



The effect of custom made composts on the performance of a carrot crop and soil health

Report prepared for VG15010 A Multi-faceted approach to soilborne disease management

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SUMMARY

A large-scale compost trial was conducted with Center West Export (CWE) and C-Wise in the Gingin area of Western Australia (WA).

The focus was on disease suppression, mainly cavity spot, and maintaining organic carbon and structure in intensively cropped, sandy soils. Fresh organic matter such as manure cannot be used in the Gingin area due to stable fly issues; food safety requirements also mean that fresh manure should not be used just prior to a carrot crop. Any organic amendments must be well composted; they also needed to be of a quality than can be repeatedly produced.

If that was not the case, i.e. compost quality would be variable from batch to batch, the information from this compost trial could not be relevant for other carrot crops on the farm.

Center West Exports provided a 10 ha trial area under solid set irrigation.

C-Wise provided two types of compost – “Humicarb Compost” and “Premium Compost”. These were both used at 30 t/ha and 50 t/ha in 2 replicates of 0.5 ha each. Untreated control areas did not receive compost.

Both companies put in a considerable effort into setting the trial up and looking after it.

Data collection included:

- Soil analyses before and after planting (nutrients, pathogen DNA by SARDI)
- Pre-harvest assessment of roots against CWE grading criteria
- Carrot root analysis (nutrients)
- Commercial grading by CWE
- Field observations and photos.

Trial results can be summarised as follows:

- Compost appears to have reduced soil levels of some *Pythium* and *Rhizoctonia* species / groups that can attack carrots.
- Compost increased phosphorus availability in the soil.
- Compost had no effect on soil pH.
- Nitrogen (nitrate and ammonium) carrot roots were lower in composted areas while levels of available soil nitrogen (nitrate and ammonium N) was higher in composted areas than in the control but not above the desirable level of <50 kg N/ha.
- In composted areas, carrots had higher potassium levels, up to double that of those in the control.
- The total concentration of nutrients in the carrot roots increased with increasing compost rates and compost quality.
- The compost had no significant effect on carrot yields in its first year.
- The improved nutritional status of the carrots may have had a beneficial effect on shelf life; however, this was not investigated as part of the trial.

Recommendations

Continue to observe the trials site to assess longer term effects of compost applications on carrot crops and economic benefits.

Investigate the costs and benefits of using lower, affordable rates, and / or band placing compost to reduce initial costs.

VG15010/1/005/1805

Report

GENERAL BACKGROUND

PROPERTY AND LOCATION

Sun City Farms, Center West Exports,
LOT 55 Croot Place, Woodridge WA 6041

Farm Management by Francis Tedesco

TOP 3 SOIL ISSUES

RANK	SOIL CONSTRAINTS	REASON FOR CONSTRAINT
1	Soil borne diseases	Pythium (acidification/pH drop is a risk in connection with Pythium, need pH 6.5-7.)
2	Soil structure issues	Some compaction (subsoil), infiltration, drainage, water holding capacity – in some areas more than others
3	Loss of organic matter	Low organic matter (<1%) due to sandy soils and climate

TRIAL RATIONALE

Issues

- Land availability and cost/market price pressures do not allow for long rotations.
- 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).
- A quick brassica break crop plus chicken manure (Jarrah sawdust based) at about 7.5 m³/ha provided good 'soil rejuvenation' in the past; however, the stable fly issue and widespread P & N increase in groundwater led to a ban on using fresh chicken manure.
- Yellow Mustard biofumigation was tried but had its challenges: cost due to seed, need to irrigate up and maybe irrigate again and fertilise, especially at high seeding rate, (now using a fast growing fodder brassica); also tried field peas and Fumigator: Fumigator worked well in a couple of small scale trials but was problematic in a 50 acre (20 ha) trial, planted at 25kg/ha, due to Pythium crop loss.
- Previous experience with "compost" to replace manure has not been good as the compost contained glass and other foreign matter. 'Conditioned chicken manure' used in other crops is not suitable due to its

content of large pine shavings and acidifying effect of pine wood.

- Metham Sodium is used strategically and not each year.
- Main Pythium control is achieved via: maintaining neutral to alkaline pH, good irrigation management, balanced nutrition especially adequate potassium (K) and not too much nitrogen (N).
- Some areas of paddocks and some soils are more prone to Pythium due to poorer drainage (texture / parent material related).

Criteria for new approaches by Center West

- Fit with production imperatives
- Not too costly to implement and tying up labour and equipment and needing water, fertiliser and a lot of looking after, preferable decreased input costs, machinery use or labour
- Fit with time of year paddocks are harvested and replanted
- Not acidifying soil
- No food safety risk
- More even water infiltration and drainage, no water logging
- Easy paddock preparation
- Even crop growth – root sizing to be more predictable and even, ideally increased marketable yield, pack out of high-grade product, or total yield
- Pythium management / reduction of soil inoculum, ideally reduced or no need to use Metham Sodium due to good soil health
- Maintaining organic carbon levels and soil condition / biology.

High quality compost has been identified as one possible option of addressing the three above mentioned soil constraints, soil biology / Pythium, soil structure and loss of organic matter. It also meets or has the potential to meet (based on previous experiences on other sites) most criteria for new approaches listed above. The cost of compost (material, transport, application) could be an impediment.

The effect of custom made composts on the performance of a carrot crop and soil health

RESEARCH QUESTIONS

Do the benefits of using good, known quality compost justify the costs?

Do benefits occur straight after application, if not, when will they occur?

How long does a beneficial effect last?

Does any management input need to be adjusted (irrigation, nutrition)?

