until the stored tubers can be either processed into a saleable product or marketed as whole tubers for fresh consumption. Sprout control products can be categorized into sprout inhibitors or sprout suppressants. The duration of sprout control is greater with a sprout inhibitor and the product may alter the physiological and biochemical status of the tuber. A sprout suppressant is a transient sprout control method which may require multiple applications for long-term control.

Rendering potato tubers permanently unable to sprout is more complex than simply controlling sprouting for a desired period of time. Several products and treatments are currently available for inhibiting or suppressing potato sprouting, and other products are known to be in various stages of development. These sprout control products are described in the following section; their regulatory status is summarized in Appendix 2, including application rates and maximum residue limits (MRL).

1. Sprout Control Products and their Efficacy

Efficacy varies greatly among the various sprout control methods, and it is also affected by several other factors. These other factors include potato variety, environmental and physiological conditions during crop growth and tuber storage, and the rate, timing and number of applications of the particular sprout control product. The inherent dormancy duration of the tubers also varies substantially among varieties, and growth of any sprouts which appear is further influenced by storage temperature, storage conditions, handling and packaging. These factors can also affect the rate of loss and/or metabolic breakdown of the sprout control products which have been applied to tubers. This is important because for most of the sprout control products it is the persistent residue of the active ingredient which controls sprouting. The duration and efficacy of the control therefore depends on the level of residue present on or in the tubers. Storage temperature is particularly important to retain sprout inhibitor efficacy. The active ingredients of most sprout inhibitors are volatile and therefore can evaporate more quickly as storage temperatures rise. Also, warmer storage temperatures increase tuber metabolic rate, which leads to faster breakdown of chemical inhibitors and faster physiological ageing of the treated tubers. In general, sprout inhibitors may not be as effective for long-term sprout control when tubers are held at warmer temperatures.

The described sprout control products or methods can be used alone. Some can also be used together in sequence with each other or applied as a mixture to control tuber sprouting more effectively.

1.1 Storage at low (non-freezing) temperatures

Low temperature storage is used extensively in major potato producing areas to maintain tuber quality, to slow disease development and to delay the onset of sprouting (Burton 1989). However, there is no permanent loss of sprouting capacity in tubers treated in this manner. When the potatoes are returned to warmer temperatures the sprouting capacity of the potato is often enhanced. Storing potatoes at the lowest acceptable temperature yet still maintaining quality for the desired market is

widely used in the industry. Often cool-temperature storage is combined with one or more of the products described below.

1.2 Chlorpropham (isopropyl (N-3-chlorophenyl) carbamate; CIPC)

CIPC has been used as a potato sprout inhibitor since the mid-1950's. A low toxicity carbamate herbicide (rat oral LD50 ca. 4900 mg/kg; Meister 2001), it is very effective, reliable, and widely available at a moderate price. It is the most popular potato sprout inhibitor worldwide, and can be applied as a thermal fog, an aerosol, an aqueous spray or dip, or in a dust formulation. CIPC is applied post-harvest, after suberization of harvest injuries because it is a mitotic inhibitor which stops the cell division needed for this repair. It is preferable to apply CIPC prior to sprout formation (Ravanel and Tissut 1984), although application to sprouted potatoes is also effective, as it causes the sprouts to desiccate. Multiple applications of CIPC may be necessary, e.g. in European nations where the permitted application rate is relatively low. Recent research to reduce residues and to minimize effects on fry color has resulted in lower application rates, refined application methodologies and sequenced or combination treatments with other inhibitors.

Relatively high CIPC residues provide the greatest inhibition of sprouting or diminishment of viability (Boyd et al. 1982; Kim et al. 1972; Kleinkopf et al.1997; Noel et al. 2004). Control of sprouting by CIPC is usually considered irreversible at the rates commonly used in North America, although tubers with inadequate residues or non-uniform applications can retain the capacity to sprout. However, even low levels of CIPC residue will substantially retard sprout development and greatly affect the plant stand if a crop is planted with CIPC treated tubers. This is why CIPC is not used on seed tubers and any possibility of exposure must be minimized. In a recent two-year research study at the University of Idaho, potatoes treated with various rates of CIPC (1.3 to 10 ppm) showed yield reductions up to 94% (Frazier and Olsen 2012).

