VG15010 Demonstration Report

Can calcium cyanamide ($Ca(CN)_2$) fertiliser affect Pythium *spp. and other soilborne diseases in carrots – findings of an on-farm demonstration*

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VG 15010 A multi-faceted approach to soilborne disease management

'A multi-faceted approach to soilborne disease management' (Project VG15010) *is a three-year project (2015-2018) providing Australian vegetable growers with the tools and resources they need to manage the risk of crop losses due to soil-borne diseases.*

VG15010 delivers new information and resources about soilborne diseases to the vegetable industry through the established Soil Wealth and Integrated Crop Protection framework.

This project is a strategic levy investment under the Hort Innovation Vegetable Fund.

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Summary

Calcium cyanamide ($Ca(CN)_2$) fertiliser was tested for efficacy against *Pythium sulcatum* and *P. violae* in a grower led demonstration trial in a commercial carrot crop in Western Australia. The wax coated fertiliser was applied according to manufacturer's instructions at 300 kg/ha and 500 kg/ha of fertiliser to one full length carrot bed each. An untreated bed adjacent to each treated bed was used as control. All standard commercial crop management inputs were applied consistently to treated and control beds. This included nitrogen fertilisers.

Assessments included post-harvest soil testing for available nitrate and ammonium (N-check®), soil and root peel DNA testing for soilborne pathogens by the South Australian Research and Development Institute (SARDI). The SARDI DNA tests for *Pythium sulcatum* and *P. violae* were under development at the time of testing.

Carrots from the treated and the two control beds were harvested separately by machine and graded in a commercial factory using typical sizing and quality standards.

The pack out figures showed that total fresh yields in the $Ca(CN)_2$ treated beds were higher than in untreated beds; on average by 15.4% for the 300 kg/ha and 18.7% for the 500 kg/ha treatment. The greatest difference was in the weight of processing carrots. One reason for the higher weight of processing carrots may have been the impact the additional nitrogen from the $Ca(CN)_2$ fertiliser that became available early in the season. While it reduced root length it may have had an impact on the timing of bulking and thus final root weight at harvest. Oversized carrots are used for processing.

Calcium cyanamide fertiliser contains 19.8 % N. An application of 300 kg/ha supplies 59.4 kg N/ha, 500 kg/ha supply 99 kg N/ha. The effect of additional nitrogen was observed early in the crop as typically shorter roots and lusher tops compared to untreated controls. Despite the differences in nitrogen inputs, the treated and control beds showed no differences in available nitrogen measured just before harvest.

DNA testing results from root and soil samples suggested that cavity spot symptoms seen on carrots after harvest may be mainly caused by *Pythium sulcatum*. Both DNA tests implied that $Ca(CN)_2$ fertiliser may have reduced the *Pythium sulcatum* soil inoculum, the main pathogen causing cavity spot in carrots in Australia.

Take away messages: In research trials with $Ca(CN)_2$ fertiliser, soil N dynamics and plant biomass production (root and shoot) should be included in assessments. If $Ca(CN)_2$ fertiliser is used commercially the N mineralisation from the product must be considered in the crop's N budget and application schedule.

Replicated trials, including proven DNA testing for *Pythium sulcatum* and *P. violae* should be conducted to confirm the efficacy of calcium cyanamide fertiliser on these diseases. If efficacy is confirmed, commercial use options for carrot crops under different production conditions should be investigated.

Introduction

This report presents findings from a grower led, on-farm demonstration trial. Grower led pilot trials provide preliminary feasibility assessments of new practices. They can lead to on-farm adaptation of practices and/or replicated research trials to rigorously test assumptions made because of initial findings.

Metabolism of calcium cyanamide in the soil

Calcium cyanamide fertiliser is wax coated to prevent dust development[1]. In principle, it is a nitrogen fertiliser. Within hours after application to moist soil, hydrogen cyanamide is formed which disperses with the soil water. Hydrogen cyanamide is phytotoxic, hence the herbicidal effects and the required withholding periods before planting. It has strong fungicidal properties and thus can inhibit growth and sporulation of many pathogenic fungi. Calcium dihydroxide, which has a liming effect, is a further immediate breakdown product.

