Sustainable farming systems trials – Crop yield and quality

PW17001 Final report Appendix 18 Integrated pest management of nematodes in sweetpotato

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Summary

Two long-term field trials were conducted over the life of the project to test the feasibility of using integrated management options to minimise losses caused by Root-knot nematode (RKN) and potentially other plant-parasitic nematodes and improve soil biological health.

The Intensive trial, or Integrated nematode management long term trial following conventional sweetpotato best practice with relatively high rates of organic amendments at bed formation.

The Extensive trial or Sustainable farming systems long term trial. incorporating minimum tillage (pre-formed beds) with organic amendments and crop rotations of grasses, legumes and brassicas.

longer term trials were required for these investigations as improvements in soil biological health may not be seen immediately. Management practices included in the trials were:

- The use of diverse (largely root-knot resistant) rotation crops including legumes and inputs of organic matter from these crops.
- Application of organic amendments
- Minimum tillage and controlled traffic

A number of parameters were monitored throughout the life of the trial including populations of plant parasitic and free-living nematodes, microarthropods and nematode trapping fungi, as well as soil physical and chemical properties. Crop assessment parameters included yield, nematode damage and root defects.

Sustainable farming systems trials - Commercial crop yield and quality

Introduction

Research results (summarised by Stirling, 2014) have shown organic matter amendments are an effective strategy to improve a soil's nematode suppressiveness. Hay and Stirling (2014) and Stirling (2013) describe the value of integrated nematode management programs using crop rotations, organic amendments, minimum tillage and organic mulching farming systems. Composts are widely used (Thoden et al., 2011) and materials such as poultry manure, sugarcane trash, sawdust and mill mud have been effective in sugarcane soils (Stirling et al., 2003). These amendments provide benefits such as increased biological nutrient cycling, a source of nutrients for the crop and improved soil physical, chemical and biological fertility. Research findings on other crops need to be trialed and verified in the sweetpotato farming system given the sweetpotato plants responsiveness (positive or negative) to changes in physical and soil nutritional parameters.

Two long-term field trials were conducted over the life of the project to test the feasibility of using integrated management options to minimise losses caused by root-knot nematode (and potentially other plant-parasitic nematodes) and improve soil biological health.

The trials ran from November 2018 to June 2023. Longer term trials were required for these investigations as improvements in soil biological health may not be seen immediately. Management practices included in the trials were; The use of diverse, largely RKN resistant rotation crops including legumes and inputs of organic matter from these crops. Application of organic amendments. Minimum tillage and controlled traffic.

The Intensive trial or Integrated nematode management long term trial was conducted at Bundaberg Research Facility to assess the nematode control and soil health benefits provided by relatively high rates of organic amendments applied just prior to bed formation and planting. The intensive trial was designed to be similar to conventional best practice currently used by most sweetpotato growers. The trial incorporated five treatments, five replicates and four commercial crops from November 2018 to June 2023. A forage sorghum rotation was utilised in all plots between sweetpotato crops. Nematicide treatments (Nimitz-Fluensulfone) were included to determine if the organic amendments approach reduced RKN populations to an extent that a nematicide was no longer necessary.

The Extensive trial or Sustainable farming systems long term trial was also established at Bundaberg Research Facility to assess the nematode control and soil health benefits provided by farming systems that incorporate minimum tillage (pre-formed beds) as well as crop rotation and organic amendments. The extensive trial was more experimental than the intensive trial in its design with the use of pre-formed beds. The trial incorporated ten treatments including a nematicide treatment using Vydate (oxamyl), four replicates and three commercial crops in the five-year period.

Image 1. Aerial view of the Long term trials at Bundaberg Research Facility

Intensive trial - Integrated nematode management

A field trial was conducted at Bundaberg Research Facility to assess the nematode control and soil health benefits provided by relatively high rates of organic amendments applied just prior to bed formation and planting. Combinations of RKN resistant rotation crops and organic matter/compost amendments incorporated at bed formation or in a furrow prior to planting vs Nimitz vs no amendment. The intensive trial was designed to be similar to conventional best practice currently used by most sweetpotato growers. Amendments were chosen due to their availability and accessibility to growers in Bundaberg, poultry manure, sugarcane trash, sawdust and compost.

Materials and methods

The Intensive trial was established in November 2018 and ran until June 2023 when the fourth commercial crop was harvested. The trial incorporated five treatments and five replicates laid out as a randomised complete block (Table 1). Due to limited available land, one buffer row was installed at each end of the trial and a two-meter area at the end of each row was designated as buffer zone, leaving a 10m length of datum plants (50 plants).

Two rotation crops were chosen due to their high resistance ratings to RKN. Forage sorghum variety Jumbo was (used in spring and summer) and White french millet (used in autumn and winter). The nematicide treatment used Nimitz (Fluensulfone) to determine if the organic amendment approach reduced RKN populations to an extent that a nematicide was no longer necessary.

Table 1. Treatments in the intensive trial

Treatment	Amendment	Application method
Treatment A	Organic Matter	A band of sawdust + chicken manure applied to the centre of the bed
Treatment B	Compost	A band of compost applied to the centre of the bed
Treatment C	V-furrow	Compost applied in a V-shaped furrow
Treatment D	Nil	No treatment control
Treatment E	Nematicide	Nimitz (Fluensulfone)

RKN inoculation

To promote a uniform high RKN population across the trial block, a sacrificial sweetpotato crop (cv. Beauregard) was planted on the 22 November 2018. The RKN species Meloidogyne javanica, commonly detected in Bundaberg, was then introduced via transplanted infested tomato seedlings. Over 1000 Tiny Tim tomato seedlings were earlier propagated at Gatton Research Facility (GRF) and inoculated with root-knot nematode M. javanica. Over 800 inoculated tomato plants were then planted in between each of the sweetpotato cuttings. Inoculation bombs were made by cutting up the remaining M. javanica infested tomato roots and mixing them with 41 litres of washed sand. 50ml of the root/sand mix was then buried adjacent to each sweet potato plant.

The sacrificial sweetpotato crop was harvested in May 2019 and block was rotary hoed. Remaining crop material (potential volunteers) were removed mechanically and by hand. Soil samples were collected from each row (rows were also plots) previously marked with a tractor using GPS. The resultant nematode counts indicated that were was an even distribution of RKN across the block with an average count of 600 RKN juveniles per 200 grams of dry soil.