CIPC is most often applied as an aerosol fog which is introduced into the ventilation airstream of the potato storage bin after harvest and the wound healing period, typically 2 to 3 weeks, and before the tubers have broken dormancy. This method is usually quite effective, but it depends on application of the correct quantity of product for the quantity of tubers being treated, and also on good distribution to all tubers via the ventilation airstream (Conte and Imbroglini, 1995; Kleinkopf et al. 1997; Noel et al. 2004). Large amounts of field soil adhering to the tubers during harvest or soil and debris surrounding the potatoes can impair the distribution of the CIPC vapour, causing inadequate treatment of some tubers. The typical single aerosol application of CIPC of 20 to 25 ppm will provide up to 9 months of sprout control for varieties such as Russet Burbank held at 7.2C. The level of sprout control is strongly correlated with the residue of CIPC on the tuber. Higher CIPC residues result in greater retardation or severity in diminishing viability (Boyd et al. 1982; Kim et al. 1972; Kleinkopf et al. 1997). Factors such as cultivar, stressed tubers, high storage temperatures, etc. may necessitate a second application of CIPC for satisfactory control throughout long term storage. Although there is some minor variability in regard to optimal dosage or duration of control, CIPC can be considered effective on all cultivars.

CIPC can also be applied in an aqueous emulsion which is sprayed onto the tubers as they pass along a conveyor or packing line. This can be done either when the tubers are entering the storage facility after harvest and suberization, or after the storage term ends when the tubers are being packed for marketing. If it is applied after packing for market, the packaging may impair CIPC distribution and reduce the effectiveness of sprout inhibition (Mondy et al. 1993). When applying CIPC after storage, it is important to respect the days to market regulations and maximum residue

limits (MRL) for the jurisdictions involved. Any sprouts which are present on tubers sprayed with CIPC in this manner will usually become desiccated within a few days after treatment. However, the eyes from which these sprouts grew may remain viable and potentially resprout at a later date. The duration of sprout control varies with time of year, variety, storage temperature, and rate of CIPC application but tubers can usually be held for at least 8 weeks after removal from storage with none to minimal sprout development.

1.3 Maleic hydrazide (l,2-dihydropyridazine-3-6-dione; MH)

MH has been used as a potato sprout inhibitor since the 1950's. It is quite effective, and has low toxicity (rat oral LD50 ca. 3800 mg/kg; Meister 2001). It is sprayed onto the live potato plants in the production field near the end of the growing season but before senescence or top-killing. The MH compound is translocated from the foliage to the tubers and prevents sprouting in storage. The timing of the application is critical because MH can alter the yield and size of the treated crop if it is applied too early, but its effectiveness is diminished if it is applied too late.

MH is sometimes applied to prevent sprouting and subsequent growth of unharvested tubers which may remain in the field after harvest, to avoid potato volunteers in the following crop. Suppression of emergence depends upon size of the tubers and the MH residue level (Newberry and Thornton 2007). Sprout development occurs with MH applications but growth is substantially delayed. Typical commercial field applications of MH will delay initial sprout initiation by approximately 30 days and severely retard sprout elongation for at least 8 months in storage. Timing of the MH application will influence the length of sprout control in storage. For long-term control the tubers are usually treated during storage with another inhibitor such as CIPC.

1.4 Essential oils

This group includes several related volatile aromatic compounds which are extracted from plants or plant parts. The mode of action is to physically damage the developing sprout, which then shrivels and becomes desiccated (Coleman et al. 2001; Baydar and Karadoga 2003/4). Additional sprout tissue will develop which must be damaged by additional product applications to achieve long-term sprout control. Due to the mode of action of these products, a sprout must be present at the time of treatment for the control to be effective. All of these essential oils can be used alone or in combination with CIPC or another sprout control product.

