



Know-how for Horticulture™

**Evaluating a product
for enhancing
dormancy and storage
qualities of potatoes**

Ian Macleod
Serve-Ag Pty Ltd

Project Number: PT01038

PT01038

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FINAL REPORT

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Evaluating a product for enhancing
dormancy and storage qualities of
potatoes

May, 2004

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25 May, 2004

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Media Summary

Many people eating McDonalds' chips would not be aware that they are eating potatoes that have been stored for up to 8 months. Most people assume that once potatoes are dug in the paddock, they are then immediately transported and processed. However, if this were to happen, there would be massive seasonal gluts at the processing factories. In order to ensure a uniform flow of tubers through the processing line, it is necessary to store potatoes over the autumn, winter and spring months. This ensures continuous year round operation of the factory. Good potato storage conditions are essential to ensure tuber quality is maintained throughout the year, so that product of a consistent quality is guaranteed to the consumer.

Control of environmental conditions is critical in maintaining tuber quality. Temperature, humidity and air movement are the most important environmental variables. Environmental conditions must be monitored and adjusted regularly in storage. Use of sprout control products can also assist with maintaining tuber quality by minimising sprouting. Currently, CIPC is the only product available to control sprouting in stored potatoes. Its effects are irreversible, making CIPC unsuitable for seed potatoes. The industry is seeking alternatives to CIPC due to food safety concerns, and hazards associated with shipment and handling.

Alternatives to CIPC have been researched in the projects 'Use of natural sprouting inhibitors for potato storage' (PT354) and 'Improving seed potato production' (PT98008). Through these projects, the dormancy enhancer, DMN, was identified as a suitable product for commercial development as an alternative to CIPC.

DMN is the common name for 1,4-dimethylnaphthalene. This product has been registered in the United States of America for use on potatoes. It is manufactured for D-I-1-4 Inc. by a Japanese chemical company, and sold commercially in the USA as 1,4Sight®.

The aim of this project was to investigate the use of DMN as an alternative sprout suppressant in Australia.

A literature review of DMN found that there is a limited amount of scientific literature available regarding this product. It is likely that a large part of the literature regarding DMN remains commercial-in-confidence.

A review of DMN chemical and physical properties determined that DMN is an extremely volatile compound. Previously, it was thought that DMN is a naturally occurring substance in potatoes. This conclusion was based on studies conducted in the early 1970's, when the detection limit for DMN was around 0.1 ppm. As part of this project, considerable time was spent developing an improved analytical method for DMN detection. Project chemists developed a new method with a detection limit of 0.1 parts per billion (ppb). This is over 10,000 times better than the previous detection limit. As a result of improved analytical procedures, the project chemists determined that DMN is an extremely volatile, ubiquitous compound and it does not occur naturally in potatoes. DMN can be detected in potatoes, but this is likely to be as a result of tuber contamination from a range of volatile sources.

Volatility of DMN presented difficulties for small scale trial work. In the first year of the project, treated potatoes were stored in sealed metal drums stored in a refrigerated container to prevent cross contamination of treatments. However, significant rot occurred under the anaerobic conditions. In the second year of the project, treated potatoes were stored in a commercial potato store. However, under these conditions it was impossible to maintain the head space concentration of DMN required for sprout control.

It is recommended that DMN trials can only be successfully conducted in a purpose built trial facility or in a commercial facility where the whole store is treated with the product. Until a residue exemption is obtained for DMN in potatoes, the costs of treating a whole store could be prohibitive. Future development of DMN for Australian markets will depend on liaison between the Australian Pesticides and Veterinary Medicines Authority and the product manufacturers.

Technical Summary

Currently CIPC is the only product available to control sprouting in stored potatoes. Its effects are irreversible, making CIPC unsuitable for seed potatoes. The industry is seeking alternatives to CIPC due to food safety concerns, and hazards associated with shipment and handling.

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A number of potato varieties from various locations were screened for DMN. As a result of improved analytical procedures, the project chemists determined that there was no evidence that 1,4 DMN or any other DMN occurs naturally in potatoes. Several literature reports relate to the absorption of PAHs (Polycyclic Aromatic Hydrocarbons), such as DMNs, by plants from root and aerial exposure, especially root vegetables. All DMNs observed in untreated potatoes in this study were consistent with the pattern found in normal PAH profiles and were environmental contaminants.

Volatility of DMN presented difficulties for small scale trial work. In the first year of the project, treated potatoes were stored in sealed metal drums stored in a refrigerated container to prevent cross contamination of treatments. However, significant rot occurred under the anaerobic conditions. In the second year of the project, treated potatoes were stored in a commercial potato store. However, under these conditions it was impossible to maintain the head space concentration of DMN required for sprout control.

It is recommended that DMN trials can only be successfully conducted in a purpose built trial facility or in a commercial facility where the whole store is treated with the product. Until a residue exemption is obtained for DMN in potatoes, the costs of treating a whole store could be prohibitive. Future development of DMN for Australian markets will depend on liaison between the Australian Pesticides and Veterinary Medicines Authority and the product manufacturers.

Introduction

Background

Potatoes used for crisp and french fry processing are typically stored over the autumn, winter and spring months to ensure a uniform flow of tubers through the factory processing line. Good potato storage conditions are essential to ensure that tuber quality is maintained throughout the year, so that product of a consistent quality is guaranteed to the consumer.

Good storage should prevent excessive dehydration, decay and sprouting. It should also prevent high sugar concentrations which result in dark coloured fried products. A potato storage facility should have adequate insulation, outside waterproofing, inside vapour proofing, ventilation, air distribution, adequate humidification, and properly designed controls for precisely maintaining the storage atmosphere (Potato Information Exchange, 2004).

Control of environmental conditions - temperature, humidity, and air movement - is most important for maintaining tuber quality. Environmental variables must be monitored and adjusted regularly in storage. Use of sprout control products can also assist with maintaining tuber quality by minimising sprouting.

Currently CIPC is the only product available to control sprouting in stored potatoes. Its effects are irreversible, making CIPC unsuitable for seed potatoes. The industry is seeking alternatives to CIPC due to food safety concerns, and hazards associated with shipment and handling.

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The aim of this project was to investigate the use of DMN as an alternative sprout suppressant in Australia.

Literature Review

Product Description

The following table gives technical information about DMN. The Material Safety Data Sheet (MSDS) for DMN is given in Appendix i. A copy of the 1,4Sight® commercial label is given in Appendix ii.

Physical properties of DMN

Tradename	1,4-DMN
Chemical name	1,4-dimethylnaphthalene
CAS #	571-58-4
Chemical family	Alkyl-substituted naphthalene
Chemical formula	C ₁₂ H ₁₂
Molecular weight	156.2
Colour	Pale yellow at 21°C
Physical state	Clear liquid at 21°C
Odour	Petroleum distillate at 21°C
Boiling Point	264°C at 744 mm Hg
Melting Point	5°C
Specific gravity	1.014 (25°C)
pH	5.9
Viscosity	6 cps at 25°C at 12 and 30rpm
Solubility	In water = 5.1 ppm at 25± °C
Vapour pressure	1.88 x 10 ⁻² mm Hg at 25°C
Flash point	122°C at 760 mm Hg (Pensky-Martens Closed Tester)
Explodability	Not explosive at 25°C at minimum drop height of 32.25 inches
Flammability	Not considered flammable under United Nations/DOT criteria. Will support combustion and decompose under fire conditions to form toxic organic materials and toxic/corrosive oxides of carbon and nitrogen.

Occurrence of DMN in potatoes

There have been several studies on the volatile aromatic compounds produced by stored potatoes. Meigh *et al* (1973) used GLC-MS analysis of the volatiles and found that DMN occurred in the ethereal extract of dry peel. They also found that DMN was effective as a sprout inhibitor. This work is the first published record of DMN being evaluated as a sprout inhibitor.

Coleman *et al* (1981) found that 1,2-dimethylnaphthalene, 1,3-dimethylnaphthalene and 2,7-dimethylnaphthalene occurred in the aromatic spectrum from baked potatoes. They did not detect 1,4-dimethylnaphthalene.

Nursten and Sheen (1974) indicated that DMN was present in extracts of steam volatiles of unpeeled cooked potatoes, but they did not conclusively identify the product.

Johnson *et al* (1971) conducted a comprehensive survey of potato volatiles and they did not find DMN in any of compounds analysed.

Evaluation for sprout inhibition

The majority of published research on DMN is concerned with its efficacy as a potato sprout inhibitor.

Following on from Meigh's paper, Beveridge *et al* (1981) published a more comprehensive study on DMN as a sprout suppressant. They found that DMN applied at 100 ppm proved an effective sprout suppressant. They also conducted a field trial with DMN-treated seed to determine if the treatment had any effect on emergence or yield. There was no adverse effect on either of these parameters. Like Meigh (1973), Beveridge *et al* (1981) recommended that DMN showed commercial potential and was worthy of further examination.

In 1985, Filmer and Rhodes used a potato shoot-tip bioassay to show that DMN inhibited sprout growth. However, they identified diphenylamine as being a better compound for development as a sprout inhibitor because it was already being used in the potato industry.

Filmer and Rhodes (1985) agreed with Meigh's conclusion that the overall inhibition of sprouting observed in the experiments could not be solely accounted for by the mono- and di-naphthalenes. They suggested the inhibition of sprouting caused by the accumulation of volatile compounds may result from interactions between several chemically distinct volatiles, each of moderate growth-inhibitory activity, rather than from very low concentrations of a single powerful inhibitor.

However, it seems there has been little work done to validate this hypothesis, or to determine the contribution of naphthalene to the growth inhibition process. Rather, work has focused on evaluating the properties of single chemicals as sprouting suppressants.

The efficacy of DMN as a commercial sprout inhibitor was evaluated as part of the Horticultural Research and Development Corporation project PT354 "Use of natural sprouting inhibitors for potato storage". The report for this project states "an extensive list of studies is available from USA". However, the reports from these studies do not seem to be currently available in public literature.