Hydrogen cyanamide completely breaks down in soils within 7 to 14 days. This leads to the formation of urea and, to a certain extent, dicyandiamide, which is known as a nitrification inhibitor. Urea eventually converts to ammonium. The dicyandiamide delays the nitrification of ammonium to nitrate, which easily leaches or is lost as nitrous oxide under wet conditions. In combination with the liming effect of the calcium dihydroxide, the nitrogen is kept in the less leachable ammonium form for some time. As for ammonium from other sources, the ammonium from calcium cyanamide can be taken up by plants and microorganisms, or temporarily fixed to clay minerals.

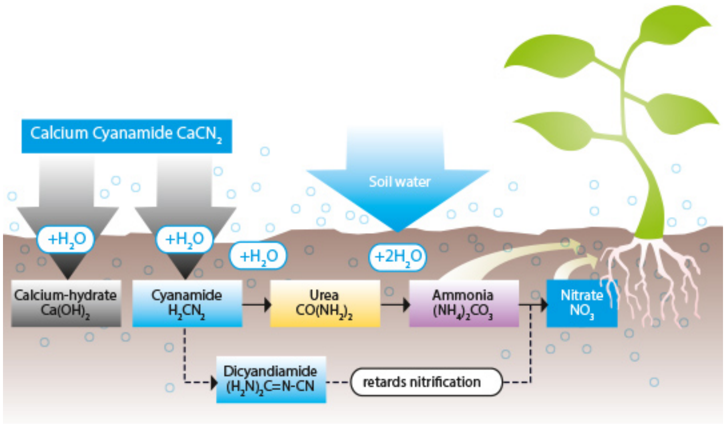


Figure 1 Calcium cyanamide breakdown products (Image used with permission (source: https://www.alzchem.com/en/agriculture/calcium-cyanamide-perlka/effect)

[1] Unrefined, industrial grades of calcium cyanamide are not formulated for the safe use as fertiliser on soils and crops; they are not wax coated to suppress dust development. The dust may be a risk to work place safety. It may contain free, carcinogenic carbide, and potentially further toxic substances. Industrial grade products may also lead to crop losses and soil contamination.

Influence of calcium cyanamide on Pythium *spp.*

Many studies have demonstrated the efficacy of calcium cyanamide fertiliser in controlling diseases caused by soilborne fungi in host/pathogen systems. In several studies, the addition of compost or soil solarisation provided added benefits. Reports about the effectiveness of calcium cyanamide fertiliser on *Pythium* spp. differ. Some trials achieved good control, others little to no control. These differences in trial results may have been due to the following factors: application rates used, the way the product was applied and incorporated, timing of application and subsequent planting, environmental production conditions or level of disease pressure.

Calcium cyanamide fertiliser use in carrots

ITEM	MANAGEMENT
Application for carrots	Recommended by manufacturer: 300-400 kg/ha 2-3 weeks before sowing
Soil moisture at application	Just below or at field capacity
Incorporation depth & method	Normal cultivation depth, can be applied to the top of soil but then N losses may occur and the effect on diseases and weeds lessened
Withholding time before seeding & impact of soil organic matter level	Rule of thumb: at least 2 – 3 days per 100 kg/ha Use the longer withholding periods in light soils and soil with low organic matter levels
Soil moisture at & after application	Conversion from calcium cyanamide to urea and then ammonium will only happen when soil conditions are moist i.e. just below or at field capacity. Conversion usually takes: 6 – 9 days for 300 kg/ha calcium cyanamide 8 – 12 days for 400 kg/ha calcium cyanamide 10 – 15 days for 500 kg/ha calcium cyanamide Soil must be kept moist to incorporation depth during the conversion time. If the crop is sown after more days than it takes to convert it (e.g. 2 weeks), keep soil moist for the duration of conversion only.
Adjacent crop safety	If there are crops close by that are in a sensitive development stage (e.g. establishment to 5 leaf for carrots) ensure that calcium cyanamide dust does not affect them