Rotation crops

The rotation component of the trial commenced on 27 May 2019 with sowing of White French Millet at rate of 40 kg/ha, (Table 2). At the conclusion of the millet rotation in August 2019, soil was again sampled from each plot for nematode analysis. The millet crop was then sprayed off and the block planted to Jumbo sorghum on September 3, 2019. A double rate was used to ensure good ground coverage and suppression of weeds and volunteers. The sorghum crop was sprayed out in December 2019 (Image 2), then mulched and incorporated using a rotary hoe. A Preplant soil samples were collected from each of the 25 rows on the 14 January 2020.

Details are listed in Table 1.

Image 2.Left to right, the intensive trial block was seeded with Jumbo Sorghum which was sprayed off prior to preparation for planting.

Table 2. Intensive trial treatments and application dates

Date	**Organic matter amendment** Incorporated and beds formed	**Compost amendment** Incorporated and beds formed	**V-furrow amendment** V furrow added after bed forming, prior to planting	**Nematicide treatment** Nimitz spray 8L/Ha, incorporated 7 days prior to planting as per label rate.	**Nil / control** No amendments or nematicides
21 Nov 18	Nematode inoculation to increase populations, sacrificial sweetpotato crop planted				
27 May 19	White french Millet				
3 Sep 19	Jumbo Sorghum				
14 Jan 2020	Poultry manure 22.4kg/row + Sawdust 33.6kg = 56kg/row. 40/60 blend	Compost 56kg/row	Compost 76L or 42.5kg/row	Nimitz applied before bed forming	No amendments or nematicides
20 Jan 20	Planted sweetpotato crop 1 cv. Beauregard				
8 Jun 20	Harvest and assess sweetpotatoes (140 DAP)				
29 Jun 20	White french millet				
20 Oct 20	Jumbo Sorghum				
19 Jan 21	Poultry manure 22.4kg/row + Sawdust 33.6kg = 56kg row. 40/60 blend.	Compost 56kg / row	Compost 42.5kg/row	Nimitz applied before bed forming	No amendments or nematicides
29 Jan 21	Planted sweetpotato crop 2 cv. Beauregard				
30 Jun 21	Harvest and assess sweetpotatoes (152 DAP)				
7 July 21	White french millet				
16 Sept 21	Jumbo Sorghum				
27 Jan 22	Poultry manure 22.4kg/row + Sawdust 33.6kg = 56kg row. 40/60 blend	Compost 56kg / row	Compost 42.5kg/row	Nimitz applied before bed forming	No amendments or nematicides
11 Feb 22	Planted sweetpotato crop 3 cv. Beauregard				
13 Jun 22	Harvest and assess sweetpotatoes (122 DAP)				
5 Jul 22	White french millet@ 40kg/Ha				
23 Aug 22	Jumbo sorghum @ 9.6Kg				
12 Dec 22	Poultry manure 22.4kg/row + Sawdust 33.6kg = 56kg/row. 40/60 blend	Compost @ 56Kg/ row	Compost 42.5kg/row	Nimitz applied before bed forming	No amendments or nematicides
15 Dec 22	Plant sweetpotato crop 4 cv. Beauregard				
8 May 23	Harvest and assess sweetpotatoes (145 DAP)				

Soil Monitoring

Soil samples were collected at critical points in the trials, such as pre plant, post-harvest and post rotation crops. Samples were sent to the project team nematologists for nematode extraction (Appendix 2 and 15), to the Department of Environment and Science (DES) for soil chemical and physical analysis (Appendix 16) and to GRF for extraction of soil biologicals (Appendix 17), microarthropods and Nematode trapping fungi (NTF). Results from these samples will allow investigation into correlation between soil characteristics, RKN populations and soil biology.

Amendments

Prior to bed formation a basal fertiliser was applied, following grower practice. PRG discussions resulted in the decision not to apply any preplant soil insect chemicals (as per current grower practice), so as not to interfere with biological soil populations at this stage. After rotary hoeing, the organic amendments were applied to the Organic matter and Compost treatments. Rates for banded amendments were based on those used in previous field trials demonstrating suppression of plant-parasitic nematodes; 56 kg/14m row or plot, is equivalent to 50 t/ha. The Organic matter amendments combined 22.4 kg/row of poultry manure plus 33.6 kg/row of sawdust (40/60 blend), providing a total of 56 kg of amendment per row (Table 2). The Compost plots were treated with 56 kg of compost per row. Amendments were hand placed on top of the rows in a 40 cm wide central band (based on GPS tracking) using buckets (image 3).

The amendments were incorporated during the bed forming process. The nematicide Nimitz was applied as per label rate at 8 L/Ha to the appropriate plots and incorporated during bed forming. The V furrow treatments were applied by opening a furrow on top of the respective beds with a double disc opener. Compost at the rate of 76 L or 42.5 kg/row applied directly into the ‘V’ shaped furrow on top of the formed beds. The furrows were then closed by shovel, using loose soil created during the furrow opening process. It is hypothesised that newly developed roots will potentially be protected from nematode attack due to increased suppressive activity in this zone enriched with organic matter.

Image 3. Amendments were weighed out and applied to the field by hand along the respective rows located by GPS.

Planting the commercial crop

The Intensive was planted with standardised hi spec vine tip cuttings (image 4), cultivar Beauregard at 20 cm plant spacing on the 20th of January 2020 (image 5). 2 January 2021, 11 February 2022 and 15 December 2022 (Table 2).

Image 4. Left to right, sweetpotato plant growth in the intensive trial. In 2020.

Image 5.the Intensive trial in 2023.

Trial maintenance

A maintenance schedule was developed for the trial blocks in conjunction with the PRG, following best practice. Regular soil and leaf tissue samples were collected for laboratory analysis to monitor critical nutrients such as nitrate analysis. Scheduled fertiliser applications were made based on the results of the analysis (image 6). Crop maintenance included irrigation scheduling, scuffling along with regular weeding until row closure. DAF designed weevil traps (VG 09052) containing pheromone attractant for sweetpotato weevil (Cylas formicarius) were installed at each corner of the block. Regular insecticide applications were carried out during the growth period based on weekly pest and disease monitoring. Selected Herbicides were used for in furrow grass control.