As part of the HRDC project, DMN was evaluated in one trial, which was conducted in modified shipping containers. DMN was applied at 60 ppm to Russet Burbank and Denali tubers. After 172 days of storage, DMN gave commercially acceptable control of sprouting in Russet Burbank tubers, but not in Denali tubers (Baker 1997). DMN residue analysis was conducted but the results remain commercial-in-confidence.

Trials with DMN have been conducted in New Zealand by Alpha Research (unpublished research). They used DMN at 10 ppm and 20 ppm and found that the 2 applications of the higher rate provided acceptable sprout control in Fianna potatoes. DMN residue analysis was conducted but the results also remain commercial-in-confidence.

Boylston *et al* (2001) found that DMN did not alter the sensory properties of Russet Burbank potatoes. However, they were unable to detect residual levels of DMN with detection limits of 0.80 –1.40 ppm. Baker (1997) conducted fry colour assessments as part of the HRDC project trial, and found that DMN did not affect the fry colour quality of the potatoes.

Lewis *et al* (1997) compared DMN to diisopropylnaphthalene (DIPN) and CIPC and found that DIPN was the most effective of the two naphthalene products for controlling sprouting in Russet Burbank potatoes. They found that DMN or DIPN was an effective sprout suppressant on a short-term basis, but they were using a rate of 300 ppm, which is very high compared to the rates recommended for 1,4Sight®.

Other product claims

The product label for DMN claims improved tuber quality as a result of DMN enhancing “the potato’s ability to heal cuts and bruises, while eliminating internal sprouting.” Similar claims are also made in the report for the HRDC Project PT354. However, no data was provided as evidence.

The manufacturers of 1,4-Sight have not provided data on wound healing and suberisation for inclusion in this project. Their product claims regarding these benefits are supported by grower observations. According to the product manufacturers, several groups of growers have observed that DMN prevents pressure bruising. As a result, they use DMN predominantly for that purpose and additional sprout control is a secondary benefit. Apparently, these growers are increasing the pile depths from 14 feet to as high as 22 feet when using DMN (Jan de Weerd, pers. comm.).

Conclusions from the literature

There is a limited amount of scientific literature available regarding a product that has been registered and commercialised. It may be that a large part of the literature regarding DMN remains commercial-in-confidence.

Storage Trials

Winter 2002

Materials and Methods

Experimental work commenced in late June/early July 2002 at Serve-Ag's research facility in Devonport. A refrigerated container was hired for storage of tubers, and sealable metal drums were purchased for storage of samples. Advice from D-I-1-4, Inc. and Alpha Research indicated that it was critical to maintain isolated headspaces for the different treatments. To do this, it was necessary to seal different treatments in sealed metal drums. DMN is permeable to all materials other than metal and glass.

Table 1 gives the intended treatment list for the 4 varieties of potatoes that were treated. The trial was set up as a completely randomised design, with 4 replicates of each treatment. Each replicate was approximately 12 kg. The exact weight of potatoes used for each replicate was recorded.

Ranger Russet and Russet Burbank were chosen as representative processing varieties. Shepody was chosen as a representative seed variety and Bintjie as a representative ware variety. A subsample of Shepody and Bintjie varieties was taken and cut as seed pieces with sterilised knives. Following cutting and prior to DMN treatment, potatoes were treated with Fungiflor 750 WSP and Tecto® Flowable SC. Fungiflor was applied at 20 g/2 L water (15 g/L imazalil a.i.) with 2 L chemical solution applied per tonne of tubers. Tecto was applied at 1 L/22 L water (22 g/L thiabendazole a.i.), with 2 L chemical solution applied per tonne of tubers.

Prior to product application, a subsample from each replicate was taken for endogenous DMN analysis. Weights after sampling were recorded.

Product application was with a Dyna-Fog® Cyclone ULV™, Model 2730. Application time was according to the rate specifications supplied with the fogger. It was necessary to heat the DMN with hot water in order to ensure even flow through the fogger. Treatments were applied in late June, with first application commencing on 25/06/03. Potatoes for treatment were placed in plastic mesh baskets and packed into a sealed chamber. Fog was applied through an opening, which was sealed for 24 hours immediately after treatment application. Treatments were applied at increasingly higher rates to ensure no cross contamination of samples.

After treatment, potatoes were moved to 20 L metal drums and sealed with a ring seal. Drums were shifted into the refrigerated container, and different treatments were randomised throughout the container.

At each assessment, the weight of potatoes sprouting and showing signs of rot was recorded, and results were expressed as a percentage by weight.

Storage Trials (Cont.)

No.	Product	Product rate (ppm)	No. of Applications	Schedule
Russet Burbank				
1	Untreated control			
2	DMN	20	3	Application 1: 28/6/02 Other applications when DMN = 1ppm
3	DMN	40	2	Application 1: 27/6/02 Other application when DMN = 1ppm
4	DMN	80	1	Application 1: 30/6/02
5	CIPC	60	1	Application 1: 4/07/02
Ranger Russet				
1	Untreated control			
2	DMN	20	3	Application 1: 28/6/02 Other applications when DMN = 1ppm
3	DMN	40	2	Application 1: 27/6/02 Other application when DMN = 1ppm
4	DMN	80	1	Application 1: 30/6/02
5	CIPC	60	1	Application 1: 4/7/02
Shepody				
1	Untreated control			
2	DMN	10	1	Application 1: 1/7/02
3	DMN	20	1	Application 1: 28/6/02
4	DMN	40	1	Application 1: 3/7/02
Bintjie				
1	Untreated control			
2	DMN	10	1	Application 1: 1/7/02
3	DMN	20	1	Application 1: 2/7/02
4	DMN	40	1	Application 1: 3/7/02

Table 1 - Intended treatment list for Storage Trial 1.

Storage Trials (Cont.)

Results

The first assessment was conducted one month after treatment (23/07/02), at which time more than 70% of early variety tubers were sprouting in the untreated control (Table 2). There was no sprouting in all DMN and CIPC treated tubers.

Treatment	% of tubers sprouting after approximately one month of storage (% by weight)			
	Russet Burbank	Ranger Russet	Shepody	Bintjie
Untreated Control	77	77	79	28
DMN 40 ppm	0	0	0	0
DMN 80 ppm	0	0	0	0
CIPC	0	0	0	0

Table 2 - Sprouting incidence in tubers approximately one month after initial treatment

The second assessment was conducted approximately two months after treatment (20/08/02). An anaerobic bacterial rot, thought to be caused by *Clostridium* sp., had developed in most of the drums. Assessment for sprout development was misleading because rot had affected sprout development.

The extent of rot was such that it was necessary to transfer the tubers back to aerobic storage conditions. However, this meant that separate head spaces were no longer maintained, and technically the different rates of DMN were indistinguishable. At this point it was decided to discontinue treatment applications, and to just make observations on the tubers from the first application. The final assessment was made on 8/10/02. There was 100% rot in all samples, and this high level of rot had altered sprouting physiology to the point where it was impossible to assess for sprout development (Figures 1 and 2).

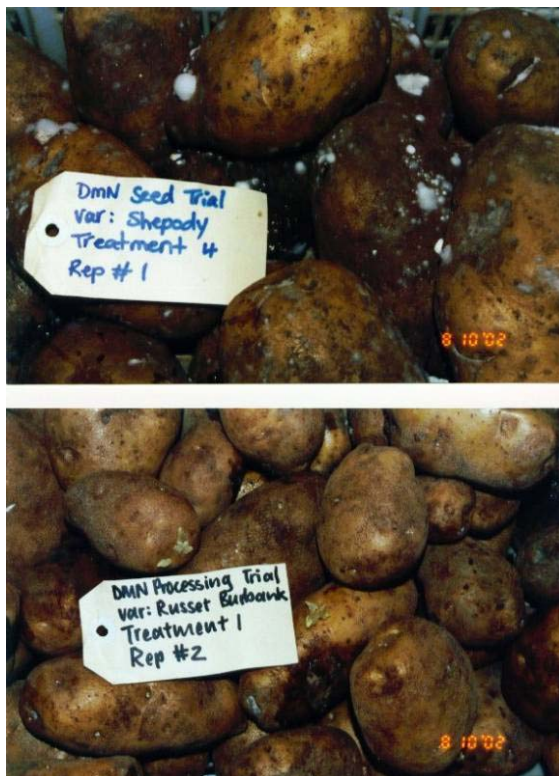


Figure 1 - Rot in whole tubers at final assessment



Figure 2 - Rot in cut tubers (Bintjie) at final assessment

Storage Trials (Cont.)

Winter 2003

Materials and Methods

Previous trials had demonstrated the need to undertake trials under commercial storage conditions. Simplot Ulverstone offered their facilities for trial work in winter 2003.

Russet Burbank potatoes were used for trial work. Treatments included an untreated control, DMN applied at 40 ppm and DMN applied at 80 ppm. DMN applications were made on 24/06/03 and 13/08/03. Potatoes were bagged into onion bags, and placed in a sealed chamber for fogging. Approximately 10 kg of potatoes were used for each replicate (bag). There were 10 replicates (bags) per treatment. The exact weight of tubers treated was recorded. DMN applications were made using a commercial fogging machine hired from a local pest control operator. The fogger and fogging chamber used are shown in Figure 3.

24 hours after treatment, potatoes were removed and transported to the commercial potato store. Potatoes were placed on top of the commercial pile as shown in Figure 4. DMN treated potatoes were stored in Shed 14. CIPC was applied to this shed at the start of the storage season, before DMN treated tubers were placed in there. Untreated control potatoes were stored in Shed 12.

Through every step of treatment, handling and sample collection, efforts were made to ensure that untreated control tubers were always handled first followed by DMN at 40 ppm and finally DMN at 80 ppm. Every effort was made to avoid cross-contamination of samples.