TRIAL DETAILS AND METHOD

COMPONENT	DETAILS
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 200cm+. Associated with limestone, pH - neutral. ¹
Compost supply	C-Wise, 139 Nambelup Rd, Nambelup
Trial set up and data collection	Francis Tedesco, Center West and Justin Wolfgang, C-Wise
Data Analysis	Doris Blaesing, RMCG and Liam Southam-Rogers, AHR
Trial area	10 ha paddock under solid set irrigation
Individual plot area	0.5 ha
Rotation / previous land use	Field pea green crop
Soil preparation (depth)	Ripping (30 cm), Discing (30 cm), Rotary hoeing (20 cm)
Crop management	Standard across all treatments including the fertiliser program.
Irrigation scheduling across all treatments	Soil moisture probes and ETo used as guidance plus visual / tactile checks of soils
Compost spreading dates	9/6/2016 & 10/6/2016
Planting date	13/6/2016
Pre-harvest assessment	17/11/2016
Harvest date	20/11/2016 - 24/11/2016

¹ Henry J. Smolinski and G G. Scholz 1997; Soil assessment of the west Gingin area. http://researchlibrary.agric.wa.gov.au/land_res/15/

TREATMENTS

PLOT	TREATMENT	AMOUNT
Beds 22/32	Premium compost	30 m ³ /ha
Beds 24/34	Premium compost	50 m ³ /ha
Beds 26/36	Humicarb compost	30 m ³ /ha
Beds 28/38	Humicarb compost	50 m ³ /ha
12 Beds	No compost	Control

DATA COLLECTION

DNA Testing

Plant and soil sampling for DNA testing was conducted as per SARDI instructions ("Sampling for SARDI Soil DNA pathogen testing VEGETABLE CROPS").

1. Pre-plant soil DNA test (standard Predicta test prior to development of specific *Pythium sulcatum* and *P. violae* test) – SARDI
2. DNA test of soils and roots at harvest (standard Predicta test prior and specific *Pythium sulcatum* and *P. violae* test – test under development).

Site visits / observations

Regular site visits to check on crop development and take photos.

Plant sampling – nutrient analysis

At growth stage 4.8, just before harvest, 30 random carrot roots (subsamples) were collected across each treated and control block, the central section of each root was submitted for NU-test sap nutrient analysis. The purpose of this analysis was to determine differences in nutrient uptake as influenced by the compost treatments.

Soil sampling - nutrient analysis

10 random subsamples were taken to 30 cm depth across each treated block and control blocks, combined & mixed well. The 10 subsamples from the 2 replicates blocks of each treatment made up one composite sample per treatment (= 3 soil samples). 500g of the mixed sample was submitted for soil analysis.

Pre-harvest assessment

30 carrots per plot were hand harvested on 17/11/2016. During sampling, stems of some carrots snapped; these carrots were then not removed from the ground and a different one was chosen for sampling. This braking off of tops was most noticeable in control plots.

After sampling, carrot tops were removed and roots washed. Carrots were then assessed for weight, individual root diameters (Small: 28-35 mm, Medium: 35-45 mm, Large: >45mm) and defects (Pythium, less than 7.5 cm length or less than 28 mm diameter, splits, cracks, badly deformed roots); photos were taken of each sample.

Rejected carrots (roots with defects) were not measured and were excluded from size distribution and average carrot weight assessments. Most rejections were due to Pythium, either forking or cavity spot.

Factory pack out

Each plot was harvested separately and graded in the factory applying the usual quality standards. They were graded into small, medium and large carrots (Pre-packs, Small: 28-35 mm, Medium: 35-45 mm, Large: >45mm) and defects (Pythium, less than 7.5 cm length or less than 28 mm diameter, splits, cracks, badly deformed roots); weights recorded for each category.

DESKTOP RESEARCH

Interpretation of findings were guided by findings from a literature review on Pythium species causing cavity spot and forking in carrots.

FINDINGS & DISCUSSION

DESKTOP RESEARCH FINDINGS

The main Pythium species affecting carrots in Australia have been identified as *P. sulcatum* (in most cases) and *P. violae* (in some cases).

Factors affecting cavity spot development and survival

Dormant resting spores of Pythium species formed during pathogenic and/or saprophytic colonisation of plant tissues have long been identified as the primary sources of inoculum for succeeding crops.

P. sulcatum, which is the main pathogen causing cavity spot of carrot in Australia according to Davison and MacKay 1998 and 2000, appears to have a relatively restricted host range compared with *P. violae* (main cause

of cavity spot in carrots in most other countries and identified in some part of Australia). Apart from carrots, *P. sulcatum* has been isolated from parsley (Plaats-Niterink 1981², Minchinton et al. 2006, 2007³), from parsnip (Minchinton et al. 2008) and in a very low frequency from spinach (McKay and Davison 2000).

Pythium spp. survive as resting spores between susceptible crops. *Pythium sulcatum* only infects carrots and closely related plants, it can survive for at least two years between carrot crops. Cavity spot caused by *Pythium sulcatum* is most severe in summer and autumn harvested crops.

Pythium violae has a much wider host range and can survive for at least five years between carrot crops. Cavity spot caused by *Pythium violae* is most severe in winter harvested crops.

Temperatures

The prime growth temperatures for *P. sulcatum* are: minimum 2 to 3°C, optimum 20 to 28°C, and maximum 36 to 37°C. The optimum temperature for saprophytic growth of *P. sulcatum* (25°C) is higher than that for *P. violae* (19°C). 30°C is a lethal temperature for *P. violae*⁴. This sensitivity to high temperatures may be a reason for the low number of *P. violae* detections in Australia. The relatively high optimum temperature for *P. sulcatum* may be one reason why it is not a predominant species causing carrot cavity spot in most Northern Hemisphere countries.