ITEM	MANAGEMENT
N fertiliser program (needs adjusting)	As with any N-fertiliser the application rate of calcium cyanamide may depend on the nitrogen requirements of the crop and the nitrogen supply from the soil (residual N from crops or cover crops and mineralisation from organic matter)
Liming	Needs adjusting given calcium cyanamide has a liming effect
Environmental	Even where chemical pesticides must be omitted in part or entirely, calcium cyanamide may still be used to take advantage of its phytosanitary effects in addition to its effect as fertiliser In light soils, N may be washed through the rootzone – monitoring recommended

(source of information https:// www.alzchem.com/en/ agriculture/calcium- cyanamide-perlka)

Demonstration trial questions

The trial was to provide preliminary information on the following questions. If results were encouraging, the plan was to conduct a fully replicated follow up R&D trial.

1. Could calcium cyanamide reduce cavity spot / forking incidence and severity caused by *Pythium* spp. in carrots?
2. Could calcium cyanamide reduce *Pythium* spp. inoculum?
3. Should nutrient inputs be adjusted when using calcium cyanamide fertiliser (especially nitrogen nutrition)?
4. How long would a beneficial effect last?
5. Would the economics stack up?

Site details

Property and location

Sun City Farms, Center West Exports, LOT 55 Croot Place, Woodridge WA 6041; Farm and trial management by Francis Tedesco.

- Land availability and cost/market price pressures do not allow for long rotations; therefore, a carrot crop will be grown on the same land at least once each year.
- The economically ideal gap between two crops would be 6 months (to fully utilise the factory and other resources).
- Metham sodium fumigation is used strategically and not every year. Reducing the

use of fumigation is desirable.

- Largely, satisfactory *Pythium* control is achieved via: maintaining neutral to alkaline pH, good soil moisture management, balanced nutrition, especially adequate potassium (K) inputs and carefully managing nitrogen (N) available to the crop, keeping it adequate but low.

Some areas of paddocks and some soils are more prone to *Pythium* due to poorer drainage which is influenced by soil texture / parent material.

FACTOR	COMMENT
Main soil type and texture	Weakly leached siliceous sands represented by Karakatta, Spearwood, Cowalla and Battordal Soil Series formed in alluvial-lacustrine sediments. Brown weak clayey sand becoming yellow-brown with depth 200 cm+. Associated with limestone, pH – neutral.[2]
Trial set up and sampling	Francis Tedesco, Center West and Justin Wolfgang, C-Wise
Soil DNA testing	Michel Rettke, SARDI
Interpretation of findings	Doris Blaesing, RMCG, and Michel Rettke, SARDI
Trial plot area	1 standard bed per treatment
Soil preparation (depth)	Ripping (30 cm), discing (30 cm), rotary hoeing (20 cm)
Crop management	Standard across all treatments including fertiliser and irrigation programs
Irrigation scheduling across all treatments	Soil moisture probes and Et_o used as guidance plus visual / tactile checks of soils
Application of wax coated calcium cyanamide fertiliser	4 weeks before sowing
Sowing	July 16
Harvest	December 16

[2] Henry J. Smolinski and G G. Scholz 1997; Soil assessment of the west Gingin area. http://researchlibrary.agric.wa.gov.au/land_res/15/

Methods

Chemical properties of wax coated calcium cyanamide fertiliser

PROPERTY	DETAIL
Total nitrogen	19.8%
Nitrate nitrogen	1.8%
Cyanamide nitrogen	> 15%
Dicyandiamide nitrogen	approx. 0.5%
Neutralising value (CaO)	> 50%

Treatments

PLOT	TREATMENT	AMOUNT
1	Control 1	0 kg/ha $Ca(CN)_2$
2	Calcium Cyanamide	500 kg/ha $Ca(CN)_2$
3	Control 2	0 kg/ha $Ca(CN)_2$
4	Calcium Cyanamide	300 kg/ha $Ca(CN)_2$

Data collection

Site visits / observations

- Regular site visits and observation of crop development and soil moisture by the farm manager to check on crop development.