Samples were collected for assessment on 3/06/03 (pre-treatment), 12/08/03, 10/10/03. Samples were collected from treatment bags, and from the commercial pile at separations of 0, 1 and 5 m from where the treatment bags were stored. The purpose of sampling the commercial pile at various separations from the DMN treated tubers was to determine the extent of DMN movement throughout the commercial store. Samples were collected and stored frozen separately. Untreated control samples were always stored in a completely separate facility to DMN treated potatoes to avoid contamination problems encountered in previous trial work.



Figure 3 - Fogger and fogging chamber.



Figure 4 - DMN treated tubers stored on top of commercial pile.

Storage Trials (Cont.)

On the final assessment date, samples were collected for specific gravity (Figure 5) and cooked colour tests (Figure 6). One tuber was selected from each replicate bag to make a total of 10 tubers. All of these tubers were chipped and cooked, and one representative chip from each tuber sample was selected for total testing (total of 10 chips).



Figure 5 - Specific gravity testing



Figure 6 - Cooking chips for colour testing

Results

At the final assessment, all tubers in the trial were sprouting. There was more sprouting in shed No. 12, where untreated tubers were stored. The higher incidence of sprouting in this shed was due to environmental conditions (see Figures 7 and 8).



Figure 7 - Shed 12. Untreated control tubers. Environmental conditions promoted sprouting.

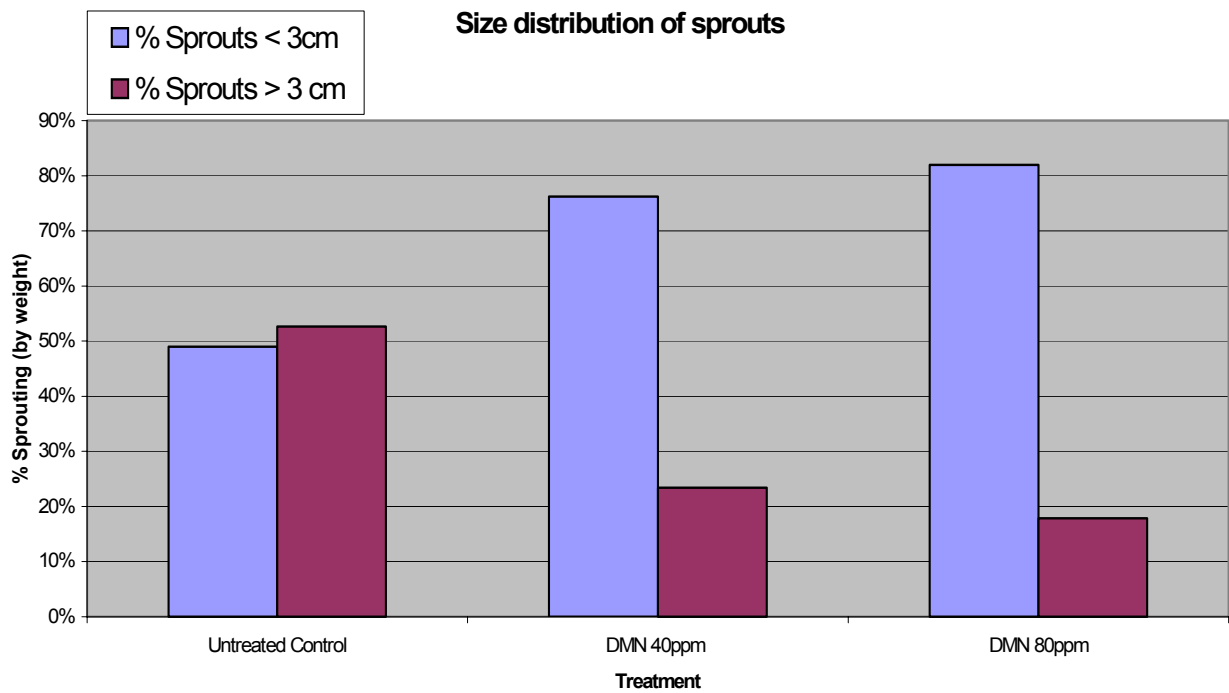


Figure 8 - Shed 14. DMN treated tubers. Environmental conditions less conducive to sprouting.

Storage Trials (Cont.)

Given that all tubers were sprouting, the degree of sprout development was assessed. Tubers were graded according to the length of developing sprout, with the two categories being: i) less than 3 mm, ii) greater than 3 mm.

Sprout assessment showed that both rates of DMN were slowing sprout development, with less large sprouts compared to the untreated control (Graph 1). DMN at 80 ppm was more effective than DMN at 40 ppm at slowing sprout development.



Graph 1 – Sprouting severity in trial tubers (sprouting shown by % weight of sample)

Storage Trials (Cont.)

Specific gravity and colour testing showed no differences in specific gravity values and all treatments produced chips of good colour (Table 3). There were increased sugary ends in the tubers treated with the highest rate of DMN (Figure 9).

Treatment	Specific gravity Acceptable range is 1.080 to 1.086.	Cook test (colour) 0 is light, 5 is dark. Up to value 2 is commercially acceptable						Sugary ends
		0	1	2	3	4	5	
Untreated Control	1.083	100%	0%	0%	0%	0%	0%	0%
DMN 40 ppm	1.082	100%	0%	0%	0%	0%	0%	1%
DMN 80 ppm	1.084	100%	0%	0%	0%	0%	0%	50%

Table 3 – Specific gravity and colour cook test results at final assessment



Figure 9 - Cook tests results. C1 = Untreated control, C2 = DMN 40 ppm, C3 = DMN 80ppm.
Note increased number of darkened ends in chips from DMN 80 ppm treated tubers.

Analytical Studies

Solvent extractions

Organic solvents, hexane and dichloromethane (DCM), were initially used to extract 1,4 DMN from potato tissue. However, the organic solvents were found to contain traces of the compound and concerns about the possible contamination of untreated (control) potato samples with 1,4 DMN, given its high volatility, were raised. Furthermore, it was queried as to whether 1,4 DMN was in fact an endogenous compound in potatoes given that naphthalene, methylnaphthalenes and dimethylnaphthalenes are all widely recorded as environmental contaminants.

The following test was undertaken to assess whether the DMNs were likely contaminants of potatoes by examining their relative abundance in the organic solvent DCM and that found on the skin of potatoes.

Untreated potatoes (Russet Burbank) were harvested from a commercial crop grown on the northwest coast of Tasmania. The potatoes were kept from laboratories that (to the knowledge of the researchers) had been previously exposed to elevated levels of 1,4 DMN. The potatoes were washed to remove soil, and the skins were peeled then diced to smaller pieces. 500 grams of the peel tissue was snap frozen using liquid nitrogen and finely ground using a mortar and pestle. 1 litre of Dichloromethane (DCM) was added to the ground tissue and the tissue was extracted using a soxhlet distillation technique.

After 12 hours distillation, the solvent was collected and concentrated to 5 mL using a rotary evaporator. DMNs were monitored using GCMS (Gas Chromatography Mass Spectrometry). Naphthalene, methylnaphthalenes and dimethylnaphthalenes were all detected under full scan mode over a narrow range (Figure 10 a). The detection of dimethylnaphthalenes was confirmed by detection of m/z 141 (a daughter ion of m/z 156) when running GC-MSMS (Figure 10 b,c).

An additional 500 mL of DCM was concentrated to 5 mL to determine the level of the naphthalenes in the solvent used. The level of 1,4 DMN detected in the solvent (approx 1ppb) accounted for the DMN found in the potato extract. Since 1,4 DMN is a common contaminant of solvents, and the level in potatoes appears to be extremely low (<1ppb), the solvent extraction method proved to be unsuitable. Furthermore, the similar peak distribution between the two samples (DCM and DCM plus potato peel) indicates that any DMN detected in the skin of potatoes using this method were environmental contaminants rather than endogenous compounds (Figure 11).