In 2021, sweetpotato weevil were a problem, with weekly pheromone traps collecting in excess of 200 weevils, despite regular chemical applications. Upon investigation, it was discovered that the spray equipment at Bundaberg Research Facility did not provide the coverage required for weevil control. A local grower then kindly provided machinery and an operator to ensure correct chemical application. Weekly weevil numbers in pheromone traps subsequently dropped to < 10 weevils.

Image 6. Left, Rachael Langenbaker (Bundaberg Research Facility),applying fertiliser to the sorghum cover crop. Right irrigation was applied to cover crops to ensure optimal growth.

Harvest

In Bundaberg, sweetpotatoes planted in January usually take 150 days to reach maturity. To monitor growth, three plants were dug up from the buffer rows at around 90 and 120 days after planting, to monitor root development. Prior to the harvest, the 2m buffer zones on the end of each row were hand dug and roots were removed. Rows were top chopped (pulversied) to remove the foliage and roots were left to harden for 3 weeks to prevent skinning during harvest. A potato harvester was used to lift the sweetpotato roots to the surface where they were manually hand-picked into hessian bags and placed into plastic half ton bins (image 7). Roots were freighted overnight to Gatton Research Facility (GRF) for assessment.

Image 7. Left rows were top chopped and roots were harvested.

Assessment

Harvested roots were washed in a chlorine solution using a standard butternut pumpkin washer. Once washed, roots were then sorted into eight size categories based on commercial packing sizes: extra-small, small, small-medium, medium, medium-large, large and jumbo (table 2). Roots were then graded based on marketability: first or premium grade, second grade and non-marketable (table 3). Root number and root weight were recorded in each plot.

Table 3. Shape and size grading for classifying sweetpotatoes.

Size	Weight gms	Length mm	Diameter mm
Extra small	60-150	100-180	25-50
Small	150-230	130--220	35-50
Small medium	230-350	200-300	35-50
Medium	350-550	180--300	45-70
Medium large	550-700	230-300	65-85
Large	700-1200	>300	70-90
Jumbo	>1200	>300	>90

Table 4. Quality grading for classifying sweetpotatoes.

Marketable roots	
Premium grade	Smooth skin, even elliptic shape, free from damage and defects.
Second grade	Smooth skin, slightly irregular shape or **one** of the following: shallow constriction, bump, bend, small (healed) growth crack or one area of slight damage.
Nonmarketable roots	
Too small	under 150g, 120mm or 40mm diameter
Defects	Irregular, uneven shape, constrictions, growth cracks, longitudinal grooves, alligator skin, veins
Damaged	Pests, mechanical
Long and thin	Long and thin roots

Raised pimples are commonly associated with RKN infection, however it is unknown if other skin lesions such as black pimples, are related to nematode infection, either directly or indirectly and what effects if any, the organic treatments may have on sweetpotato skin quality and incidence of soil insect damage. The teams 20 years of trial work and commercial sweetpotato production has led to the identification of 26 types of skin defects. A damage characterisation system was designed for the harvest assessments to capture skin lesions and defects and identify any possible associations (table 4, image 8).. Each root underwent close visual scrutiny and all lesions and defects were recorded. At the fourth harvest a severity rating system (high, medium or low) was incorporated. A large amount of data was collected at each yield and quality assessment. This was sent to a DAF biometrician for a complete analysis. Just under 25,000 roots were individually weighed and assessed over the four crops to determine yield and quality.

Table 5. Skin lesions and defects recorded during harvest assessments.

Categories	Lesions and defects recorded
Nematode related damage	Raised pimples, Black pimples, Nematode cracks, Barnacles.
Insect damage	Wire worm (*Agrypnus spp*.- true wireworm, *Pterohelaeus spp*., *Gonocephalum spp*. - false wireworm), White grub (various species), Sweetpotato weevil (*Cylas formicarius),* Flea beetle (various species), Symphylans (various species).
Breakdown (Bacterial and Fungal)	Soil Pox (*Streptomyces ipomoeae*), Geotrichum sour rot (*Geotrichum candidum)*, Circular spot (*Sclerotium rolfsii*), Collar rot or mottle necrosis (xxxx), Other rots and breakdown.
Lenticel changes	Elongated lenticels, DLSR, Sunken lenticels.

Physiological defects	Misshapen, Veining, Longitudinal grooves, Constrictions, Concertina effects, Chimeras.
Physical defects	Sunburn, Broken, Animal damage,

Image 8 A range of skin lesions were recorded including nematode related damage, insect and animal damage., bacterial and fungal infections and physical defects.

Subsequent harvests

After harvest, the site was raked and deep ripped, to remove any visible sweetpotato material (vines or roots). The block was again sown with White french millet and the process was repeated as detailed in Table 2. Subsequent harvests were conducted in June 2021, June 2022 and May 2023.

Results and Discussion

Environmental factors

Bundaberg experienced higher than average rainfall events during 2021 and 2022.Rainfall data for Bundaberg from the Bureau of Meteorology is listed below. Darins were constructed at the sides of the trial block to allow water in flooded furrows to drain away.

Table 6. Rainfall during the 5 month growing period preceding crop harvest

Annual rainfall in Bundaberg 2018 to date	
Intensive Trial	rainfall (mms)

2018	743
2019	334
2020	654
2021	931
2022	1280
2023 to date	417

Image 9.Left and right, intermittent flooding in the long-term trial.

Each root underwent close visual scrutiny and all lesions and defects were recorded. After the 2020 harvest, several defects were consolidated into groups due to low incidence. For example, where all rots such as soil pox, Geotrichum. sour rot and circular spot which were previously recorded individually were recorded under the general defect of "rot". Misshapen, veins, longitudinal grooves and constriction were classified as "physiological defects". Animal damage, broken, sunburn and growth cracks were recorded as general physical defects. However, due to increased rainfall in 2021, and increased incidence of rots lesions and defects were recorded individually in 2022 and 2023. At the fourth harvest in 2023, a severity rating system (high, medium or low) was incorporated. Just under 25,000 roots were individually weighed and assessed over the four crops to determine yield and quality.