- Clove oil - Clove oil is the essential oil extracted from dried flower buds of *Syzygium aromaticum*. The active ingredient is eugenol (rat oral LD50 ~1900 mg/kg). It can be an effective sprout suppressant if applied at approximately 100 ppm and under favorable storage conditions, although multiple applications are needed for full-season control (Kleinkopf et al. 2003). It is applied as thermal fog or as a spray, and may also be used in combination with or as a supplement to CIPC or other sprout inhibition treatments. Clove oil also has some fungicidal properties. An aerosol application of clove oil, depending upon storage temperature and variety, can provide sprout suppression for 2 to 5 weeks.

- Mint oils - The essential oils extracted from spearmint (*Mentha spicata*) and peppermint (*M. piperata*) are potato sprout suppressants. These mixtures of aromatic compounds, consisting mainly of carvone (*M. spicata*) or menthol and menthone (*M. piperata*). They can be applied by wicking, cold aerosol, or thermal fogging. The vapours physically damage the

sprout tissue, but multiple applications are necessary for full-season control. The effectiveness of mint oils to inhibit potato sprouting is cultivar-dependent. (Kleinkopf et al. 2003). The flavour of the treated tubers can be affected by some mint oils. An application of mint oil, depending upon temperature and variety, can provide sprout suppression for 2 to 5 weeks.

- Carvone - Carvone is the main component of the essential oil from caraway seed (*Carum carvi*) and related plants (rat oral LD50 ca. 1600 mg/kg). The inhibitory effect of carvone on potato sprouting was first recognized in the 1990's (Hartmans et al. 1995; Oosterhaven et al. 1995). It is a very effective sprout suppressant if applied properly (Hartmans et al. 1995; Kalt et al. 1999; Pranaitiene et al. 2008), and provides some fungicidal activity against certain postharvest pathogens (Hartmans et al. 1995). It does not affect the color of processed products such as French fries or potato chips. Carvone can also be used in combination with CIPC or other sprout control products. Carvone is useful for seed tuber applications (Sorce et al. 1997).

Carvone, mint oils and clove oil have little to no effect on seed viability and can be used to manage sprouting of seed potatoes. Treated seed potatoes will produce a healthy potato crop.

1.5 Naphthalenes

This group includes substituted naphthalene compounds with sprout inhibition activity, which was first reported in the 1950's.

- 1,4-Dimethylnaphthalene (DMN) (Beveridge et al. 1981a and b)
  DMN was developed as a commercial potato sprout control treatment in the 1990's (Lewis et al. 1997). It is very effective, has low toxicity (rat oral LD50 ca. 2700 mg/kg), and has little or no effect on processing color. DMN can be applied as an aerosol, a thermal vapour or as an aqueous spray. Sprouting is delayed, and when sprouts appear they are short and radially expanded. Multiple applications are needed for full-season control, but the effects are reversible. Beveridge et al. (1981b) and Knowles et al. (2005) found 1,4-DMN to be usable for seed potatoes, and some products are recommended to enhance field performance. DMN can be combined or supplemented with CIPC to reduce the application rates, and therefore residue levels, of both products in marketed tubers.

- 2,6- Diispropylnaphthalene (DIPN)
  DIPN is another of the substituted naphthalenes (rat oral LD50 ca.3400 mg/kg). A very low concentration of DIPN is found naturally in tubers. It was one of several volatiles collected from dormant tubers in a study during the early 1970's (Beveridge et al. 1981a). Its function in the tuber is believed to be associated with dormancy and rest. Exogenous application of DIPN has been found to inhibit sprouting in storage (Lewis et al. 1997). DIPN is almost exclusively applied in combination with CIPC.

The naphthalenes have little to no effect on seed viability and DMN is currently recommended to prevent premature sprouting of seed tubers.