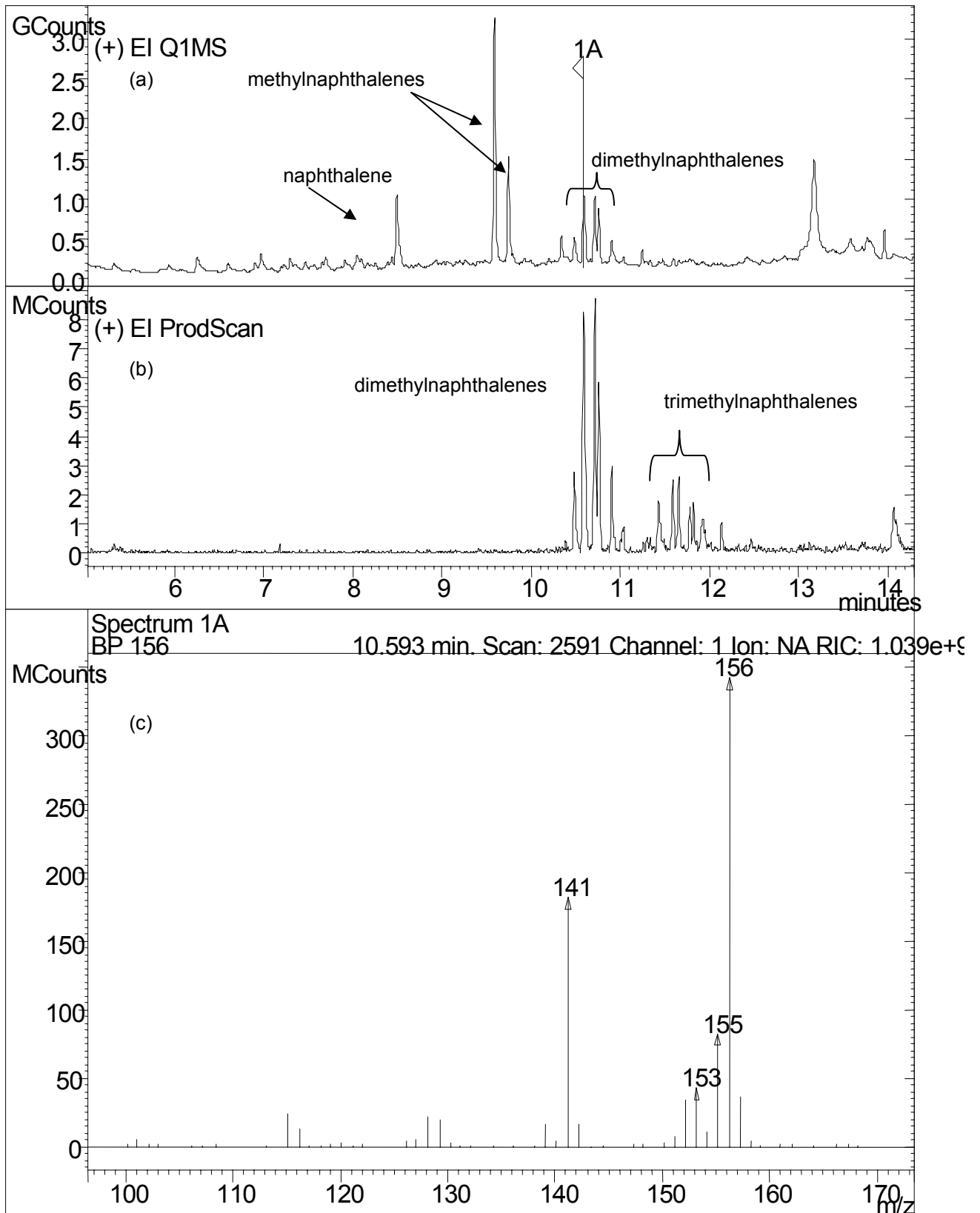


Figure 10. GCMS chromatograms of potato peel extracted using DCM, (a) Full Scan MS mode; and (c) partial mass spectrum from a DMN isomer; (b) GCMSMS chromatogram m/z 151 \rightarrow 141.

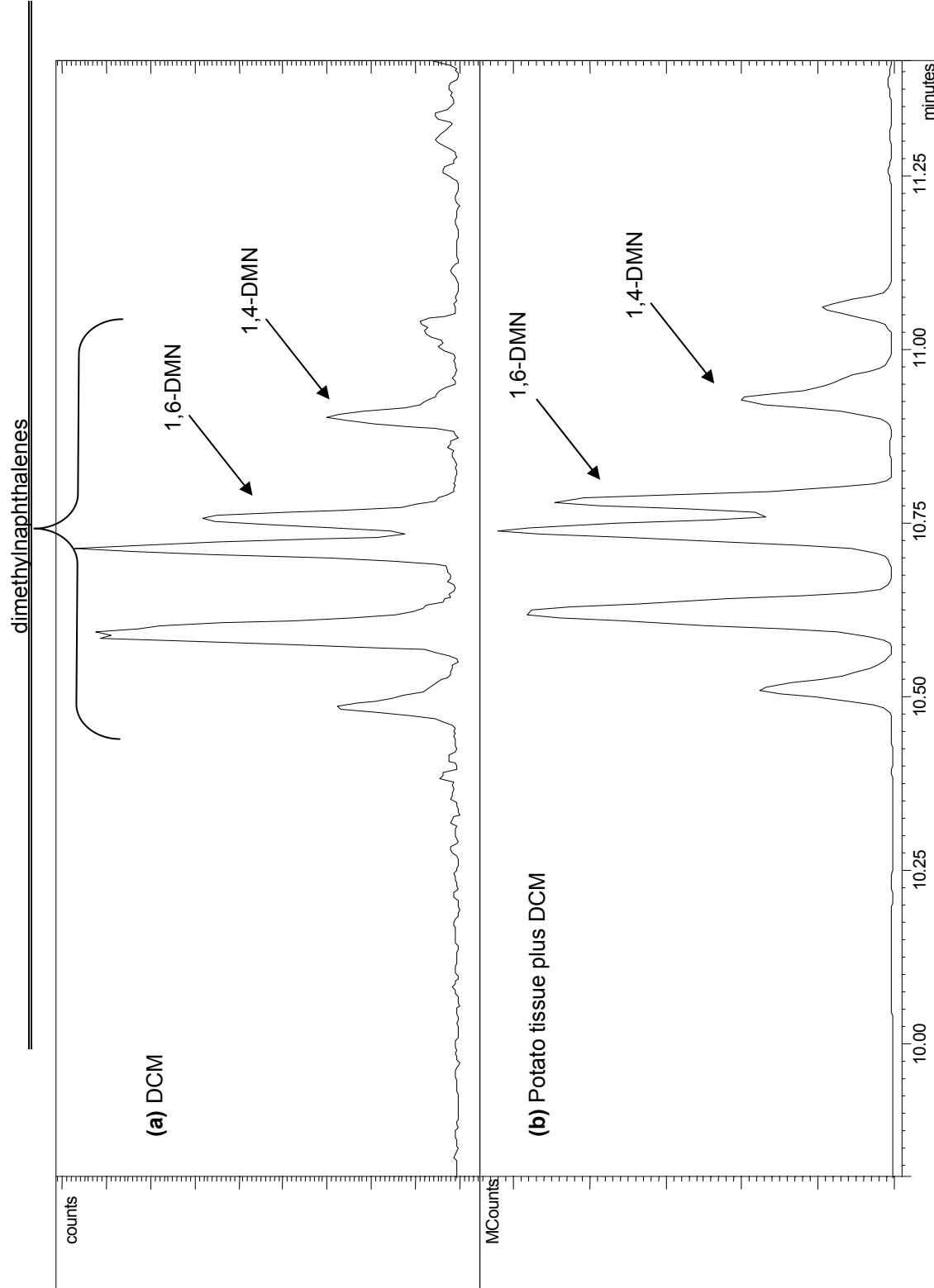


Figure 11. GC/MS/MS Chromatograms m/z 151 → 141 of dimethylnaphthalenes (DMN) in (a) concentrated DCM and (b) concentrated potato tissue in DCM

Analytical Studies (Cont.)

Headspace - SPME (Solid Phase Microextraction)

Given that organic solvents contain trace levels of 1,4 DMN, and that the levels in potatoes are extremely low (< 1 ppb), improved methods of detection were required. In the present study, the use of a Headspace - SPME to sample the volatile 1,4 DMN and quantification by GCMS SIM (Selection Ion Monitoring) was developed. This method was employed to report levels of 1,4 DMN in the experiments conducted during 2003.

Sample preparation

Three frozen potato tubers were washed to remove soil. The wash-water was collected and the concentration of 1,4 DMN in the water was determined (as described below) and expressed as the total amount of 1,4 DMN (ng) washed from the potatoes.

After washing, the skin from the potatoes was removed using a potato peeler and weighed. An equal weight of distilled water was added to the skin (i.e., the ratio of skin:distilled water added was 1:1 (w/w)), then homogenised using a blender.

The cortex was finely chopped and a sub sample taken weighing approximately 50 g. An equal weight of distilled water was added to the cortex sample (i.e., the ratio of cortex:distilled water added was 1:1 (w/w)), then homogenised using a blender.

1,4 DMN quantification by Headspace-SPME

20 g of wash water or puree (skin or cortex) was added to a 40 mL glass vial used for headspace analysis (screw top lid with teflon/silicon seal). The samples were stirred (to create a vortex) during headspace analysis using a magnetic stirrer. A SPME-PDMS (polydimethylsiloxane) fibre was inserted into the headspace of the vial for 5 minutes adsorption period (Figure 12). The volatiles were then desorbed from the fibre and quantified using GC/MS (Figure 13).



Figure 12. SPME method used to adsorb volatiles from the headspace. The solution was stirred to create a vortex during the 5-minute adsorption period



Figure 13. Varian 1200 Triple Quad GC/MS used to detect DMN

Analytical Studies (Cont.)

GC/MS settings for Headspace-SPME analysis

GC settings: 30 m Varian 'Factor Four' VF-5ms capillary column (0.25 mm, 0.25 micron film) was used. The flow rate was 1.5 mL/min (constant flow on), the injections were in splitless mode, the injector was held at 220 °C, and the column oven was held at 50 °C for 2 minutes, then ramped to 200 at 20 °C per minute, then to 250 at 30 °C per minute. The ion source was at 200 °C, the transfer line at 280 °C, and electron ionisation mode at 70 eV. Selected ion monitoring (SIM) was used to detect trace levels on ions at m/z 128, 141, 142 and 156, which gave naphthalene, methyl naphthalenes and dimethyl naphthalenes. The MS multiplier gain was varied depending on the amount of DMN expected in the samples - for the ultra trace work it was 1400 V, for the much higher levels of DMN treated samples it was 1000 V.

Recovery of DMN

1,6 DMN spikes were used to determine the recovery by SPME, and to set detection limits. 1,6 DMN was used instead of 1,4 DMN to avoid contamination occurring due to the high volatility of the DMN compounds.

Detection limits, given in Table 4, were set at 10 times the background noise. Peaks lower than the detection limits, but 3 times higher than the background noise, were referred to as trace detections and all peaks less than the trace levels were referred to as not detected (n.d.).

Table 4. Detection limits of 1,4 DMN using SPME method

Component	Detection limits
Wash water	0.004 ppb
Potato cortex	0.018 ppb
Potato peel (skin)	0.030 ppb

The recovery of DMN was greatest from water (Figure 14). The recovery from cortex was ca. 4.5 times lower than water, while the recovery from skin tissue was ca. 8 times lower than water. Five separate replicates of cortex tissue (from the same untreated potato), spiked with 1,6 DMN at 1 ppb, were assessed to test the precision of the SPME technique employed. A coefficient of variation of 10.3% was recorded. The strong peaks from 100 ppb (Figure 15a) and 10 ppb (Figure 15b) spikes of 1,6 DMN to potato peel illustrate the high sensitivity of the SPME method.