DAF biometricians Bill Mayer and Carole Wright conducted data analysis using a range of fir for purpose statistical methods. In 2023, Root weight was mostly analysed using analysis of variance (ANOVA)., Root numbers were analysed using a generalised linear model with a Poisson distribution and a log link. Incidence data has been analysed using a generalised linear model with a Binomial distribution and complementary log-log link. Terms fitted in the models were replicate + treatment. Results were reported as a percentage of non-marketable roots in that size class. Means, standard errors (se) and average 95% least significant differences are presented. Significance testing was performed at the 0.05 level. The 95% lsd is used to make pairwise comparisons where a significant effect is detected.

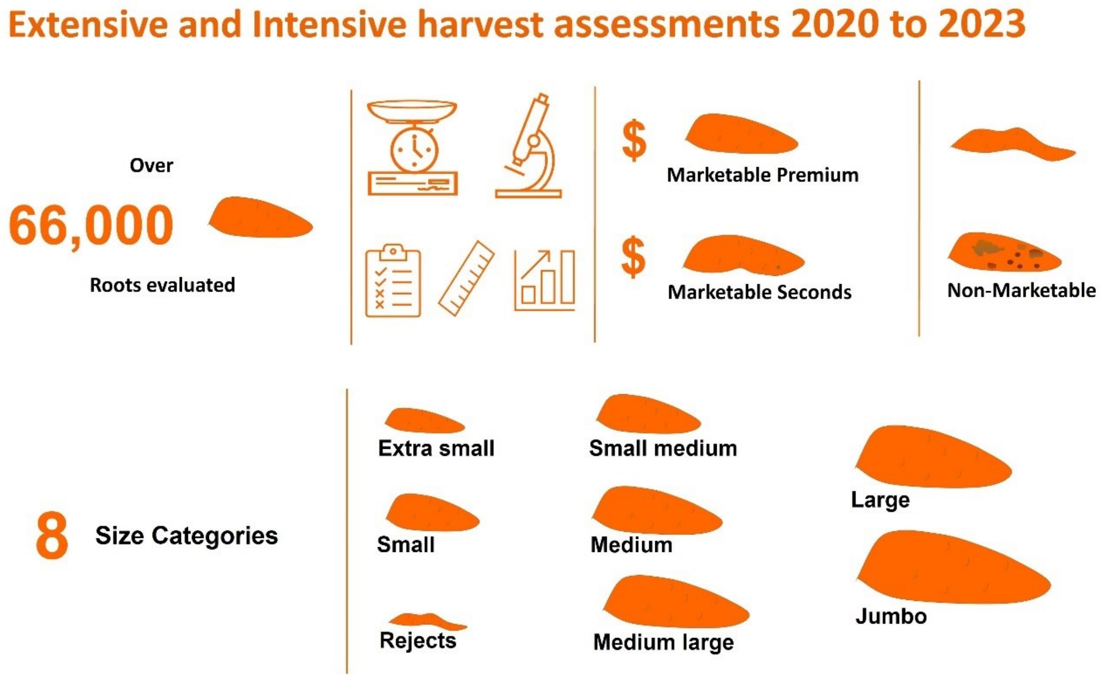


Image 10. Root grades and marketability.

Root weights

At the first harvest in 2020 the Organic matter treated plots produced a significantly higher weight of marketable roots than all other treatments (Figure 1). The Nil treatment plots produced the lowest weight of marketable roots. At the second harvest in 2021. The Nimitz plots produced a significantly higher weight of marketable roots than the organic matter and V Furrow plots but not significantly different form the Nil, and compost treatments. By the third harvest in 2022, the Organic matter treated plots again produced a significantly higher weight of marketable roots than all other treatments. There were no significant differences between the Nil, Nimitz, Compost and V furrow plots. There were no significant differences in the weight of marketable roots produced in all treatments in the last harvest in 2024.There were no significant differences in the weight of non-marketable roots produced in all treatments in any of the harvests.

In summary the Organic matter treatment had statistically higher meant root weight in two of the four years and yielded well in the other two years. In only one year (2020) were the other treatments significantly better than the nil treatment.