Soil analysis

- One week before harvest, 10 random subsamples were taken to 20 cm depth across each treated block and control blocks, combined and mixed well. Then, 500 g of each mixed sample was submitted to AgVita Analytical for N-check® soil analysis (for available nitrate and ammonium).

DNA testing

- Carrot root (peel) and soil sampling for DNA testing was conducted at harvest (06/12/2016) as per instructions provided by SARDI ("Sampling for SARDI Soil DNA pathogen testing VEGETABLE CROPS").
- DNA test of soils and root peel at harvest (standard Predicta test plus specific *Pythium sulcatum* and *P. violae* test – the *P. sulcatum* & *violae* tests were under development at the time of testing)

Factory pack out

- Each plot (entire bed) was harvested separately in early December 2016 and graded over the commercial grading line applying commercial quality standards. Carrots were graded into the classes (pre-packs, small: 28-35 mm, medium: 35-45 mm, large: >45mm) and defects (cavity spot, forking, less than 7.5 cm length or less than 28 mm diameter, splits, cracks, badly deformed roots); weights were recorded for each class.

Findings and discussion

Results from the demonstration trial must be viewed with caution. Treatments were not replicated, while samples within treatments were replicated and bulked. Like results from replicated trials, results from demonstration trials are influenced by the specific production conditions at the chosen location. In this case conditions included sandy soils and agronomic practices typical to the farm. An unusually cool growing season may have had an impact on crop growth and nitrogen dynamics.

Available nitrogen (N) after harvest

Calcium cyanamide fertiliser contains 19.8 % N. An application of 300 kg/ha supplies 59.4 kg N/ha, 500 kg/ha supply 99 kg N/ha. Observations during the season showed that carrot roots in the treated bed were shorter and tops larger, with longer, lusher leaves, than in control beds and the remainder of the paddock. The 'stumpy' appearance of treated carrots suggests excess N availability early in the season, when root length is determined.

The table below shows that, despite the extra N inputs via calcium cyanamide fertiliser, available soil N levels just before harvest did not differ between treatments. The additional N inputs may have been partly used to produce extra carrot biomass (tops and root bulk); some of it may have leached from the rootzone, given the light, sandy soil in the paddock, and higher than normal rainfall during the early growing season (Bureau of Meteorology, data not shown).

Take away message: In research trials with $Ca(CN)_2$ fertiliser, soil N dynamics and plant biomass production should be included in assessments.

PADDOCK	POST HARVEST NO_3-N (KG/HA)	POST HARVEST NH_4-N (KG/HA)	TOTAL N (KG/HA)
CONTROL (average of two beds)	25.0	2.2	27.2
300 (kg/ha) $Ca(CN)_2$	27.6	1.9	29.5
500 (kg/ha) $Ca(CN)_2$	26.1	3.0	29.1

Commercial harvest results

The table below shows the pack out results from the commercial trial harvest.

TREATMENT	CONTROL 1	CONTROL 2	300 (KG/HA) $Ca(CN)_2$	500 (KG/HA) $Ca(CN)_2$
Grades	**Packed out weight (kg)**			
All Class 1	17,025	14,715	17,170	18,770
All other marketable	9,900	10,350	5,400	8,550
Processing	8,550	9,000	17,550	13,950
TOTAL Fresh	35,475	34,065	40,120	41,270

The pack out figures show that yields in the $Ca(CN)_2$ treated beds were higher than in untreated beds. Differences were 15.4% for the 300 kg/ha treatment and 18.7% for the 500 kg/ha treatment compared to the average of the two controls. The greatest increase was in the weight of processing carrots. One reason for the higher weight of processing carrots may have been the impact the additional nitrogen from the $Ca(CN)_2$ fertiliser that became available early in the season. While it reduced root length it may have had an impact on the timing of bulking and final root weight at harvest. Oversized carrots are used for processing.

Given the trial's location within a commercial crop, nitrogen fertiliser rates could not easily be adjusted to account for the additional N inputs via $Ca(CN)_2$ fertiliser.