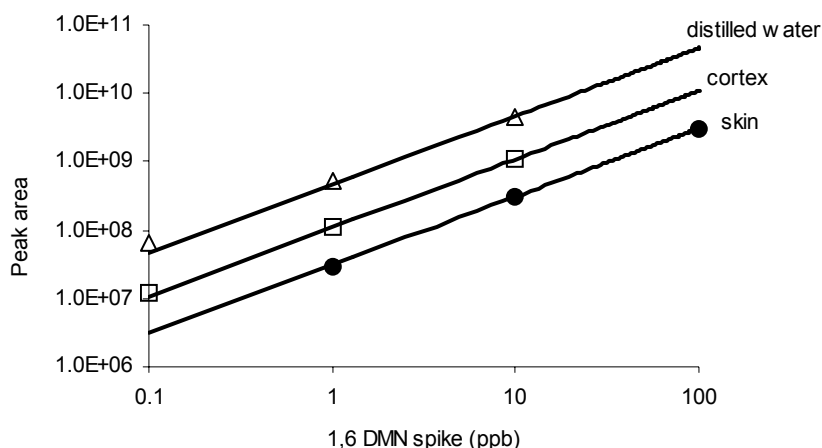


Figure 14 - Relationship between 1,6 DMN spikes (ppb) and peak area from GCMS SIM at m/z 156 for water, potato cortex and potato skin matrix using SPME technique. Linear regressions are shown. Both axes are shown on log₁₀ scale.

Analytical Studies (Cont.)

Winter 2003

Materials and Methods

Sample preparation, and detection method was consistent with the Headspace - SPME (Solid Phase Microextraction) outlined above.

Results

The level of 1,4 DMN detected in the skin of untreated potatoes (stored in separate container at a different location to 1,4 DMN treated) did not significantly ($p < 0.05$) change over the storage period (23 June – 10 October 2003) and ranged from 0.143 - 0.244 ppb (Table 5). A typical group of DMN peaks from untreated potato skin is given in Figure 17a. The relative height and distribution of the peaks is consistent with the distribution associated with environmental contamination.

Potatoes treated with 1,4 DMN at 40 ppb and 80 ppb displayed strong peaks of 1,4 DMN (Figure 17b), ranging from 80 to 200 ppb in the skin, and 6 -12 ppb in the cortex (Table 5). The large variability between replicates, combined with the low number of replicates assessed, made changes associated with storage duration impracticable to deduce. Furthermore, a large proportion of 1,4 DMN was washed from the surface of the potatoes (Table 5) prior to tissue sampling, and therefore was either bound to the soil particles or to the surface of the potato skin.

Untreated potatoes stored in the same commercial storage container as 1,4 DMN pre-treated potatoes showed an elevated level of 1,4 DMN relative to the other DMN peaks (Figure 17c). This was consistent with the ca. 5 fold increase in 1,4 DMN detected in the skin from the commencement of storage (23 June 2003) (Figure 17). This elevated level of 1,4 DMN in these skins demonstrates the high volatility of 1,4 DMN and its high affinity for potato skins.

Only trace levels of DMN were recorded in the cortex of untreated potatoes (Table 6), while a small amount was washed from the surface of the potato (Table 6).

Most of Tasmania's vegetable production occurs along the northwest coast on the fertile red ferrosol soils. Approximately 300 grams of this soil type were collected from three separate sites. Each soil sample contained traces of DMNs (Figure 18) in distribution consistent with environmental contamination.

Potato tubers from different cultivars were also purchased from a local market. Only trace levels were detected in both the peel and the cortex tissue of all 7 cultivars assessed (Table 7).

Conclusion

There was no evidence that 1,4 DMN or any other DMN occurs naturally in potatoes. Several literature reports relate to the absorption of PAHs (Polycyclic Aromatic Hydrocarbons), such as DMNs, by plants from root and aerial exposure, especially root vegetables. All DMNs observed in untreated potatoes in this study were consistent with the pattern found in normal PAH profiles and are environmental contaminants.

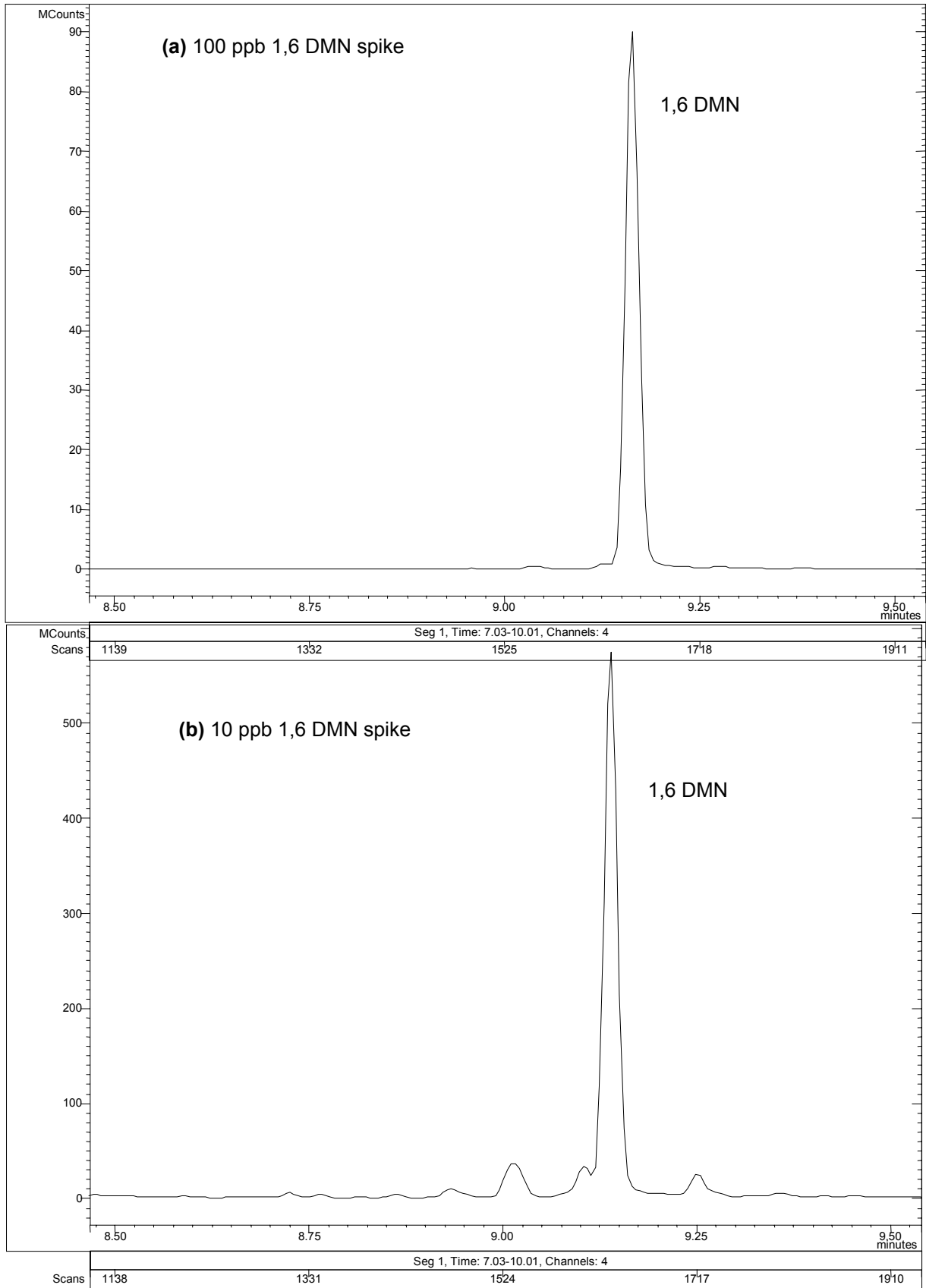


Figure 15 - Mass chromatograms m/z 156 from SIM showing potato peel spiked with 1,6 DMN at (a) 100 ppb, and (b) 10 ppb. Headspace – SPME sampling technique used.

Analytical Studies (Cont.)

Table 5. Level of 1,4 DMN in water used to wash potatoes, the peel and cortex. Potatoes were treated on the 23 June 2003 with 40 or 80ppm 1,4 DMN and stored until 10 October 2003. Standard deviation in parentheses, n=3 for peel samples.

Sample Date	Wash Water (ng)		
	Untreated	Treated 40 ppm	Treated 80 ppm
23-Jun	16.400*	NR	NR
12-Aug	NR	362.5	407.8
10-Oct	NR	573.2	1163.9

Sample Date	Potato Peel (ppb)					
	Untreated		Treated 40 ppm		Treated 80 ppm	
23-Jun	0.182	(0.046)	NR		NR	
12-Aug	0.244	(0.072)	84.3	(27.2)	202.0	(71.4)
10-Oct	0.143	(0.040)	119.5	(36.6)	95.6	(13.5)

Sample Date	Potato Cortex (ppb)		
	Untreated	Treated 40 ppm	Treated 80 ppm
23-Jun	trace	NR	NR
12-Aug	trace	12.968	12.560
10-Oct	trace	9.843	6.148

Cortex trace < 0.018 ppb; skin trace < 0.030 ppb; N.R. = Not Recorded. * Post sampling contamination