Soil moisture

High soil moisture supports greater Pythium infections; refer to comments under 'irrigation' in the next section (management approaches).

Management approaches

Varieties

Genetic tolerance to *Pythium* spp. varies however, there are currently no resistant varieties.

Chemical control

Metalaxyl can reduce the incidence and severity of cavity spot disease when applied at or shortly after

² Plaats-Niterink AJ van der (1981) Monograph of the genus Pythium. Studies in Mycology 21, 242pp.

³ Minchinton EM, Auer D, Martin H, Tesoriero L, Thomson F, Trapnell LN, Forsberg L, Nadesan S, Vujovic S (2006) Scoping study to investigate management of root-rot diseases in parsley. Report of Horticulture Australia Project VG04025, 87 pp.

Minchinton EM, Auer D, Martin H, Thomson F, Vujovic S (2007) Identification and management of parsley root rot. Report of Horticulture Australia Project VG06046.

⁴ Suffert F, M. Guibert. 2006. The ecology of a Pythium community in relation to the epidemiology of carrot cavity spot. Applied Soil Ecology 35 (2007) 488-501

seeding. However, if it is used too frequently it can lose its effectiveness because of an increase in its rate of breakdown in soil⁵. Bailey and Coffey (1985)⁶ reported that Metalaxyl had a half-life of 28 days in sandy soils due to biological degradation. It also leaches from sandy soils. *P. sulcatum* is considered by some researchers to be naturally tolerant of Metalaxyl⁷. However, the reason for this may be enhanced degradation with repeated use in some soils.

A UK study found a correlation between the half-life (degradation) of Metalaxyl and pH; the higher the pH, the faster the degradation. In Australia, the half-life varied from less than 1 day to 43 days, compared with a published value of 70 days. Enhanced breakdown of Metalaxyl appears to be a widespread problem.

Metham sodium has failed to control cavity spot⁹ in trials in WA. Still, is used commercially in Australia to control the disease.

Soil pH

In WA, it has been shown that liming soil to increase pH reduces the incidence and severity of cavity spot¹⁰. The recommended range is pH 6.5-7.5 with a target pH of 7.2 or higher (measured in calcium chloride)¹¹. The effect of lime (calcium carbonate) may be due to inducing a soil microflora that is inhibitory to filamentous fungi like *Pythium*. However, this is not confirmed. The application of lime may also be beneficial in the longer term via increased calcium availability.

Nutrition

UK research found that increasing the level of exchangeable calcium above 8 meq/100 g soil decreased the incidence of cavity spot¹². High inputs of available calcium pre-planting (e.g. 15 t/ha as Limex) also decreased cavity spot incidence. In both cases, *P. violae* was the target organism.

According to the review by Minchinton et al. (2012), reports on the effects of nutrition on cavity spot vary.

She concludes: "In general, there do not appear to be any clear cut or consistent relationships between soil nutrition, plant nutrition or other soil factors (conductivity, moisture holding capacity, organic matter, total and exchangeable calcium and particle size distribution) reported." The reason for this may be that in experiments involving nutrients researchers often try to test the effect of a certain nutrient on the disease, rather than comparing a well-balanced, site specific nutrition program (and overall crop management) with practices that lead to imbalances, oversupply or shortages.

Irrigation

Previous work on a *Pythium* species showed that cyclic wetting and drying reduced *Pythium* populations in the field¹³. Observations by growers confirm that high soil moisture levels support the development of cavity spot. However, a threshold soil moisture tension/ water potential and the length of time at a certain tension/potential is required to cause infection with *P. sulcatum* or *P. violae* has not been found. Literature recommendation talk about minimising total water inputs e.g. < 30 mm/wk. However, when using fungicides early in the season, at least 15 mm were required to get the fungus to grow rapidly at the time of application to achieve good control (UK). The assumption is that soil moisture above field capacity may be too high. However, the level of oxygen in the soil may be an important factor. This may mean that a clay soil or a compacted soil (soil with a lack of fast draining pores) may not supply sufficient oxygen to the rootzone, even at field capacity.

Rotation

Rotation with broccoli has shown promising results in WA. However, *P. violae* can attack broccoli¹⁴ and using this as a rotational crop may exacerbate cavity spot where *P. violae* is present. When *P. sulcatum* is present rotation with broccoli, lettuce or onions is mentioned as beneficial. For *P. violae*, rotation with onions, corn, potatoes or beans are mentioned. Views on the positive effect of rotation in publications differ.

⁵ Davison, E.M. and McKay, A.G. (1999). Reduced persistence of metalaxyl in soil associated with its failure to control cavity spot of carrots. *Plant Pathology* 48, 830-835.

⁶ Bailey AM, Coffey MD, (1985) Biodegradation of metalaxyl in avocado soils. *Phytopathology* 75, 135-137.

⁷ Minchinton E. et al. 2012. Identification of IPM strategies for *Pythium* induced root rots in Apiaceae vegetable crops. Final report for VG08026.

⁸ Davison, E.M. and McKay, A.G. 2001. Integrated management of *Pythium* diseases of carrots. Final Report for VG98011

⁹ Davison E.M. and McKay A.G. 2000. Cavity spot in Australia. *Agriculture Western Australia*. Proceedings of the Carrot conference Australia, Perth 2000.

¹⁰ Galati, A. and McKay, A.G. (1996). Carrot yield decline. Final Report HRDC Project VG036.

¹¹ Davison, E.M. and McKay, A.G. (1999). Cavity spot disease of carrots. *Farmnote* 29/99, *Agriculture Western Australia*.