Take away message: If $Ca(CN)_2$ fertiliser is used commercially, the N mineralisation from the product must be considered in the crop's N budget and application schedule.

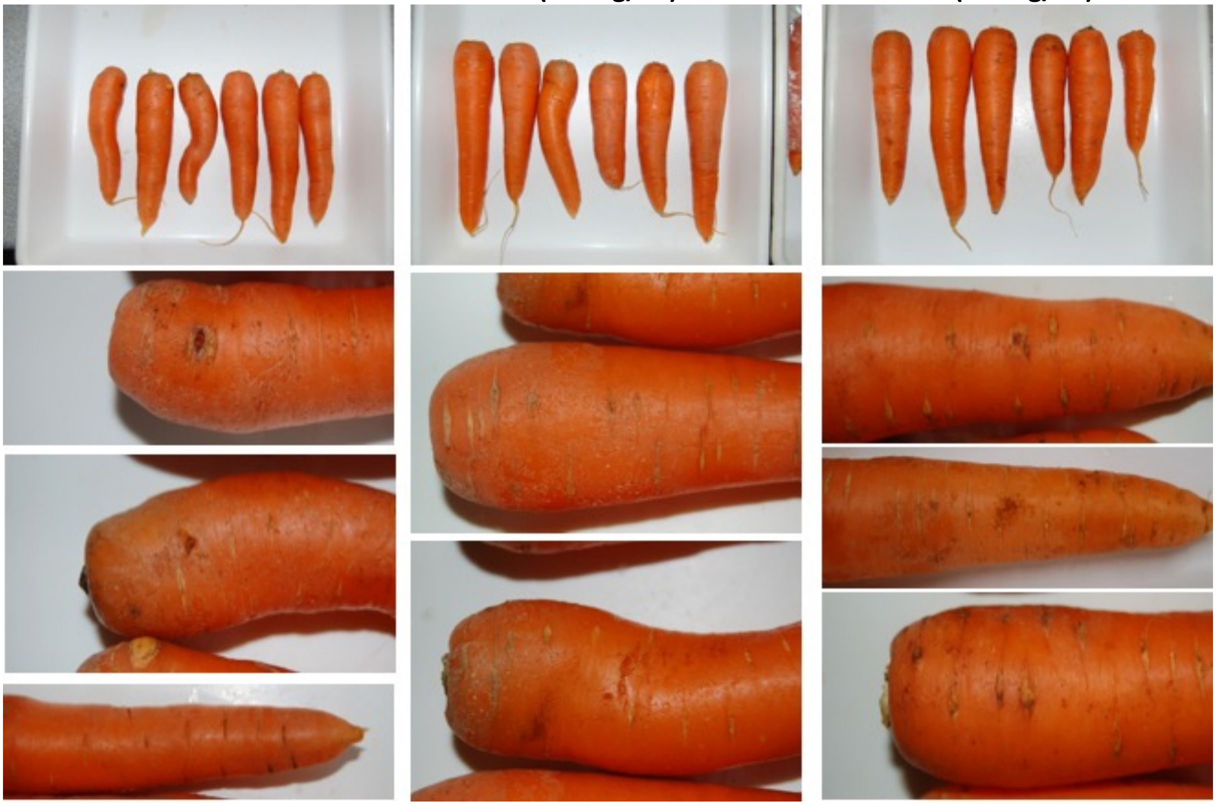
DNA testing of soil and carrot roots

DNA assays for *Pythium sulcatum* and *Pythium violae* were in the development phase at the time of this trial. The trial was used to assist in their development. Therefore, results must be viewed with caution. Any questions about the tests and results should be directed to Michael Rettke (SARDI), mobile 0401 122 124 or email michael.rettke@sa.gov.au.

Cavity spot symptoms were easily found in the trial a month before harvest, especially in a low-lying, wetter area across the trial beds. A visual assessment indicated that cavity spot and forking may have been more prevalent in the control beds than the treated beds. However, these treatment differences were not distinctly noticeable during random sampling of carrot roots for DNA testing across the entire trial area.