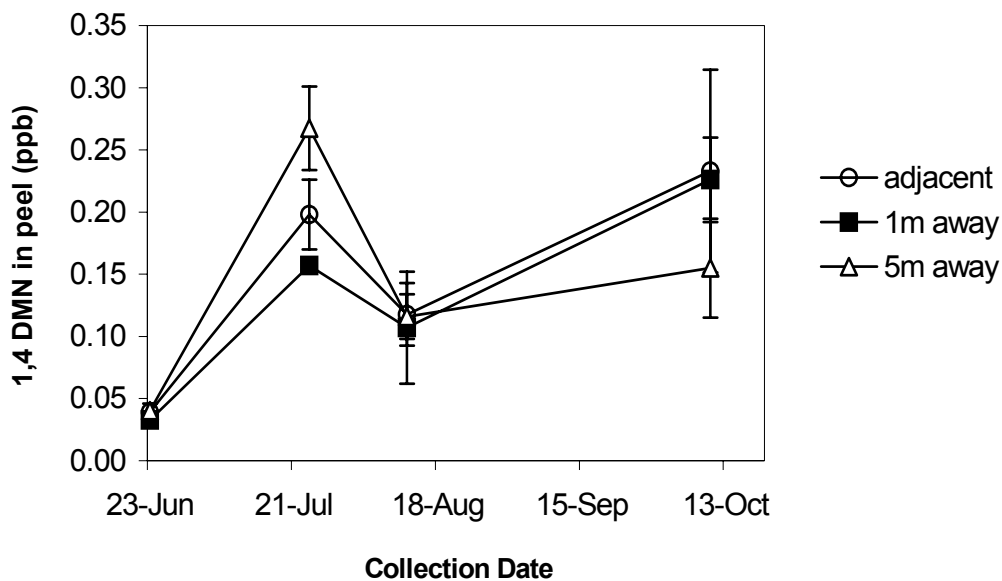


Figure 16 - Level of 1,4 DMN in the peel of potatoes stored adjacent, 1 m or 5 m away from potatoes pre-treated with 1,4 DMN at 40 and 80 ppm. Potatoes were sampled 23 June (start of storage), 24 July, 12 August, and 10 October 2003 S.E.M bars are shown where larger than symbol, n=3.

Analytical Studies (Cont.)

Table 6. Level of 1,4 DMN in water used to wash potatoes, and in the potato cortex. Values are shown for potatoes stored adjacent, 1 m or 5 m away from potatoes pre-treated with 1,4 DMN at 40 and 80ppm. Potatoes were sampled 23 June (start of storage), 24 July, 12 August, and 10 October 2003.

Sample Date	Wash (ng)		
	Adjacent	1m Away	5m Away
23-Jun	14.2		
24-Jul	29.7	32.8	29.0
12-Aug	19.0	22.7	35.5
10-Oct	40.5	29.2	60.4

Sample Date	Cortex (ppb)		
	Adjacent	1m Away	5m Away
23-Jun	trace	trace	trace
24-Jul	trace	trace	trace
12-Aug	trace	trace	trace
10-Oct	trace	trace	trace

Cortex trace < 0.018 ppb, skin trace < 0.030 ppb

Table 7. Level of 1,4 DMN in cortex and skin of a range of potato cultivars. Potatoes were sourced from a local market.

Cultivar	cortex	skin
Binjte	trace	trace
Bismark	trace	trace
Desiree	trace	trace
Dutch Cream	trace	trace
Nadine	trace	trace
Pinkeye	trace	trace
Sweet Potato	trace	trace

Cortex trace < 0.018 ppb, skin trace < 0.030 ppb

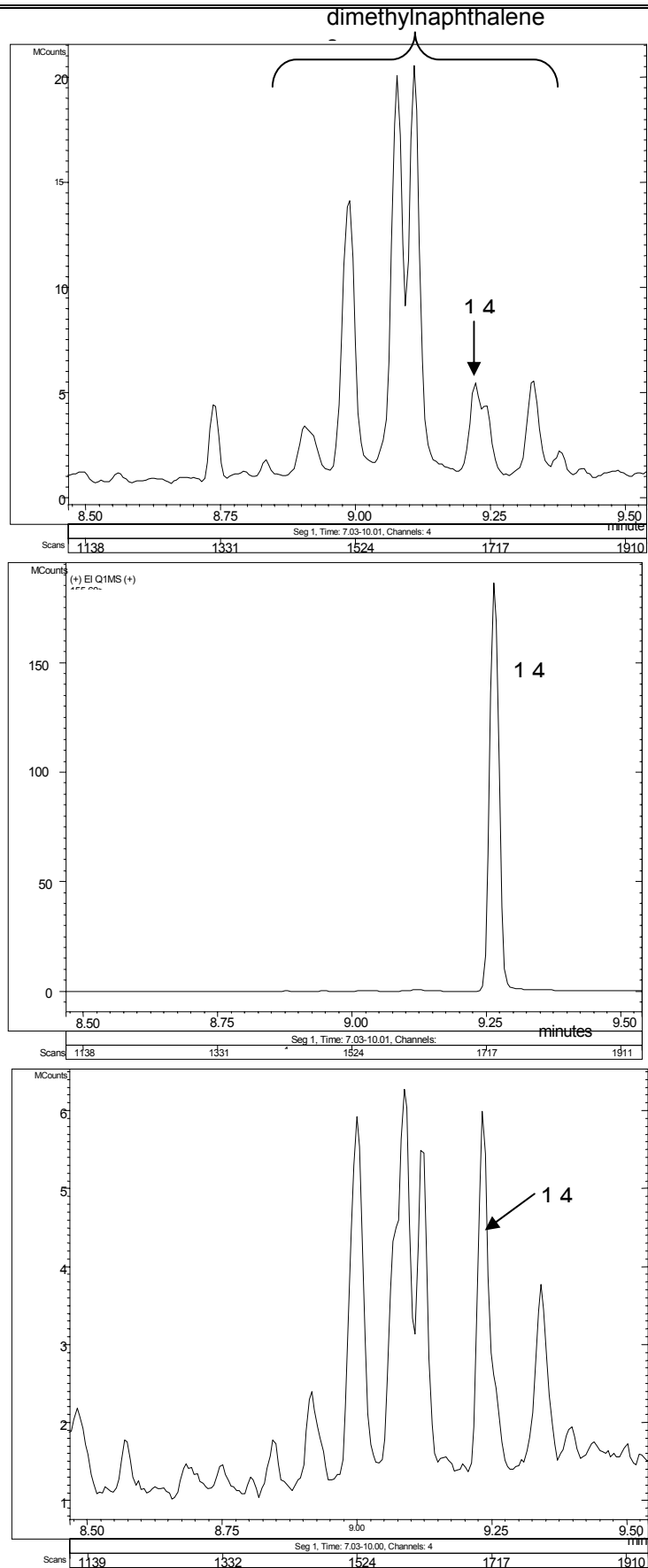


Figure 17 - Mass chromatograms m/z 156 from SIM of (a) untreated potato peel, (b) potato peel 50 days after treatment with 1,4 DMN at 40 ppm, and (c) peel from potato stored in close proximity to the 1,4 DMN treated potatoes. Headspace – SPME sampling technique used

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dimethylnaphthalenes

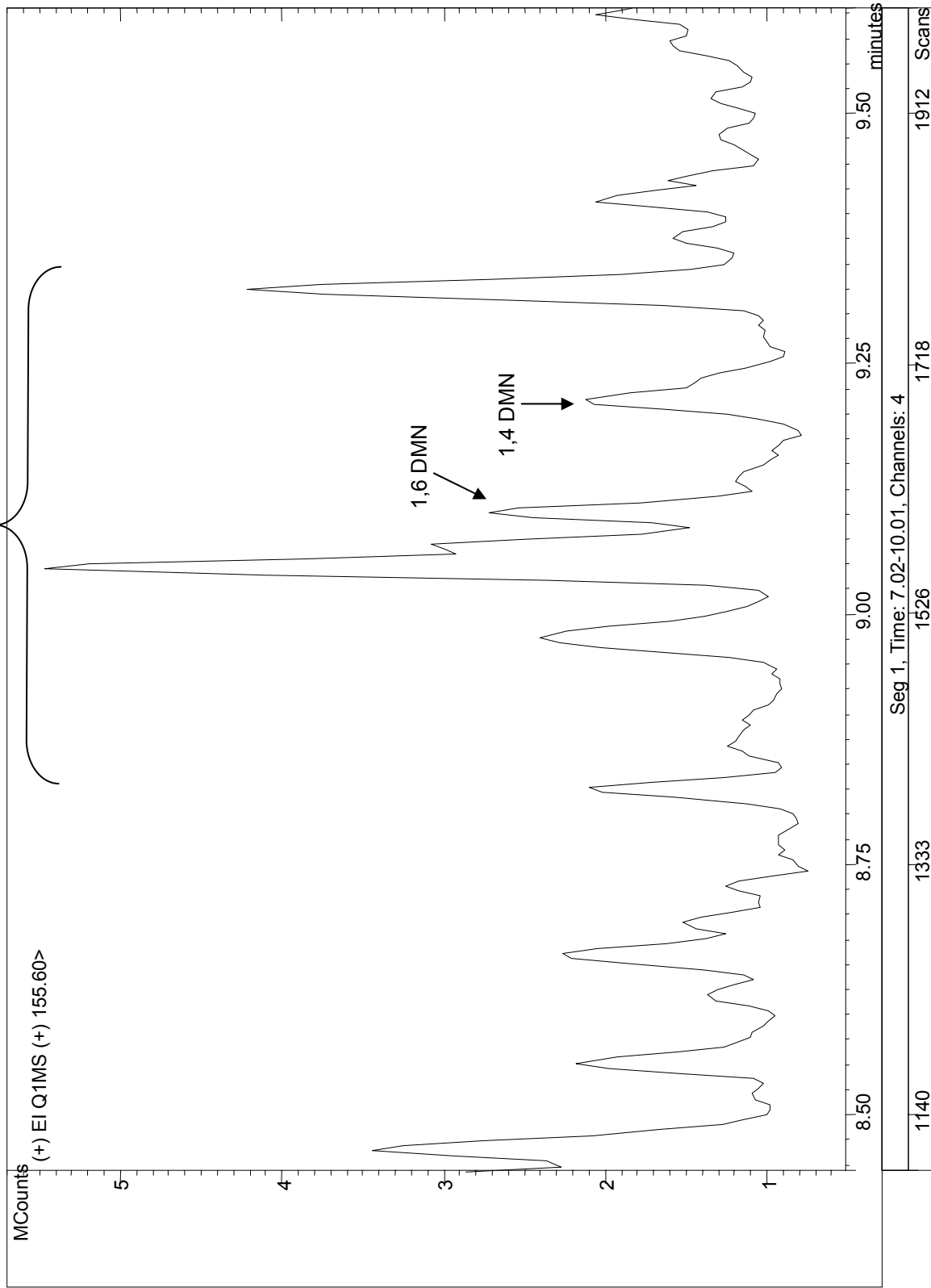


Figure 18 - Mass chromatograms m/z 156 from SIM showing trace levels of DMN in red ferrosol soils used for cropping on northwest coast of Tasmania. Headspace – SPME sampling technique used.