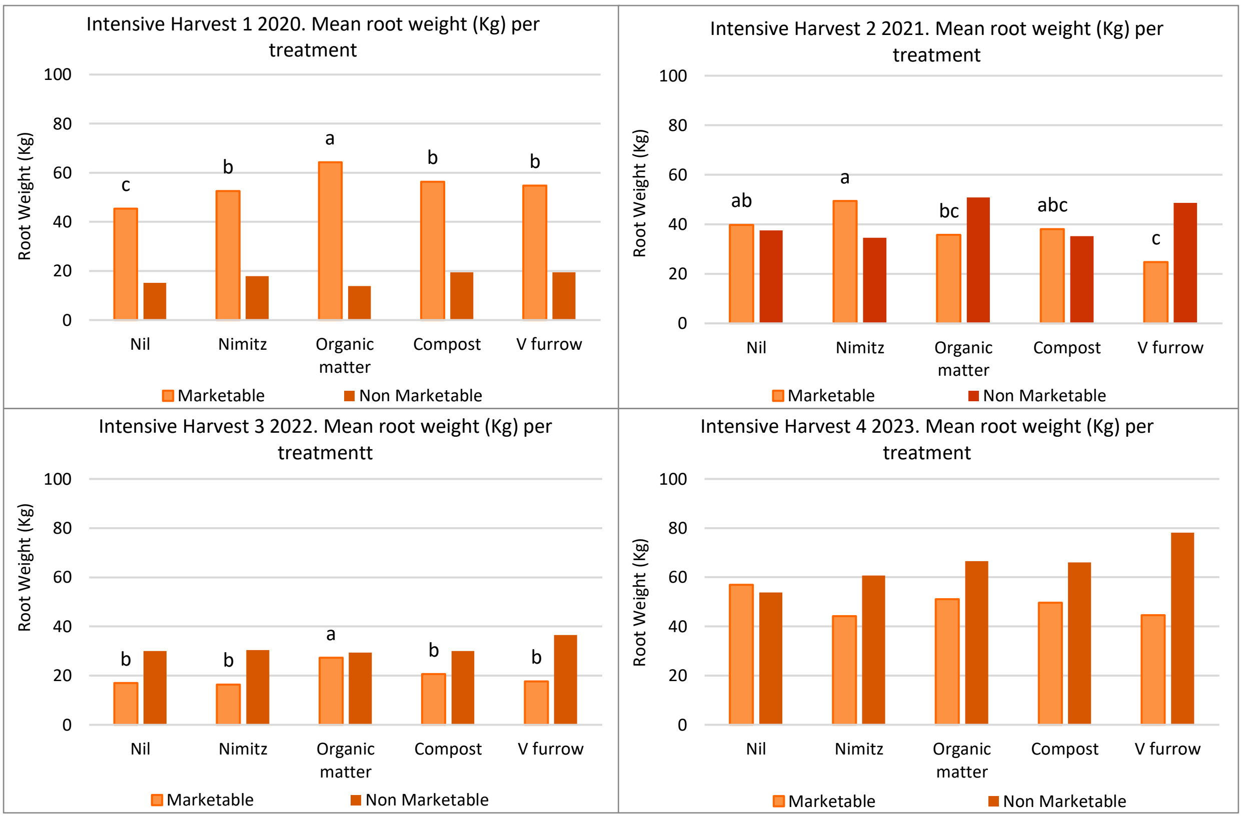


Figure 1. Intensive trial root weights across the four harvests, 2020 to 2023.

Root numbers

Analysed data from the first harvest in 2020 (figure 2), indicated that the Nil plots produced a significantly lower number of total medium roots than all other plots. The Organic matter and Compost plots produced a significantly higher number of total roots per plot, but this was not significantly different to the Nimitz, and V furrow plots. There was no significant difference in the mean number of marketable medium roots. The 2021 harvest Nimitz plots produced a significantly higher number of roots than the V furrow plots but this was not significantly higher than the Nil plots. By the third harvest, the organic matter plots produced a significantly higher number of roots than all other treatments except the Compost. The Compost numbers were not significantly different form the Nil, Nimitz, and V furrow lots. There were no significant differences in root numbers produced in 2023, though the Nil and Compost plots root numbers were higher.

Summarizing all years, plants in the Organic matter treatment produced a significantly higher number of medium marketable roots in one year (2022), as did plants in the Nimitz treatment (2021). Both treatments were similar to all others over the other years of the trial. The V furrow treatment produced good root number, although not statistically different in most years with the exception of 2021 when it produced a statistically lower number of roots.

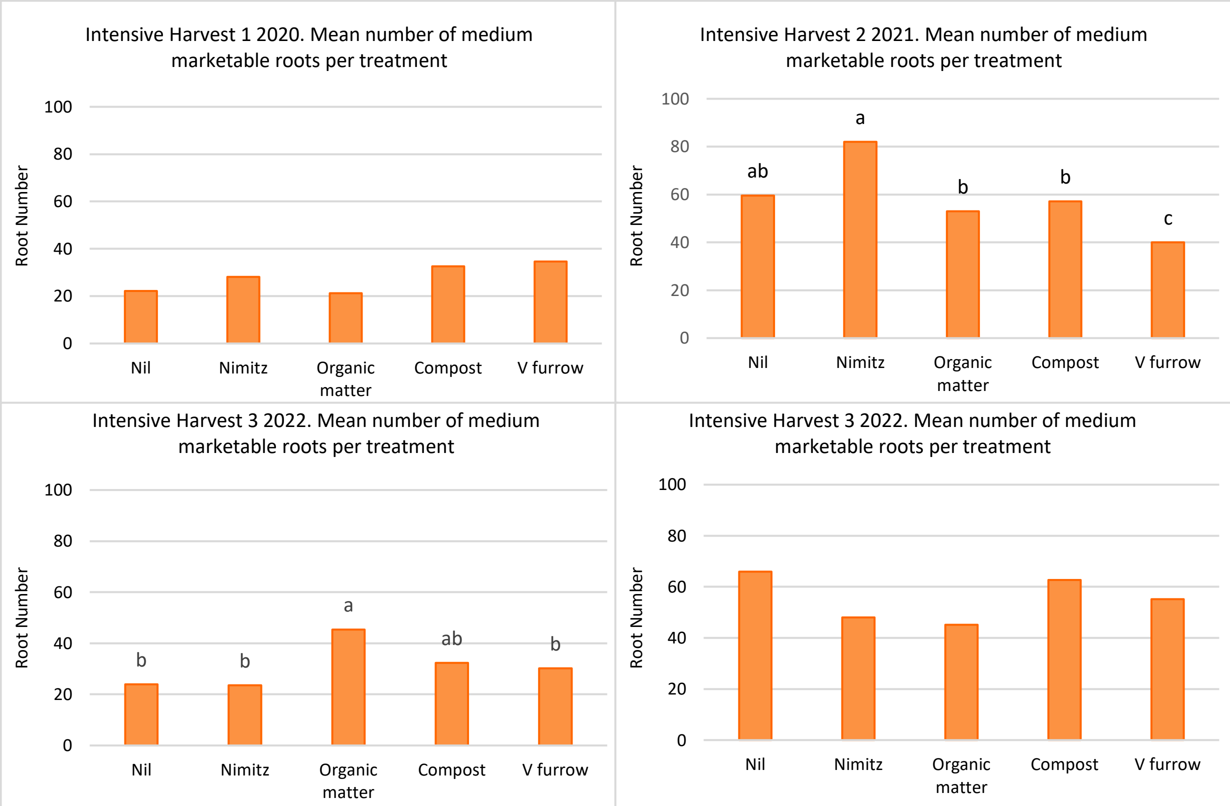


Figure 2. Intensive trial root numbers across the four harvests, 2020 to 2023.

Nematode related lesions

Raised Pimples

In 2020 roots from the Organic matter treatment had significantly fewer raised pimples than Nil, Nimitz and V furrow treatments and a similar although lower percentage that the compost treatment (Figure 3) . A significantly higher percentage of raised pimples was recorded in roots form the V furrow treatments although this was not significantly different form the nil and nematicide treated plots. In 2021 the Nil treatment of small marketable, small non-marketable, all smalls, all marketable and all marketable + non-marketable roots category roots had a significantly higher mean of raised pimples comparted to the Compost, Nimitz, Organic matter and V furrow treatments. While there was no significant difference between Compost, Nimitz, Organic matter and V furrow, the Nimitz and Organic matter treatments tended have the lowest incidence of raised pimples across the categories. 2022 and saw no significant differences between any of the treatments. By 2023 the population of RKN had reduced dramatically and there were no raised pimples recorded form any treatments.