¹² Scaife et al. 1983. Cavity spot of carrots—observance on a commercial crop. *Ann. Appl. Biol.* 102: 567-575.

¹³ Stanghellini ME, Burr TJ (1973) Effect of soil water potential on disease incidence and oospore germination of *Pythium aphanidermatum*. *Phytopathology* 63, 1496-1498.

¹⁴ Schrandt, J.K., Davis, R.M. and Nuñez, J.J.(1994). Host range and influence of nutrition, temperature and pH on growth of *Pythium violae* from carrot. *Plant Disease* 78, 335-338.

*“Severe cavity spot caused by *Pythium violae* and *P. sulcatum* may develop on carrots grown in newly cleared land or cultivated fields where umbelliferous crops have never been grown. Conversely, fields where carrot has been cultivated repeatedly may have no history of cavity spot. Fields known to produce carrots infected with cavity spot may not show disease from one year to the next depending on environmental conditions.*

Crop rotation is not recommended because there is no relationship between cropping history and cavity spot severity nor any evidence that rotation will reduce cavity spot. Carrot should not be planted in soils with a high clay content.

While no direct relationship between soil nutrients and cavity spot has been shown, decreasing the level of chemical fertilizers applied to a field has been observed to reduce the severity of cavity spot.”

(from: Howard R.J., J. A. Garland, W. L. Seaman (Editors). 1994. Diseases and Pests of Vegetable Crops in Canada: an illustrated compendium. Co-published by: Entomological Society of Canada).

Cover crops/biofumigation

Reports on the benefits of cover crops and biofumigants vary. In some instances, good control or reduction of disease incidence were achieved, especially with mustards, in other trials and field experiments by growers, cavity spot incidence or severity were not altered or the disease was even worse. It appears that biofumigation or cover crops may not reduce inoculum levels, even in cases where disease expression is reduced. The conclusion is that the effect of cover crops on *Pythium sulcatum* and *P. violae* is not well enough understood to make recommendations.

Other

Crop hygiene, selection of planting date and crop density, tillage to ensure good drainage, crop residue management, and timely harvest are some cultural practices to reduce the impact of root diseases.

Some ICP strategies that may help reducing the likelihood of infection in combination with other management practices listed above are: *Bacillus subtilis* and other biocides¹⁵, Calcium Cyanamide or use of silicon (to induce a defense reaction). So far reports on the efficacy of integrated approaches vary.

Conclusions

While some general rules apply, especially the need for managing soil moisture, pH soil calcium and crop maturity, carrot producers will have to find their own optimum combination of additional management strategies that fit their production system and growing conditions.

DISEASE PREDICTION

A substantial research effort has been made to predict *Pythium* inoculum levels in vegetable crops, including carrots. Most research had a focus on identifying threshold levels of inoculum rather than identifying conditions (temperature, soil moisture, soil (solution?) nutrient levels, level of other diseases or pests) that cause infections to occur in different commercial production systems.

SARDI is working on the development of a DNA probe for *P. sulcatum* and *P. violae*. Once these have been developed and tested, the next step is to understand the relationship between inoculum levels and production factors, both environmental and production factors.

COMPOST TRIAL FINDINGS AND DISCUSSION

WEATHER CONDITIONS DURING THE TRIAL PERIOD

2016 weather data was compared to long term averages (Gingin Aerodrome). Below tables show that temperatures for the months July to October consistently were below the longer-term average (average). September was especially cold with all temperature indicators around 2 (°C) below the average. In November, temperatures, apart from the mean minimum, were higher than average.

MONTH	MEAN MIN TEMP (°C) 2016	MEAN MIN TEMP (°C) 21 YR AVERAGE	MEAN MAX TEMP (°C) 2016	MEAN MAX TEMP (°C) 21 YR AVERAGE
Jul	6.0	6.2	17.6	18.3
Aug	6.1	6.5	17.6	19.1
Sept	5.3	7.4	18.8	20.6
Oct	8.1	9.2	22.7	24.4
Nov	10.6	12	29.2	28

¹⁵ Seaman, Abby, Editor. (2015) Production Guide for Organic Carrots for Processing. Publisher: New York State Integrated Pest Management Program, Cornell University (New York State Agricultural Experiment Station, Geneva, NY).

MONTH	MEAN 9AM TEMP (°C) 2016	MEAN 9AM TEMP (°C) 14 YR AVERAGE	MEAN 3PM TEMP (°C) 2016	MEAN 3PM TEMP (°C) 14 YR AVERAGE
Jul	11.1	12	16.5	17.1
Aug	11.8	12.8	16.2	17.6
Sept	13.2	15.1	17.2	18.9
Oct	17.4	17.9	20.9	22.1
Nov	22.4	21.1	26.5	25.6

The table to the right shows that rainfall was above average for July, August and October, but below average for September and November. Total rainfall for the 5 months was about 29 mm (7.2% above average).