1.6 Ethylene gas

Ethylene gas is a well-characterized plant growth regulator which all plants are believed capable of producing and responding to at some stage of their life cycle. Dual effects of ethylene on potato sprouting were first reported in the 1930's, i.e. ethylene both promoted and inhibited sprouting (Elmer 1936). This apparent contradiction was later attributed to differences in the duration of exposure (Rylski et al. 1974). The commercial potential of ethylene as a potato sprout inhibitor was identified in the 1990's (Prange et al. 1998), and it has been used commercially in several countries for approximately a decade.

Ethylene potato sprout suppressant acts by inhibiting the elongation of the growing sprouts (Prange et al. 1998). The tubers must be exposed to ethylene continuously throughout the storage term. Sprout development is delayed in ethylene-treated tubers compared with untreated tubers and these sprouts remain short and weakly attached to the tubers, although the response varies somewhat among cultivars (Prange et al. 1998; Daniels-Lake et al. 2005). The inhibitory effect of ethylene is not permanent, and sprout growth proceeds when the ethylene exposure is ended. This makes it useful for delaying the sprouting of seed tubers.

1.7 Hydrogen peroxide

Hydrogen peroxide suppresses potato sprouting by physically damaging the sprout tissue (Afek et al. 2000). It is applied as an aqueous mixture through the humidification system of the storage building, and frequent reapplications are necessary for control of sprouting (Kleinkopf et al. 2003). Hydrogen peroxide has also been found to reduce pathogens in lab studies. Sprout control by hydrogen peroxide is temporary only; new sprouts eventually regrow from the potato eyes.

1.8 Irradiation

Irradiation was shown in the 1950's to effectively inhibit potato sprouting (Sawyer and Dallyn 1956; Sparrow and Christiansen 1954). Since that time, researchers have studied the use of irradiation from various sources including X-rays, electron beams, or gamma rays from radioactive isotopes, applied at dose rates from 0.01 to 2.0 kGy[5], with storage after treatment at temperatures ranging from 1 to 29 ºC (Burton 1975; Frazier et al. 2006; Olsen et al. 2011; Rezaee et al. 2011; Todoriki and Hayashi 2004; Thomas and Sparks 1984). Some cultivars were found to be more sensitive to irradiation treatments than others. The timing of the irradiation treatment, i.e. time after harvest or the physiological age of the tubers, was found to influence the efficacy of sprout inhibition in some studies. Some researchers found that the irradiated potatoes did not produce viable sprouts or plants even at relatively low dose rates, whereas in other reports the response was found to be dose related, with little effect at low dose rates and greatest inhibition of sprouting with higher dose rates and earlier treatment (Frazier et al. 2006; Olsen et al. 2011; Rezaee et al. 2011; Todoriki and Hayashi 2004; Thomas and Sparks 1984). The duration of storage after irradiation ranged from 1.5 to 9 months in most studies, with a few early studies of 1 or 2 year duration.

[5] Following the convention of IAEA (1997), the irradiation dosages are given in the SI units, i.e. Gray or kGray (Gy or kGy, respectively). Note: 1 Gy = 100 rad.

In the International Atomic Energy Agency's extensive compilation of research findings, it was concluded that
"*In potatoes doses between 0.05 and 0.15 kGy, preferably a dose range from 0.07 to 0.15 kGy is sufficient to inhibit sprouting regardless of cultivar, time of irradiation and post irradiation storage temperature*". This document also advises that "*Sprouts already present wither off during storage and development of new sprouts is prevented. Doses exceeding 0.15 to 0.20 kGy can result in increased darkening or browning, decreased wound healing ability, increased storage rot, spoilage, sweetening, decreases in vitamin content and changes in chemical composition which do not disappear during subsequent storage*" (IAEA 1997).