The following photos were taken from sampled roots prior to DNA testing. They show that roots from the untreated control bed had some deep cavity spot lesions; roots from the treated areas appear to be somewhat affected by *Pythium* as well.

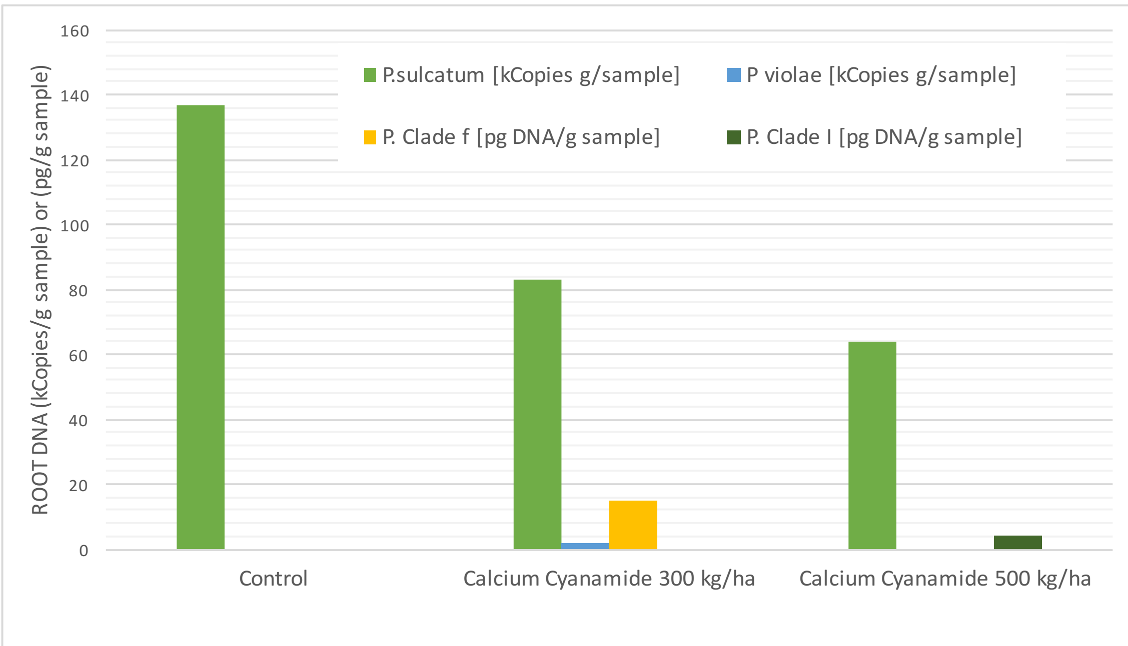
Control	Calcium Cyanamide (500 kg/ha)	Calcium Cyanamide (300 kg/ha)