MONTH	MONTHLY RAINFALL (MM) 2016	MEAN MONTHLY RAINFALL (MM) 18 YR AVERAGE	2016 RAINY DAYS >1 MM	MEAN NUMBER OF DAYS OF RAIN ≥ 1 MM
Jul	145	125.8	10	13
Aug	153.2	107.3	14	12.1
Sept	47.4	83.2	6	10.5
Oct	49	35.6	11	5.5
Nov	5.6	19.6	2	3.6
Total	400.2	371.5	43	44.7

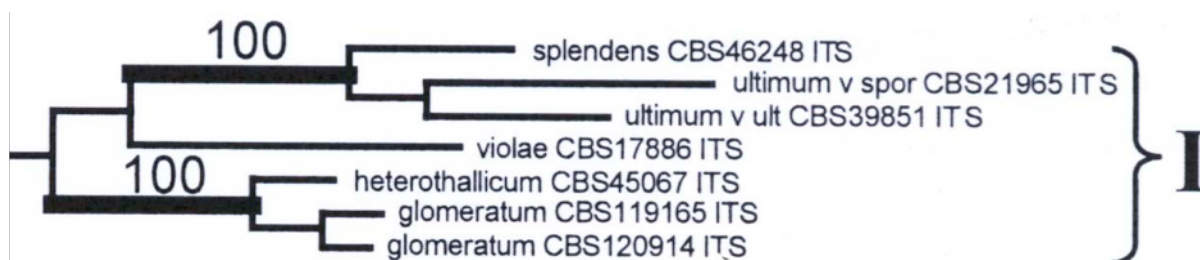
August was especially wet and quite cold while September was especially cold but not wet. The weather conditions led to a slower than normal development of the crop.

PRE-PLANT SOIL DNA TEST

At the time of planting, a specific test for *P. sucatum* or *P. violae* was not yet available. SARDI offered a general horticultural soil test. The interpretation of results for carrots must be done with caution because the use of DNA test for carrots is in the very early development stage.

The standard Predict B test (SARDI) produced the following results, which may be relevant:

- 1 pg DNA/g soil of Pythium Clade I – this may be an overall low level



Above: Clade I Pythium species - No obvious common morphological characters in this clade. Most species do not produce zoospores.

2. 15 pg DNA/g soil of Rhizoctonia solani AG4

This anastomosis group (AG) can cause crown rot and cavity spot like symptoms in carrots. We do not know whether the level found poses a commercial risk to carrot crops.

OBSERVATIONS

Visual assessments of carrots on 21/08/2016 and 19/9/2016 showed little difference between treatments. The addition of compost appeared to have led to carrots developing more fine roots than in the control. However, without root length measurements a definite statement cannot be made.

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PRE-HARVEST ASSESSMENTS

The below table shows treatment averages for carrot root weight, percentage of weight difference to the control and the percentage of defects. Defects consisted mainly of forking and cavity spot.

TREATMENT	MEAN ROOT WEIGHT (G)	MEAN % WEIGHT DIFFERENCE FROM CONTROL	MEAN DEFECT RATE (%)
30 t/ha Humicarb compost	131	5.7	0.0%
50 t/ha Humicarb compost	129	4.1	6.7%
30 t/ha Premium compost	120	-3.1	8.0%
50 t/ha Premium compost	120	-2.7	8.7%
Control	124		6.3%

The Humicarb compost treatment produced slightly higher root weights and a lower defect rate compared to the Premium compost.

The next table shows the averaged size distributions for the pre-harvest carrot samples.

TREATMENT	SMALL (28-35MM)	MEDIUM (35-45MM)	LARGE (>45MM)
30 t/ha Humicarb compost	7.1%	73.7%	19.2%
50 t/ha Humicarb compost	5.5%	78.5%	16.0%
30 t/ha Premium compost	8.8%	71.4%	19.8%
50 t/ha Premium compost	15.1%	67.5%	17.4%
Control	7.9%	74.0%	18.1%

The Humicarb compost treatment produced slightly more medium size carrots and less small carrots compared to the Premium compost.

COMMERCIAL HARVEST RESULTS

The next table shows the results from the commercial harvest.

TREATMENT	YIELD (T/HA)	DEFECT RATE (%)	PACK OUT RATE (%)
30 t/ha Humicarb compost	42.1	20%	80%
50 t/ha Humicarb compost	41.6	21%	79%
30 t/ha Premium compost	42.2	25%	75%
50 t/ha Premium compost	41.0	22%	78%
Control	42.9	21%	79%

The control and Humicarb compost had slightly higher pack out rates than the Premium compost treatments. The control had the overall highest yield but differences to other treatments were not significant. The defect rate was slightly higher in the Premium compost treatments.

The size distribution of carrots obtained from the commercial packing operation is shown in the following table:

TREATMENT	PREPACK	SMALL (28-35MM)	TOTAL < 35MM	MEDIUM (35-45MM)	PACK OUT RATE (%)
30 t/ha Humicarb compost	12%	60%	72%	24%	3%
50 t/ha Humicarb compost	12%	62%	74%	23%	3%
30 t/ha Premium compost	19%	51%	70%	24%	5%
50 t/ha Premium compost	19%	48%	67%	25%	3%
Control	15%	58%	73%	24%	3%

The commercial pack out showed that most carrots were in the < 35 mm range (prepacks and smalls) while the pre-harvest assessment had most roots in the medium range.

In the factory pack out, the Humicarb compost and untreated control produced a slightly greater amount of carrots in the < 35 mm range than the Premium compost treatment. This compares to the medium size carrot pack out in the pre-harvest assessment. The percentage of medium and large carrots packed out were about the same in each treatment.