Although there a significant trend over the first two harvests in 2020 and 2021 between treatments and raised pimples, with lower levels of raised pimples in some size categories in the Organic amendment and Nimitz treatments, this trend did not continue in the last two harvests in 2022 and 2023.

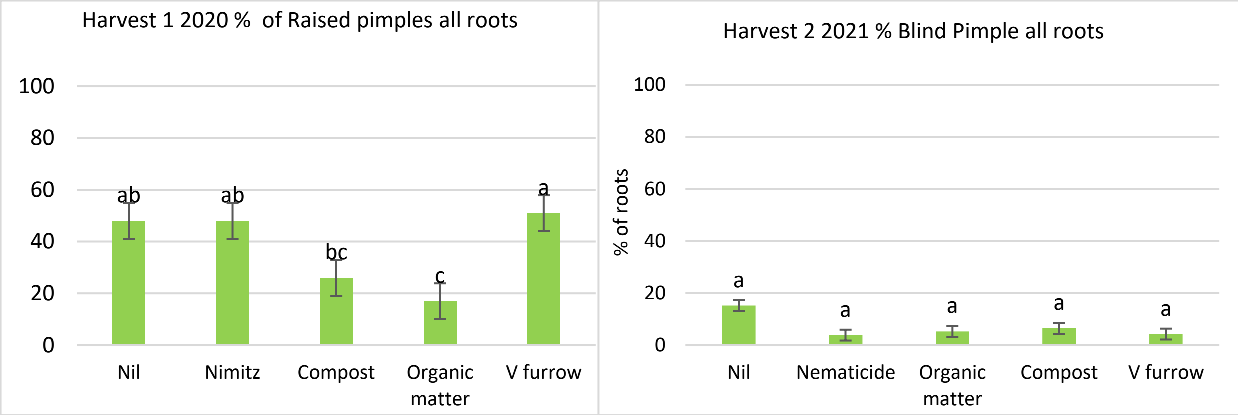


Figure 3 Intensive trial incidence of raised pimples per treatment in the First and second harvests.

Black Pimples

Organic matter treatment had the lowest level of Black pimples in 2020 non-marketable roots (figure 4). In 2021 the incidence of Black pimples in large unmarketable roots was lowest in the Organic matter treatment and highest in the Nil treatment although this was statistically similar to the Compost treatment. In the 2022 trial only medium roots showed any significant differences to level of Black pimples. The Organic matter treatment showed the lowest number of black pimples being similar to the V furrow treatment and significantly lower than the Nimitz, Compost and Nil treatments. The Nimitz treatment while similar to the Compost and V furrow treatments had significantly lower black pimples than the control treatment. There was a low incidence of Black pimples in 2023 and no differences were seen between treatments.

While treatment effects were only seen in a few root categories throughout the trial, the Organic matter treatment over all years had a lower level of black pimples.

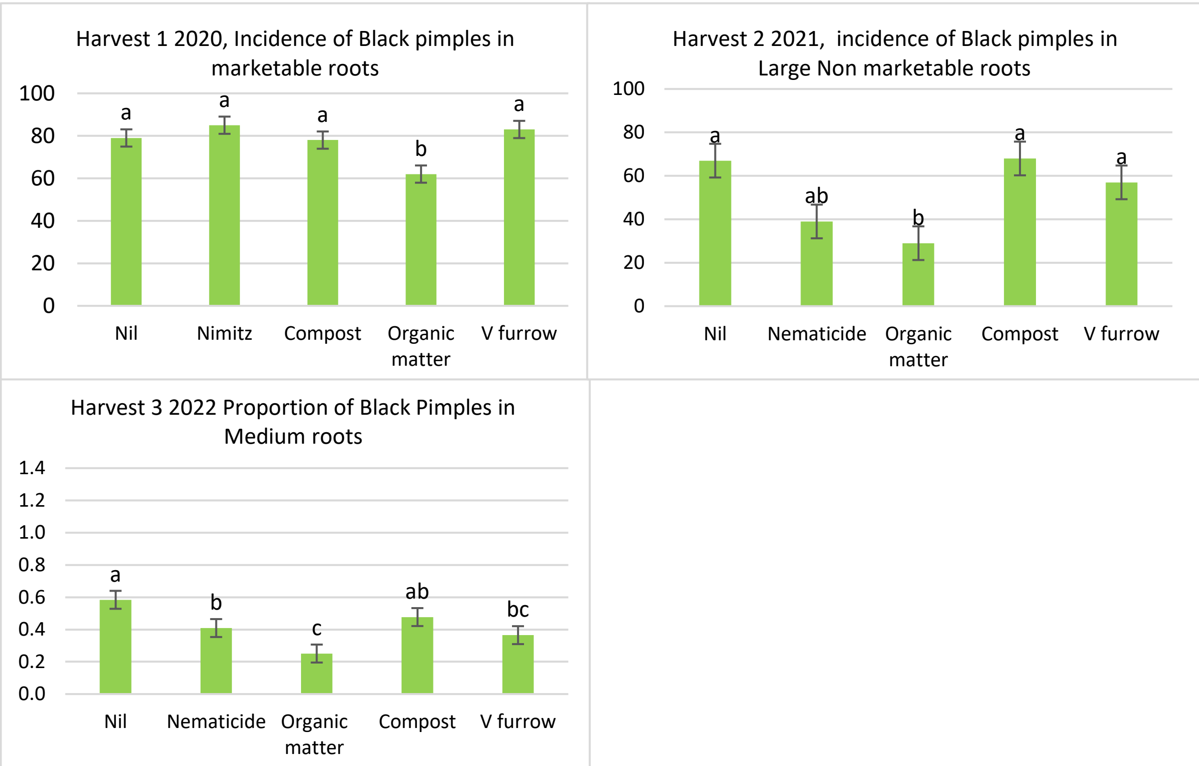


Figure 4. Incidence of black pimples in the intensive trial in 2020, 2021 and 2022.

Nematode cracks

There were few nematode cracks observed in 2020 and incidence decreased in subsequent harvests. There were no significant differences in incidence over the four harvests.

Barnacles

There were no significant differences in the incidence of Barnacles in 2020, 2021 and 2023. However, in 2022, small sized and total roots (small + medium + large) grown in the Organic matter plots had a significantly lower incidence of Barnacles than all other treatments but was not significantly different to the Compost treatment.