Increased physiological disorders, increased susceptibility to disease, reduced tuber quality, reduced wound healing, increased tuber sugar concentrations and darker processing colour have been reported at various dosages, although they are worse at high dose rates (Burton 1975; Islam et al. 1985; Frazier et al. 2006; Olsen et al. 2011; Rezaee et al. 2011; Thomas 1982). The recent research has focussed on application of lower doses of irradiation to reduce the negative effects (Frazier et al. 2006; Olsen et al. 2011; Rezaee et al. 2011; Todoriki and Hayashi 2004). Commercial irradiation of potatoes is not currently being conducted in North America, and research is on-going to evaluate the feasibility of utilizing irradiation for this purpose.

1.9 Products currently in development but not yet used in a NAPPO country

- Unsaturated ketone
  3-Decen-2-one is one of several related compounds with sprout suppression properties in potatoes. It is permitted in the USA as a flavouring agent in foods, and registration as a potato sprout inhibitor is underway in both Canada and the USA. This compound physically damages the sprouts and season-long control has been achieved with only a few applications. However, the inhibitory effect of 3-decen-2-one is not permanent; the tubers will eventually re-sprout. Aerosol applications will give approximately 3 to 8 weeks of sprout control depending upon variety and storage temperature.

- Other compounds
  Several additional compounds have been found to inhibit potato sprouting, including salicylaldehydes, jasmonates, farnesene, glyphosate, etc. Research has shown them to be effective, although none have been commercialized yet or adopted by the potato industry. Based on the reported research findings to date, none are expected to permanently render tubers non-viable.

2. Sub-optimal Performance

Sub-optimal sprout inhibitor performance can result from a number of different circumstances. This includes application of an insufficient quantity of the sprout inhibitor to achieve the desired result, uneven or incomplete application to the tubers, application at an inappropriate time or growth stage, and storage of the treated tubers under conditions which can reduce the effectiveness of the sprout inhibitor or accelerate physiological ageing of the tubers. Care is required to ensure that the sprout control treatment is applied at the appropriate concentration and under optimal temperature and

ventilation conditions to achieve the desired results, i.e. delaying the sprouting of treated tubers for an extended period of time. Furthermore, some sprout inhibitor active ingredients including chlorpropham can be significantly reduced at high storage temperature (Şanli et al. 2010), e.g. in natural storage under ambient conditions.

The obvious effect of sub-optimal sprout inhibitor performance is the possibility that the treated potatoes would produce sprouts and/or grow new plants at some point in time after being treated. In addition to the risk of pest dispersal, other possible consequences include reduced tuber and culinary quality, reduced market appeal, accelerated weight loss and shriveled appearance, increased tuber sugar concentrations, and possible violation of Plant Breeders Rights or International Plant Patents.

3. Candidates for Consideration by the Potato Panel

Among the available potato sprout inhibition methods described above, CIPC and irradiation are the most likely to provide sufficient duration of control to merit consideration by the Potato Panel. MH alone or in combination with CIPC can substantially retard sprout development and may beneficial in an integrated program for long-term sprout control. All others provide only short-term or reversible sprout suppression and are therefore not good candidates for this purpose. In addition, under natural storage using ambient conditions, the duration of control by any sprout inhibition product may be significantly shortened.

CIPC is slightly volatile, and the tubers can also metabolize it slowly into less inhibitory compounds. As the time after application increases, the residue of CIPC on treated tubers gradually diminishes and therefore so does the inhibition of sprouting. If the CIPC treatment was poorly distributed, or if the initial application rate was low, or if the CIPC residue has diminished with time, some of the tubers may begin to sprout and produce a potato plant. This possibility is increased as the tubers age physiologically and/or when the tubers are exposed to favourable growing conditions such as warm temperatures. Although other sprout inhibitors such as DMN, DIPN, or clove oil applied alone give shorter duration of sprout inhibition than does CIPC applied alone, when applied in combination or in sequence with CIPC inhibition of sprouting the combinations may be more effective than each product alone. However, there is little published research on whether these combinations of treatments can render tubers completely non-viable, or prevent sprouting for an extended period of time to be suitable for the needs of the Potato Panel.