General Discussion

Trial work within small sealed drums was conducted in winter 2002 but conditions proved to be too anaerobic for the potatoes, and were completely different from commercial environmental conditions.

In the following storage season, treated tubers were stored in a commercial storage shed in order to achieve correct environmental conditions. However, the volatile DMN quickly moved out of the treated tubers and did not maintain adequate sprout suppression. DMN was detected in tubers adjacent to the treated tubers, indicating that it was moving through the storage shed.

Evaluation of DMN requires specific facilities that were not available in the course of this project. Due to the volatility of DMN, a sealed facility is required.

Commercial application of DMN in Australia will rely on storage facilities being well sealed, with good environmental management within the store.

In both years of trial work, results indicated that DMN is able to inhibit sprout development in potato tubers. However, due to the limited ability to conduct trials simulating commercial conditions, it is difficult to make any judgments on commercial efficacy of the product. Overseas information indicates that typically 4 or 5 DMN applications are required throughout the storage season. The economic feasibility of this application regime versus current CIPC use was not considered in this project, but it would be an important consideration prior to further product development work. In the course of this project, a new solid block formulation of CIPC has been registered for use in Australia. This formulation, known as Tato-Bloc, has reduced occupational health and safety concerns compared to the old liquid formulation of CIPC.

Ideally, DMN should be evaluated in a small commercial store where the product is tested with existing application technology and environmental conditions. The smallest commercial stores available to the project team were 700 t. It was beyond the budget of the project to treat this volume of potatoes, because all tubers would have to be destroyed and compensated at market value.

Analytical results from this project were very significant. DMN does not appear to be an endogenous product in potatoes. DMN is a very volatile, ubiquitous substance and it can occur as a contaminant in potatoes. Previously reported levels of endogenous DMN were likely to have resulted from detection of contaminants.

The new analytical method developed by the University of Tasmania can detect DMN at levels around 0.01 ppb. This is around 10,000 times better than methods previously reported in the scientific literature. The project chemists found that sample contamination with other DMN isomers was problematic, and they developed a method of head space analysis to avoid this problem.

Recommendations

- Physically separated and purpose built trial facilities are required to ensure that contamination of untreated tubers does not occur. Trial facilities must be a simulation of environmental conditions in commercial storages. Practically, this is very difficult to achieve.
- A detailed biochemistry study is required to determine how DMN is metabolised within the potato, and what is the role of other naphthalene compounds. All indications to date suggest that DMN is an effective sprout inhibitor. What is its mode of action?
- In order to develop DMN as a commercial product in Australia, data will need to be provided to the Australian Pesticides and Veterinary Pesticides Authority (APVMA). At this stage, it is not clear what extra studies may be required to satisfy APVMA requirements. This will need to be determined by consultation between a registrant and the APVMA.

Technology Transfer

- Information about this project has been presented to:
 - Simplot Industry Session
 - Agricultural Research and Advisory Committee Industry Communication Day
- An article about this project appeared in “Eyes on Potatoes”.
- A scientific paper is in preparation for the *Journal of Agriculture and Food Chemistry*.
- Current promotional material for the product states that DMN is a naturally occurring compound in potatoes. Given that the findings from this project dispute that claim, the project team have been reluctant to widely promote outcomes to industry at this stage.

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Thanks to Leon White and Peter Hardman, Simplot Ulverstone, for provision of space in Simplot commercial stores. Leon White did the specific gravity and cook testing of trial potatoes.

Thanks to McCain Foods Australia Pty Ltd, Simplot Pty Ltd, Forth Farm and Arnotts Snack Foods for provision of potato samples. Thanks to Alpha Research Limited (Paul Munro) for the loan of the fogger used in the first year of trials. Thanks to Adrian at Smith's Pest Control for the loan of the fogger used in the second year of trials.

Thanks to various industry advisers including Garry Elliot, Les Murdoch, Peter Hardman, Fraser Mearns, Kevin Clayton-Greene, Iain Kirkwood, Allan Smith and Tony Gietzel.

Appendix i - MSDS for 1,4Sight®

1,4SIGHT® (1,4-DIMETHYLNAPHTHALENE) MATERIAL SAFETY DATA SHEET Revision Date: September 22, 1999	
EMERGENCY TELEPHONE NUMBER: CHEMTREC 1-800-424-9300	
SECTION 1: MANUFACTURER'S INFORMATION	
D-I-1-4, Inc. 2307 E. Commercial Street Meridian, ID 83642 Telephone: 208-887-9766	
SECTION 2: PRODUCT IDENTITY	
TRADENAME: 1,4SIGHT® CHEMICAL NAME: 1,4-Dimethylnaphthalene COMMON NAME: 1,4-DMN CAS #: 571-58-4 CHEMICAL FAMILY: Alkyl-substituted naphthalene CHEMICAL FORMULA: C ₁₂ H ₁₂	
SECTION 3: HAZARDOUS INGREDIENTS	
EPA PESTICIDE PRECAUTION: WARNING INGREDIENTS STATEMENT 1,4-Dimethylnaphthalene: 94.7% Related impurities: 5.3% PERMISSIBLE EXPOSURE LIMITS: None established.	
SECTION 4: PHYSICAL DATA	
COLOR: Pale yellow @ 21°C PHYSICAL STATE: Clear liquid @ 21°C ODOR: Petroleum distillate @ 21°C BOILING POINT: 264°C @ 744 mm Hg MELTING POINT: 5°C SPECIFIC GRAVITY (H ₂ O=1): 1.014 (25°C/25°C) pH: 5.9 VISCOSITY: 6 cps @25°C @ 12 and 30 rpm SOLUBILITY: Water = 5.1 ppm @ 25°±1°C	

VAPOR PRESSURE (Air =1): 1.88 x 10⁻² mm of mercury @ 25°C (2.5 Pa @ 25°C)
 4.85 x 10⁻² mm of mercury @ 35°C (4.85 Pa @ 35°C)
 8.75 x 10⁻² mm of mercury @ 45°C (11.7 Pa @ 45°C)
 FLASH POINT: 122°C @ 760 mm Hg (Pensky-Martens Closed Tester)
 EXPLODABILITY: Not explosive @ 25°C @ minimum drop height of 32.25 inches

SECTION 5: FIRE AND EXPLOSION HAZARD DATA

FLAMMABILITY: Not considered flammable under United Nations/DOT criteria. Will support combustion and decompose under fire conditions to form toxic organic materials and toxic/corrosive oxides of carbon and nitrogen.

FLASH POINT: 122°C @ 760 mm Hg (Pensky-Martens Closed Tester)

EXPLODABILITY: Not explosive @ 25°C @ minimum drop height of 32.25 inches

EXTINGUISHING MEDIA: Water spray, CO₂ or dry chemical.

SPECIAL FIRE FIGHTING PROCEDURES: As in any fire, prevent exposure to smoke, fumes and products of combustion. Evacuate non-essential personnel. Fire fighters should wear NIOSH/MSHA-approved full-face, self-contained breathing apparatus and impervious clothing.

SECTION 6: TOXICOLOGY/HEALTH HAZARD DATA

ACUTE LD₅₀ ORAL = 2730 mg/kg (rats)

ACUTE LD₅₀ DERMAL > 2000 mg/kg (rabbits)

ACUTE LC₅₀ INHALATION > 4.2 mg/L (rats); 4-hour exposure

SKIN IRRITATION: Can cause moderate irritation

EYE IRRITATION: Can cause moderate irritation

HYPERSENSITIVITY: Did not cause hypersensitivity reaction (guinea pigs)

HYPERSENSITIVITY INCIDENTS: None

MUTAGENICITY - Gene Mutation: Non-mutagenic

MUTAGENICITY- Micronucleus Assay: Non-mutagenic (Ames Test)

MUTAGENICITY- Unscheduled DNA Synthesis: Non-mutagenic (mouse)

CARCINOGENICITY: Not listed as a carcinogen by IARC, NTP, ACGIH or OSHA

SECTION 7: ENVIRONMENTAL HAZARDS

AVIAN ACUTE ORAL TOXICITY: LD₅₀ >2000 mg/kg (Bobwhite quail)

FRESHWATER FISH TOXICITY: LC₅₀ = 0.67 mg/L (Rainbow trout)

FRESHWATER INVERTEBRATE TOXICITY: LC₅₀ = 0.56 mg/L (*Daphnia magna*)

This product is highly toxic to freshwater fish and aquatic invertebrates. Do not contaminate water by disposal of equipment wash waters.

SECTION 8: EFFECTS OF OVEREXPOSURE

This section covers effects of overexposure by inhalation, eye/skin contact, ingestion and other types of overexposure information in the order of the most hazardous and the most likely route of overexposure

ROUTES OF EXPOSURE: The primary routes of exposure are inhalation and skin contact.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: There are no medical conditions that are known to be aggravated by exposure to this product.

ACUTE EXPOSURE: Can cause substantial but temporary eye injury. Harmful if swallowed. Do not get in eyes, on skin, or on clothing. Wear goggles, face shield or safety glasses. Wash thoroughly with soap and water after handling and before eating, drinking or using tobacco. Remove and wash contaminated clothing before reuse.