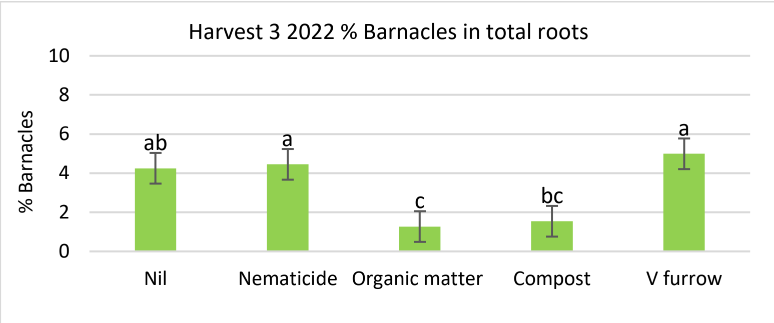


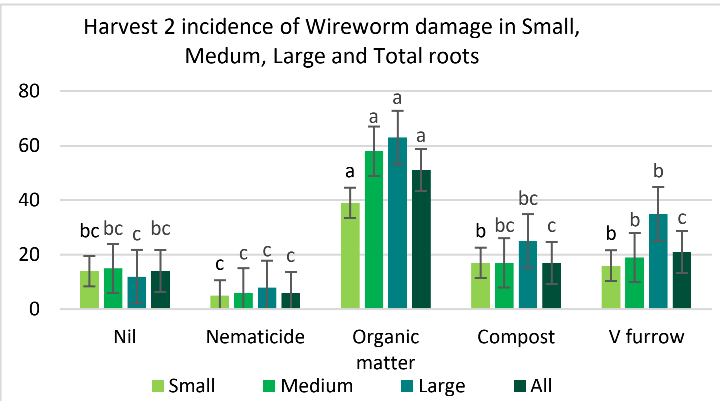
Figure 5.Incidence of Barnacles in harvest 3.

Insect damage

Wireworm

In 2020 wireworm presence was low so was not analysed. Wireworms were a problem during 2021 (figure 8). The Organic matter treatment. 2021 saw a high incidence of wireworm damage across all categories of roots (small marketable, small non-marketable, small all, medium marketable, medium unmarketable, medium all, large marketable, large unmarketable, large all and all). In all of these categories roots in the Organic matter treatment significantly showed most damage. The Compost and V furrow treatments also showed a higher level of damage. Nimitz showed least damage in all categories often significantly so. The next treatment for least damage was the nil treatment. In 2022 and plantings wireworm was present, but damage levels were not affected by treatments. At the fourth harvest in 2023 roots form the Organic matter and Compost treatments had a significantly higher incidence of damage by sweetpotato weevil than the Nimitz plot but this was not significantly different to roots from the Nil and V furrow treatments.

While significant differences in incidence were only observed in 2021 and 2023, it is noticeable that the wireworm damage was more prevalent in all treatments containing organic matter. Whether this was a once off occurrence due to the sudden increase of organic matter into the soil or could be an issue to contend with if using Compost, Organic matter or V furrow treatments cannot be confirmed.



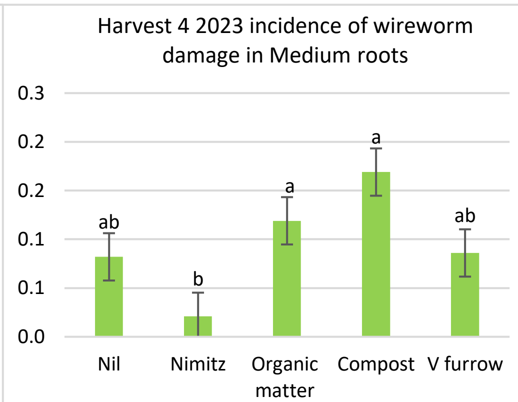


Figure 6. Incidence of Wireworm damage at Harvest 2 and Harvest 4.

White grub

As there was not a high level of white grub in 2020 so data was not analysed for any effects of this pest. In 2021 the large unmarketable category did show treatment effects for white grub damage. The Organic matter treatment showed significantly less damage than Nimitz and V furrow but was not dissimilar to Compost or Nil treatments. There were no significant differences between treatments in 2022. In 2023 the Organic matter treatment suffered significantly more damage than the Nil, Nimitz and marketable roots of the V furrow treatment.

Similar to wireworms, when white grub did occur it tended to cause more damage in treatments with higher levels of organic matter.

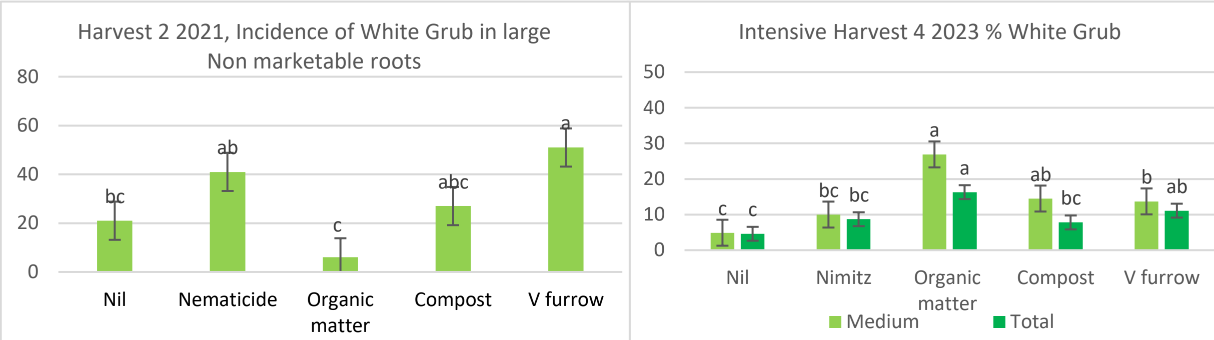


Figure 7. Incidence of White grub by treatment in the intensive trial in 2021 (left, and 2023 (right).

Symphilids

Symphilids were only recorded in 2023 and there were no significant differences in occurrence between the treatments.