SOIL AND PLANT TESTING AT HARVEST

Post-harvest soil DNA test

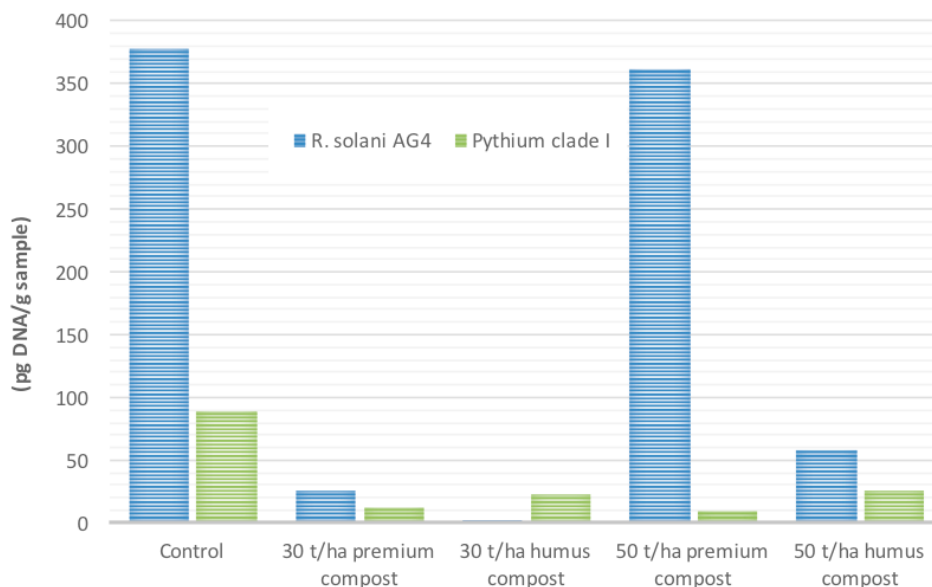
At the time of harvest, SARDI's specific test for *P. sucatum* or *P. violae* was available as a research tool. The interpretation of results is tentative because the use of DNA testing for carrots is in the very early development stage and the specific Pythium tests need further research.

The soil DNA test did not detect nematodes or other pathogens than the ones discussed below.

Below graph illustrates post-harvest findings of pathogen DNA in the soil (pg = pico gram).

Rhizoctonia solani AG4 levels increased during the growth of the crop from a starting point of 15 pg/g soil sample. The increase was greatest in the control and the 50 t/ha Premium compost treatment. It is not clear why the 50 t/ha treatment had similar levels to the control. This treatment had the highest defect rate and a low average root weight in the pre-harvest assessment. It also had the highest level of small roots and second highest defect rate (after the 30 t/ha Premium compost treatment) in the commercial harvest assessment.

Pythium clade 1 levels also increased in the soil during crop growth. The increase was substantially higher in the control plots than in the compost treated plots. Overall, the 30 t/ha Humicarb treatment had the lowest level of pathogens.

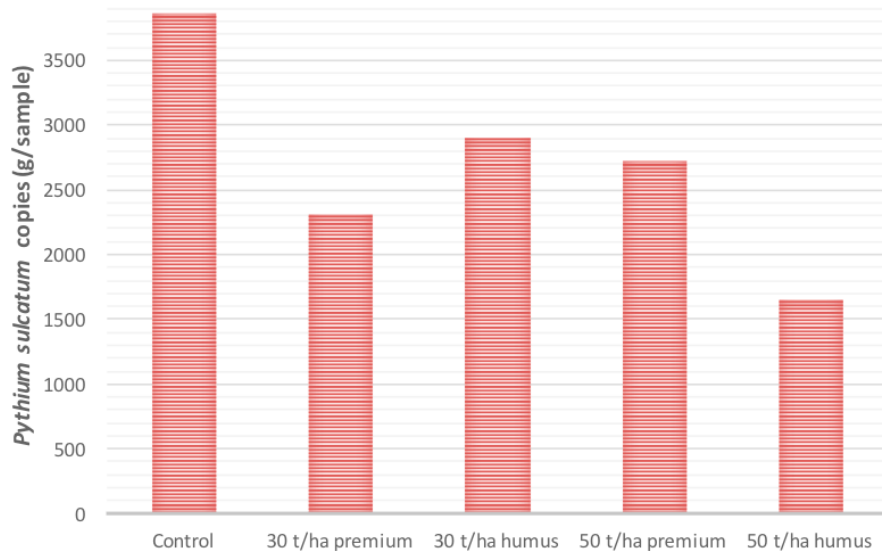


Humus compost = C-Wise Humicarb, premium compost = C-Wise Premium compost

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The next graph shows *Pythium sulcatum* counts as copies/g sample. *P. violae* was not detected. Again, the control treatment had the greatest *Pythium* level of this species.

These are results obtained as part of a SARDI led Hort Innovation R&D project VG15009. They are first indications only as the research is still in its early stages.



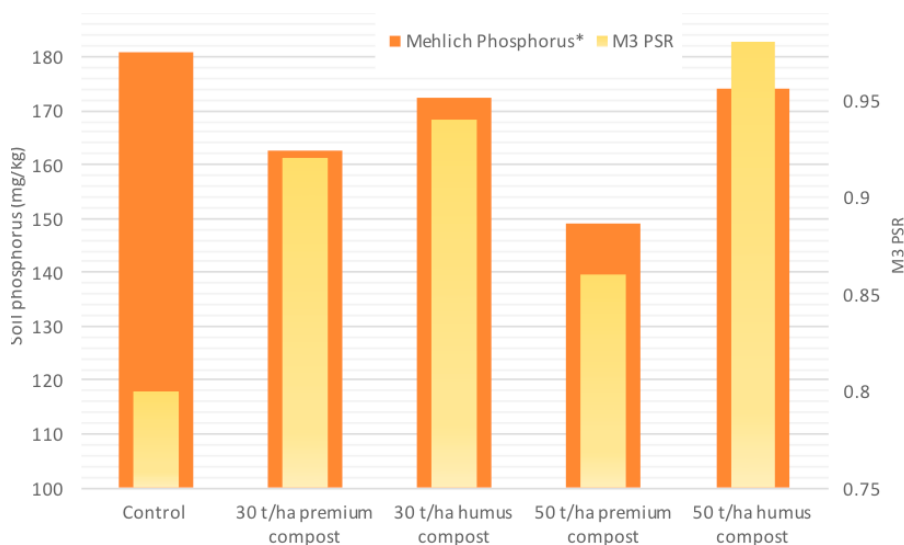
Humus compost = C-Wise Humicarb, premium compost = C-Wise Premium compost

Soil nutrient levels at harvest

The following graphs illustrate treatment differences in soil nutrient levels shortly after harvest.