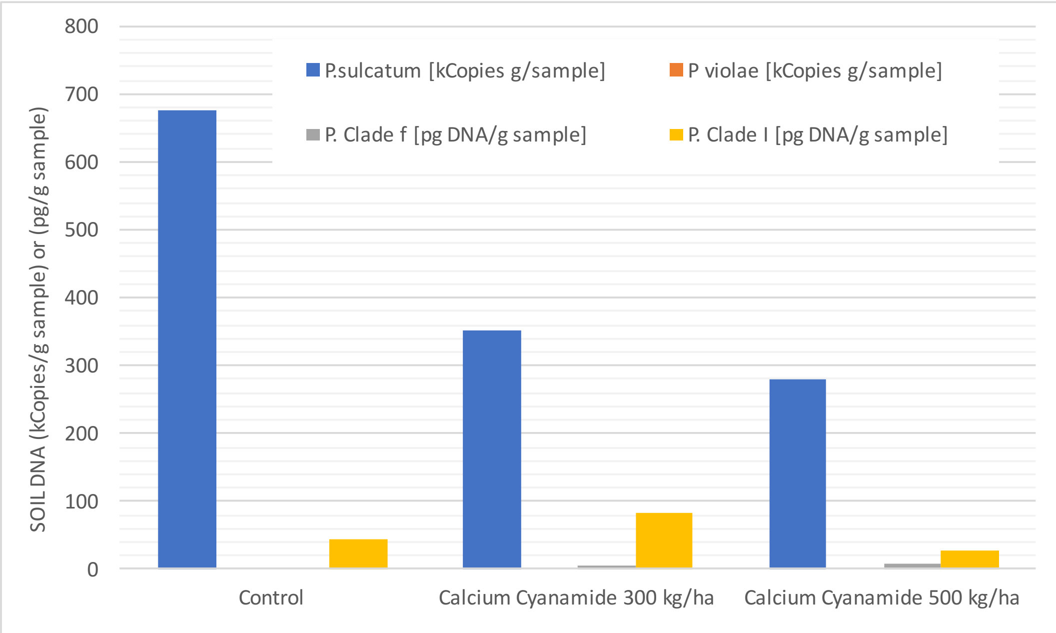
Photos by Michael Rettke, SARDI

The following graphs show the results from the DNA assay, which is under development by SARDI (VG15009).

DNA testing results of carrot roots (peel) shown below suggest that cavity spot symptoms seen on carrots roots may have been caused by *Pythium sulcatum*. N.B. At the time of the trial, limited testing had been conducted using this assay on peel and soil samples.



DNA testing results from soil samples are shown below. They support the above suggestion that symptoms seen on carrots may be mainly caused by *Pythium sulcatum*. Both tests imply that $Ca(CN)_2$ fertiliser may have reduced soil inoculum levels of *Pythium sulcatum,* the main pathogen causing cavity spot in carrots in Australia. Still, soil results for *Pythium sulcatum* appear to be high (Michael Rettke, pers. comms). A single, low level detection of *Pythium violae* suggests that this pathogen could be present in the soil; however suitable research is required to test this hypothesis



Answers to trial questions

	Question	Answer
1	Could calcium cyanamide fertiliser reduce cavity spot and forking incidence and severity in carrots?	Potentially yes, and if caused by *Pythium*
2	Could calcium cyanamide fertiliser reduce *Pythium* inoculum levels in soils?	Potentially yes
3	Should nutrient inputs be adjusted when using calcium cyanamide fertiliser?	Yes, nitrogen programs and lime inputs should be based on soil testing
4	How long does a beneficial effect last?	Needs further investigation
5	Do the economics stack up?	Needs further investigation
6	What are negative side effects?	Potentially excessive nitrogen available to young crops

Next steps

Results of the initial on-farm demonstration trial are encouraging, especially the potential inoculum reduction and the possible yield increase. Still, follow up research and on-farm trials are required to substantiate initial findings. Well designed trials with $Ca(CN)_2$ fertiliser would have to be undertaken to:

- Confirm the effect of $Ca(CN)_2$ on *Pythium* spp., especially *P. sulcatum* and *P. violae*
- Understand soil N dynamics and N effects on plant biomass production including root to shoot ratios
- Develop an approach of adjusting the nitrogen fertiliser program to account for the N content in $Ca(CN)_2$
- Investigate whether calcium cyanamide fertiliser should be used ahead of a cover crop to avoid providing excessive N to young vegetables
- Confirm the magnitude of a liming effect via $Ca(CN)_2$ fertiliser additions
- Reduce the proportion of processing carrots
- Look at the fit of $Ca(CN)_2$ fertiliser in production systems / rotations

- Determine optimum rates and application timing ahead of a carrot crop under different Australian production conditions (soils, climate, agronomic practices)
- Determine the longevity of a potential reduction in *Pythium* inoculum
- Determine whether a reduction in *Pythium* inoculum is cumulative with repeated $Ca(CN)_2$ fertiliser applications
- Determine the effect of $Ca(CN)_2$ on other soil borne diseases e.g. *Rhizoctonia*
- Determine whether $Ca(CN)_2$ fertiliser use in combination with other measures e.g. compost or cover crops will provide added benefits, and
- Determine economic benefits.

In smaller production units and for other crops, e.g. greenhouses, a combination of $Ca(CN)_2$ fertiliser use and soil solarisation may be worth exploring.

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