EMERGENCY AND FIRST AID PROCEDURES

If in **Eyes:** Call a physician. Hold eyelids open and flush with a steady gentle stream of water for at least 15 minutes.

If **Swallowed:** Call a doctor or get medical attention. Do not induce vomiting or give anything by mouth to an unconscious person. Drink promptly a large quantity of milk, egg whites, gelatin solution, or, if these are not available, drink large quantities of water. Avoid alcohol.

If on the **Skin:** Wash with plenty of soap and water. Get medical attention.

If **Inhaled:** Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

SECTION 9: REACTIVITY DATA

STABILITY: No decomposition for 14 days @ 55°C in dark
13.7% decomposition for 14 days @ 55°C in light
No decomposition for 1 hour @ 100°C in presence of Al, Fe, and Sn powders

HAZARDOUS POLYMERIZATION: Will not occur.

INCOMPATIBILITY (MATERIALS TO AVOID): Strong oxidizing agents.

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide, carbon dioxide and nitrogen oxides may form during combustion.

SECTION 10: SPILL OR LEAK PROCEDURES

For spill, leak, fire, exposure, or accident call CHEMTREC 1-800-424-9300.

STEPS TO BE TAKEN IF MATERIAL IS SPILLED OR RELEASED: Immediately evacuate the area and provide maximum ventilation. Remove all ignition sources. Unprotected personnel should move upwind of spill. Only personnel equipped with proper respiratory and skin/eye protection should be permitted in area. Dike area to contain spill. Take precautions as necessary to prevent contamination of ground and surface waters. Recover or absorb spilled material on sawdust or vermiculite and place in closed containers for disposal. After all visible traces have been removed, thoroughly wet vacuum the area.

WASTE DISPOSAL METHOD: Dispose of contaminated sawdust and vermiculite in a permitted hazardous waste management facility. Care must be taken when using or disposing of chemical materials and/or their containers to prevent environmental contamination. It is your duty to dispose of the chemical materials and/or their containers in accordance with the Clean

Air Act, Clean Water Act, the Resource Conservation and Recovery Act, as well as any other relevant federal, state, or local laws/regulations regarding disposal.

SECTION 11: SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: Face-sealing goggles, unless a full-face respirator is worn; and a respirator with an organic vapor-removing cartridge with a pre-filter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C) or a canister approved for pesticides (MSHA/NIOSH approval number prefix TC-14G) or a NIOSH approved respirator with an organic vapor (OV) cartridge or canister with any R, P or HE prefilter.

VENTILATION: General or local exhaust sufficient to minimize employee exposure.

EYE PROTECTION: Chemical goggles or face shield.

OTHER PROTECTIVE EQUIPMENT: Applicators and other handlers must wear long-sleeved shirt, long pants, shoes plus socks, and chemical resistant gloves (such as Nitrile or Butyl). For reentry into treated areas during application and prior to ventilation or settling of aerosol fog, workers must additionally wear coveralls.

SECTION 12: SPECIAL PRECAUTIONS

GENERAL

- 1,4SIGHT® is used as an aerosol to enhance the dormancy of potatoes during the storage phase.
- 1,4SIGHT® must not be applied to potatoes in the field.
- Do not use on seed potatoes.
- Do not allow vapors to come in contact with storage areas used for seed potatoes within 60 days of their planting.

STORAGE

- Keep container closed. Do not contaminate water, food, or feed by storage or disposal. This product temporarily inhibits germination of seed potatoes.

PESTICIDE DISPOSAL

- Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.

CONTAINER DISPOSAL

- Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or by other procedures approved by state and local authorities. Do not reuse empty container.

Revisions

Initially prepared - March 22, 1995

First revision - April 5, 1995

Second revision - July 30, 1999

Third revision - September 22, 1999

Appendix ii - Product label for 1,4Sight®

1,4SIGHT	
Aerosol Grade - Potato Sprout Inhibitor	
Active Ingredient: 1,4-Dimethylnaphthalene*	By Weight 94.7%
Inert Ingredients:	5.3%
TOTAL	100.0%
* Contains 7.9 pounds active ingredient per gallon.	
WARNING	
Keep Out of Reach of Children	
PRECAUTIONARY STATEMENTS	
Hazards to Humans and Domestic Animals	
WARNING	
Causes substantial but temporary eye injury. Harmful if swallowed. Do not get in eyes, on skin, or on clothing. Wear goggles, face shield or safety glasses. Wash thoroughly with soap and water after handling and before eating, drinking or using tobacco. Remove and wash contaminated clothing before reuse.	
Statement of Practical Treatment	
If in <u>Eyes</u> : Call a physician. Hold eyelids open and flush with a steady gentle stream of water for 15 minutes.	
If <u>Swallowed</u> : Drink promptly a large quantity of milk, egg white, gelatin solution, or, if these are not available, large quantities of water. Avoid alcohol.	
If on the <u>Skin</u> : Wash skin with soap and large volumes of water.	
Emergency Information	
For spill, leak, fire, exposure, or accident call CHEMTREC 1-800-424-9300	
Environmental Hazards	
This product is highly toxic to freshwater fish and aquatic invertebrates. Do not contaminate water by disposal of equipment wash waters.	
STORAGE AND DISPOSAL	
STORAGE	
<ul style="list-style-type: none"> Keep container closed. Do not contaminate water, food, or feed by storage or disposal. This product inhibits germination of seed potatoes. 	
PESTICIDE DISPOSAL	
<ul style="list-style-type: none"> Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility. 	
CONTAINER DISPOSAL	
<ul style="list-style-type: none"> Do not reuse as a container. Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose in a sanitary landfill, or by other procedures approved by state and local authorities. 	
See Directions for Use and Conditions of Sale on Reverse	
Net Contents: _____ Gallons	
Manufactured For: D-1-1-4, Inc. 15401 Cartwright Road Boise, ID 83703 USA	EPA Reg. Number 67727-1 EPA Est. Number _____ Made in Japan Revision D-1-S

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

NOTICE

1,4SIGHT is used as an aerosol to control the sprouting of potatoes during the storage phase.

In the event it is necessary to enter the storage building during the application or immediately afterwards, before the fog has settled, protective clothing and an appropriate breathing apparatus must be worn.

1,4SIGHT must not be applied to potatoes in the field.

1,4SIGHT should be applied to potatoes after the normal suberization process, when wound healing is complete. The visible skin must be healed over on seed potatoes.

Do not allow vapors to come in contact with, or get near to, storage areas used for seed potatoes.

Several months elapse before using treated storage area for seed potatoes. Air system components (including ducts) and building should be thoroughly cleaned before area is used for storage of seed potatoes.

FORCED AIR DISTRIBUTION METHOD

The humidity must be turned off at least 12 hours prior to the application of 1,4SIGHT. There should not be water standing in the distribution system.

Prepare the aerosol generating equipment as depicted in the diagram. The discharge from the vaporizer should be located downstream from the fans or in a location that will provide for optimum distribution.

Set the controls to recirculate only. The outdoor louvers should be covered and any large leak in the building should be sealed.

Reduced air flow in the distribution system is advantageous.

The 3-phase motors can be slowed down using a frequency drive. The airflow should be slowed only enough to prevent aerosol particle collision.

Wait 24 hours before fresh air is introduced into the storage, then return the storage to "normal" operation.

**TREATMENT OF STORAGE OR OTHER AREAS THAT DO NOT HAVE RECIRCULATING AIR SYSTEMS**

These storages and lots of potatoes are more difficult to treat. Additional steps must be taken to treat these storages.

Place air ventilation ducts on the floor before the area to be treated is filled with potatoes. These ducts should be large enough to carry the air completely under the pile of potatoes with one end open to the room and the other end closed under the pile. These ducts should be no more than 10 feet apart. The duct can be a wooden box with perforations, a corrugated metal pipe with holes, or trenches cut into the floor. When the potatoes are bagged they can be stacked over the vent ducts in such a manner to allow the free flow of air through the stack.

Locate a small fan, either a squirrel cage or tube axial, at the open end of ventilation duct. The discharge from the vaporizer should be located close to the fan inlets.

Completely close off the area to be treated. This may include vent doors in the attic and walk doors around the perimeter. The large truck doors may need to be sealed to prevent excess leakage.

Begin treatment by following the listed steps:

- A. Start the small fans.
- B. Adjust the location of the vaporizer so all the fans get an equal amount of aerosol fog. It may be necessary to move the vaporizer during the application or make the application in multiple phases.
- C. Continue to run the fans until the fog has settled.

Wait 24 hours before fresh air is introduced into the storage, then return the storage to "normal" operation.

APPLICATION

Application of 1,4SIGHT should be made after suberization is complete and before sprouting of potatoes occurs.

Apply at the rate of 1 pound of active ingredient per 50,000 lbs (500 CWT), 20 PPM on a product to potato basis, or 1 gallon per 4,000 CWT.

For volume application, use FORCED AIR recirculation through the pile at rates up to 5.0 CFM per ton of potatoes. For other applications, use the lowest FORCED AIR recirculation available for the applicator. Check for uniform air distribution throughout the pile.

Wait 24 hours before fresh air is introduced into the storage, then return the storage to "normal" operation.

If potatoes are held in storage longer than originally anticipated or sprouting occurs, the potatoes may be retreated. Apply a maximum of four times during storage season.

1 cwt. = 1.67 bushels = 2.5 cubic feet; 1 bushel = 60 pounds = 1.5 cubic feet

CONDITIONS OF SALE

1,4SIGHT, Inc. warrants that the product conforms to its chemical description and is reasonably fit for the purpose stated on the label when used in accordance with directions under normal conditions of use, but neither this warranty nor any other warranty of merchantability or fitness for a particular purpose, express or implied, extends to the use of this product contrary to label instructions, or under abnormal conditions or under conditions not reasonably foreseeable to manufacturer, and buyer assumes the risk for any such use.