The first graph shows treatment differences in soil phosphorus (P) levels, both, the concentration (mg/kg) obtained via a Mehlich 3 extraction, and an indicator for the potential P availability (for plant uptake) in the soil solution.

Soil P was quite high in all treatments. Availability was highest in the 50 t/ha Humicarb compost treatment. The type of organic matter and its effect on soil microbial activity influences P availability to plants. It is generally accepted that the level of microbial activity can have an impact on P availability.



Humus compost = C-Wise Humicarb, premium compost = C-Wise Premium compost

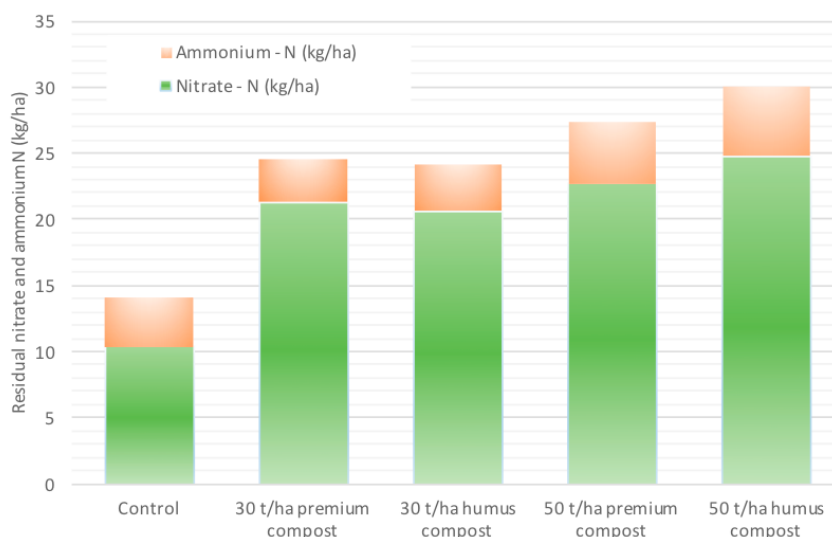
The following graph shows levels of residual nitrogen in the topsoil after harvest. All levels are relatively low, reflecting the careful management of nitrogen inputs to the carrot crop to avoid excess top growth and short tap roots.

After carrot production, residual soil nitrogen levels of about 30 kg/ha are a good level to aim at. On heavier soils, residual levels of up to 50 kg/ha are acceptable.

The below graph illustrates that the addition of compost to the soil resulted in higher residual available nitrogen levels in the topsoil, compared to the control treatment. The trend shows that higher inputs, here 50 t/ha, can lead to higher residual N levels.

Quality compost, if not used excessively, releases nitrogen slowly via microbial activity; it also improves nitrogen cycling while preventing leaching.

Research and field experience has shown that the positive effect of compost on nutrient cycling and availability will continue for more than one season (refer to the Vegetables WA Good Practice Guide).



Humus compost = C-Wise Humicarb, premium compost = C-Wise Premium compost

Nutrients in carrots at harvest

This section presents and discusses treatment differences in carrot root sap. Nutrient levels were tested shortly after harvest using NU-test technology.

The levels of the three cations potassium (K), calcium (Ca) and magnesium (Mg) are presented in the below graph. All compost treatments led to higher levels of potassium than the control. The highest level (4157.5 ppm) was found in the 50t/ha Humicarb compost treatment; the lowest level was in the control (3566.5 ppm), a 12% difference.

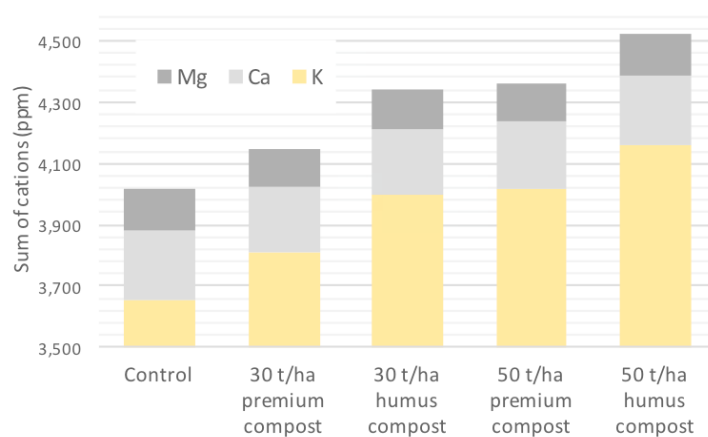
Potassium is important for regulating water loss, cell growth and sugar development.

Calcium (Ca) and magnesium (Mg) levels did not differ much across treatments. The highest levels of both cations occurred in the 50 t/ha Humicarb compost treatment, followed by the control.

The second graph shows that carrot root nitrogen levels, measured as nitrate and ammonium were overall low, reflecting the careful nitrogen management of the crop. The control had the highest levels of both N forms in the root, while the residual soil levels were low, as presented previously.