Irradiation can be a very effective sprout inhibition method, but there are some undesirable side-effects of irradiation treatment, as noted above. Like CIPC, if the irradiation treatment is applied at too low dosage to reduce the negative consequences, the treatment may not be sufficient to render the tubers completely non-viable. This could permit tubers which remain unused for a very long period of time after treatment to eventually sprout and/or grow into plants.

In at least two of the three NAPPO countries, foods which have received irradiation treatment must be clearly labeled as such on the packaging or at the marketplace display.

4. Limiting the End Uses of Potatoes in Commerce

It is useful to consider what constitutes a non-viable tuber. If the goal is complete assurance that all eyes of all tubers can never, ever sprout to produce new shoots or plants, this sets a very high standard which may not be achievable in practical terms. Potato tubers are living plant parts, and their functional purpose is to grow into a new plant. Cooking may be the only method to completely render potato tubers 100% non-viable, as all sprout inhibitors may occasionally fail under extreme circumstances, and anecdotal reports show that sometimes tubers even survive freezing or desiccation in the field. However, when the intention is to market fresh raw tubers, cooking as an anti-sprouting treatment is simply not sensible.

A more achievable target could be a sprout inhibition treatment which results in a very low possibility of sprouting before the maximum time that tubers can be expected to remain in the hands of the consumer before consumption. This would form a part of an overall system to effectively manage potatoes which are traded internationally, along with handling guidelines, inspection of tubers and facilities, and sanitation measures such as sorting, grading and washing. Although it may be impossible to control or predict all possible uses of imported potato tubers, marketplace labeling as “sprout inhibited” or “rendered unable to grow” or some similar message would help discourage deliberate use of these tubers for seed.

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APPENDIX 1: Terms of Reference for the Potato Sprout Inhibitor Technical Advisory Group

October 4, 2010

Background

The North American Plant Protection Organization (NAPPO) Potato Panel was asked during the 2008 annual meeting to consider reviewing the effectiveness of various potato sprout inhibitors. Presently, various commercially available products are used to inhibit the sprouting of potato tubers to maintain quality for intended use (fresh consumption) and in specific situations to mitigate the possible spread of pests. There is now a need to compile all relevant scientific information and impartial opinion on the levels of effectiveness of the commercially available sprout inhibitors in preventing potato tuber sprouting.

Purpose

The purpose for the Potato Sprout Inhibitors Technical Advisory Group (PSI TAG) is to collect and present scientific information on the efficacy of various treatments used to control the sprouting of potato tubers. The information and considerations presented will help guide the NAPPO, the respective regulatory authorities and industry representatives to formulate an opinion on their usefulness as a risk mitigating measure in controlling various potato pests.

Objective

Develop a discussion paper providing scientific and technical information on the effectiveness of various potato sprout inhibiting products and treatments presently available to potato growers and stakeholders. Any reference to specific treatment will be by category of active ingredient, not commercial product name.

Membership

The PSI TAG shall be comprised of three technical experts, one from each NAPPO member country, and a representative of the NAPPO Potato Panel.

Roles and Responsibilities

The PSI TAG will appoint a chair to lead the discussions, tasks and provide a discussion paper to the members of the NAPPO Potato Panel.

The PSI TAG shall review the suggested terms of reference and, if needed, seek clarifications from the members of the NAPPO Potato Panel. The PSI TAG is encouraged to provide updates regularly to the members of the NAPPO Potato Panel and seek clarification or input from them whenever required.

The members of the PSI TAG are encouraged to communicate with their collaborators and other experts to gather all valuable scientific and technical information to advance the formulation of the suggested discussion paper.

The PSI TAG members should encourage an open dialogue and the sharing of scientific and technical information, all points of view will be considered while seeking consensus.

During the process used to develop the discussion paper the PSI TAG will consider:

1. Characterizing the effectiveness of the various potato tuber sprout control products and treatments and address future products and treatments that may become available for sprout control including organics and irradiation.
2. Addressing the effects of sub-optimal performance.
3. Describing the above in context with currently available sprout inhibitors.
4. Providing an overall perspective on the utilization of tuber sprout control measures to limit the end uses of potatoes in commerce.