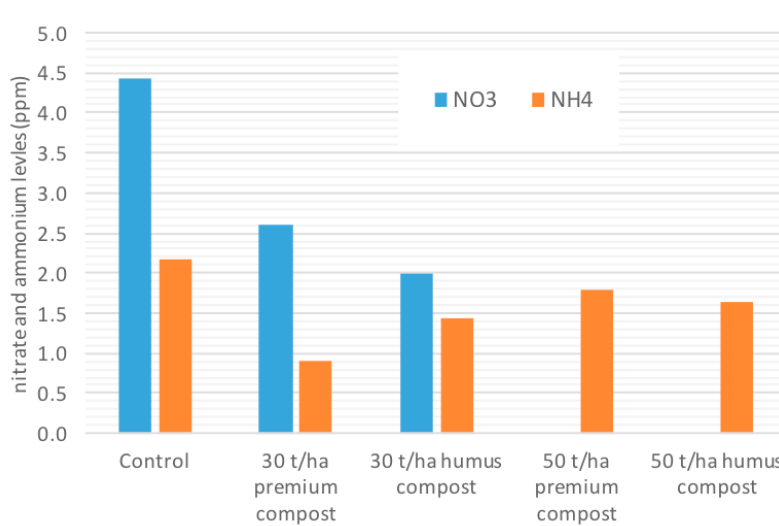
The higher compost inputs resulted in the lowest overall nitrogen uptake into carrot roots around the time of harvest, while soil levels were higher than those in the control. Nitrogen dynamics in carrot crops following the addition of compost need to be further investigated to understand why carrots grown in soil with compost amendment accumulate less nitrogen.

The effect of custom made composts on the performance of a carrot crop and soil health



Humus compost = C-Wise Humicarb, premium compost = C-Wise Premium compost

High soil ammonium levels may lead to a higher risk of cavity spot¹⁶. The fact that ammonium reduces soil pH during conversion to nitrate may play a role in this. However, the trial does not provide supporting information for this idea.



Humus compost = C-Wise Humicarb, premium compost = C-Wise Premium compost

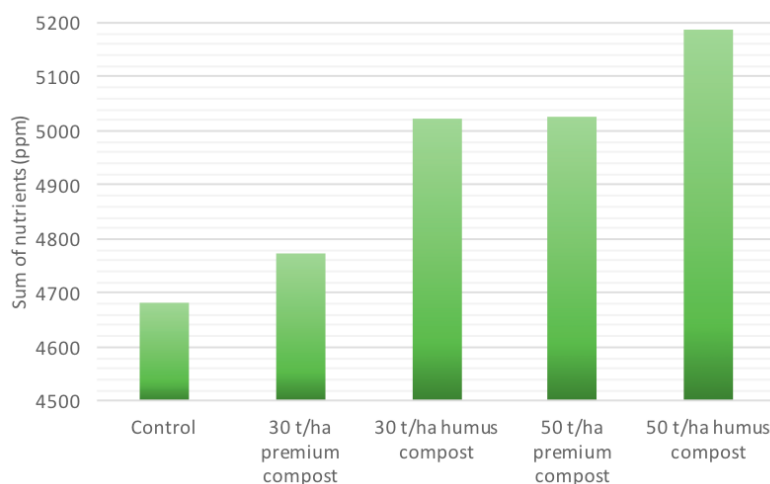
We did not find major differences in the levels of other nutrients i.e. phosphorus (P), sulphur (S) and trace elements in carrot roots.

Sodium levels were high in all treatments and the control had the highest 'salinity level' (Na ppm plus Cl ppm). The higher salinity in the control and the higher overall nutrient level in the 50 t/ha Humicarb compost treatment may be the reason for both treatments having the highest brix levels compared to the other treatments (9.3 and 9.4 respectively compared to 9.1 for the 30 t/ha Premium compost and 9.0 for the other two treatments).

The last graph illustrates the total concentration of nutrients in the extracted carrot sap. Nutrient uptake, when measured around the time of harvest, was the highest in the 50 t/ha Humicarb compost treatment. Knowledge from other crops suggest that a high nutrient concentration may have a positive effect on flavour and storage life. However, this aspect was not investigated in this trial.

¹⁶ Scaife M. A. et al. 1980. Cavity spot of carrots - an association with soil ammonium. Communications In Soil Science And Plant Analysis Vol. 11, Iss. 6, 1980

The effect of custom made composts on the performance of a carrot crop and soil health



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ANSWERS TO RESEARCH QUESTIONS

Do the benefits of using good, known quality compost justify the costs?

This will be the next assessment step. However, economic benefits of compost need to be looked at over at least a 3-year period. The trial site will be monitored over the coming years.

Do benefits occur straight after application, if not, when will they occur?

Benefits in year 1 were the improved nutrient status of the carrot roots and a decline in some diseases that attack carrots.

How long does a beneficial effect last?

This will be investigated further through the continuation of the trial.

Do any management inputs need to be adjusted (irrigation, nutrition)?

Yes, nutrient and irrigation monitoring of the crop can help to fine-tune inputs.

DOES THE TRIAL FIT WITH THE CRITERIA FOR NEW APPROACHES ON THE FARM?

PRODUCTION IMPERATIVES	
Not too costly to implement and tying up labour and equipment preferable decreased machinery use or labour	No, cost were high if looking at 1 year only
Not too costly through needing water, fertiliser and a lot of looking after, preferable decreased input costs	Yes
Fit with time of year paddocks are harvested and replanted	Yes
Not acidifying soil	Yes
No food safety risk	Yes
More even water infiltration and drainage, no water logging	Yes
Easy paddock preparation	Yes, if not counting spreading
Even crop growth – root sizing to be more predictable and even, ideally increased marketable yield, pack out of high-grade product, or total yield	Need more data over the coming years
Pythium management / reduction of soil inoculum, ideally reduced or no need to use Metham Sodium due to good soil health	Potentially, need more data over the coming years
Maintaining organic carbon levels and soil condition / biology	Yes