Process and Timeframes

It is expected that the members of the PSI TAG will conduct this assignment through conference calls, video conferencing and electronic exchange of documents.

The chair of the PSI TAG should provide regular progress report to the members of the NAPPO Potato Panel, at least one report every six months.

While there is no definite timeframe for submission of the final discussion paper, the PSITAG should consider completing this assignment by September 2011.

PSI-TAG members and Coordinates

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APPENDIX 2: Sprout inhibition methods and their regulatory status in the three NAPPO countries

Sprout inhibitor	Formulation or application method	Existing registrations, by country		
		Canada	**Mexico**	**USA**
Currently approved or in use in at least one of the NAPPO countries				
Low-temperature storage	Non-freezing temperatures, usually between 4 and 13ºC, depending on end-use for potatoes	Registration unnecessary	Registration unnecessary	Registration unnecessary
Chlorpropham	Solid or liquid for aerosol fogging, applied post-harvest after curing	rate: 1.2 to 3.75 kg a.i. per 100 tonnes of potato tubers, per application. May be repeated if necessary MRL: 15 ppm	There are no potato sprout inhibitor chemicals currently registered for use in Mexico	Rate: Depends upon storage temperature and duration. Apply 13 to 28 ppm CIPC per application. Additional application, if necessary, but not to exceed 28 ppm accumulative. CIPC and clove oil mixture rate of 5-28 ppm of CIPC. MRL: 30 ppm
	Emulsifiable concentrate, mixed with water for spraying, applied post-harvest (e.g. on the packing line)	rate: 1 kg a.i. per 100 tonnes of potato tubers MRL: 15 ppm		Rate: Maximum 10 ppm or 1% ai solution MRL: 30 ppm

Maleic hydrazide		Soluble granules, dissolved in water for pre-harvest spray application	rate: 9.27 kg a.i. per ha, applied in 300 L of water MRL: 50 ppm		Rate: 1.3 gal/A MRL: 50 ppm
Essential oils	Carvone	Liquid for fogging, applied post-harvest	not registered		Not registered
	Clove oil	Liquid for fogging, applied post-harvest	not registered		Rate: 27-87 ppm MRL: none
		Emulsifiable concentrate for spraying, applied postharvest (on the packing line)	not registered		Rate: organic formulation = 8,300 to 18,400 ppm; non-organic formulation = 8,000-19,500 ppm Non-organic formulation applied with CIPC EC = 4 – 8 % ai. MRL: none
	Mint oils	Liquid for fogging, applied post-harvest	not registered		Rate: as appropriate (~50 to 100 ppm). MRL: none
Naphthalenes	1,4-dimethyl-naphthalene	Liquid for fogging, applied post-harvest	rate: 10 to 20 mL a.i. per tonne of potato tubers MRL: none		Rate: 20 ppm MRL: none
	2,6-diisopropyl-naphthalene	Liquid for fogging, applied post-harvest	not registered		Rate: 25 ppm. Used in combination with CIPC. MRL: 2 ppm
Ethylene		Compressed gas, applied continuously post-harvest	rate: 4 ppm in storage atmosphere MRL: none		Not registered

		On-site generation from heated liquid ethanol, applied continuously post-harvest	not registered		Not registered
Hydrogen peroxide		Stabilized liquid for fogging, applied post-harvest	Not registered for sprout inhibition (bactericide & fungicide use only)		Rate: 1:5 dilution; apply as needed. MRL: none
Irradiation		Gamma-radiation from a ^{60}Co or ^{137}Cs source or X-rays from a machine source or an electron beam from a machine source	Rate: 0.15 kGy maximum exposure, from ^{60}Co source MRL: n/a		Not commercially used
<u>Under development</u>					
Unsaturated ketones	3-decen-2-one	Liquid for fogging, applied post-harvest	Registration pending		Registration pending
Other compounds	Salicylaldehydes, jasmonates, farnescene, glyphosate, etc.		None registered		None registered