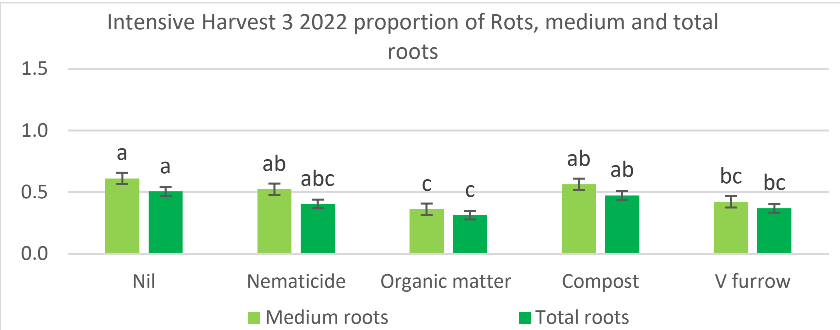


Figure 8. Proportion of rots in medium sized and total roots by treatment in the intensive trial in 2022.

Bacterial and fungal defects

Geotrichum sour rot

Due to the low level of Geotrichum sour rot in 2020, 2021 and 2022 there was no analysis done for treatment effects. In 2023 some treatment effects were seen for Geotrichum sour rot. In both Medium and Total root categories the Compost treatment was significantly more effected than Nil, Nimitz and V furrow treatments, and was similar to the Organic matter treatment. This indicates that higher levels of Organic matter may be an issue for sweetpotato roots being infected with Geotrichum sour rot, should environmental conditions favor its development.

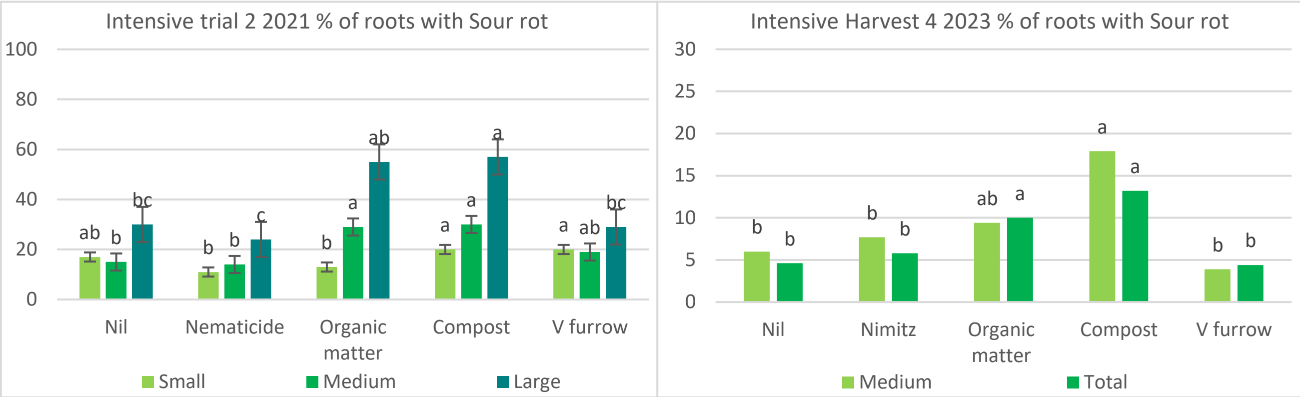


Figure 9. Proportion of Sour rot by treatment in the intensive trial in 2021 and 2023.

Streptomyces Soil Rot (Pox), Streptomyces ipomoeae

Soil pox was not an issue in 2020 and 2022. In 2021 the Nimitz treatment had significantly lower soil pox than all other treatments, followed by the nil and compost treatments. The Organic matter and V furrow treatments were significantly worse than the other treatments this was also a significant trend for roots in the in the small, medium and large sizes. In 2023 soil pox was present at a low level of infection across all root sizes. Again, the Nimitz treatment has lowest infection along with the nil and V furrow treatment.

While not clear the data does suggest that Nimitz treated blocks may have a lower level of soil pox.

Other rots and breakdown

In 2020 and 2021 seasons there was low level of root rots, so their incidence was not analysed. 2022 saw a higher level of root rots. The Organic matter treatment had significantly lower rots than nil and compost treatments. For medium roots, the size category where most of the rots occurred the Organic matter treatment also had significantly fewer rots than the Nimitz treatment. While analysis of rots was conducted in 2023 there was no significant differences between treatments. There is not enough evidence to state whether the treatments influenced the incidence of root rots.

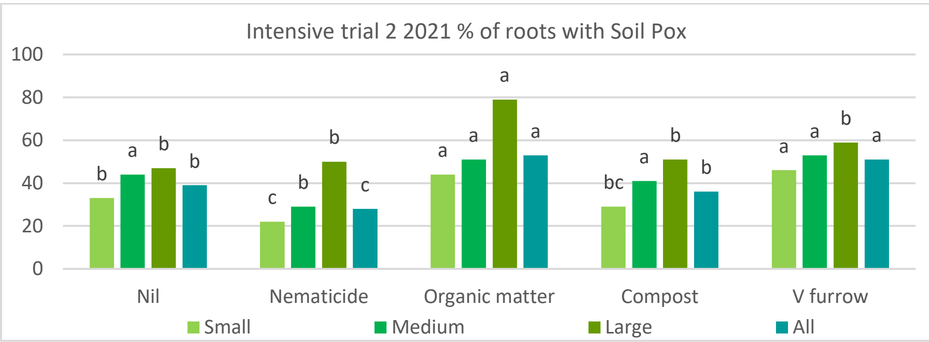


Figure 10. Proportion of Soil pox by treatment in the intensive trial in 2021.

Other defects

Darkened lateral feeder root scars (DLRS)

Darkened lateral feeder root scars (DLRS) occur when the lateral feeder roots are damaged, and a wound response is initiated. The result is an indent on the root surface filled with a darkened scab-like layer on the periderm. Cause is unknown.

There was no significant treatment effect for the level of DLRS in the 2020 planting. In 2021 only large roots showed treatment effects. In all categories of large roots, the Organic matter treatment showed significantly less DLRS than the Nil treatment (figure 6). In 2022 there was no significant differences between treatments. 2023 saw treatment effects in the medium root category, but the effects were contradictory to the 2022 results. Nimitz in 2023 had significantly lower incidence of DLRS than any treatments with added organic matter (Compost, Organic matter and V furrow treatments) and was similar to the Nil treatments.

Over the trial life the treatment results for DLRS incidence are confusing. This confusion may relate to some years having a low incidence of DLRS and trial variation being too great to identify treatment differences.

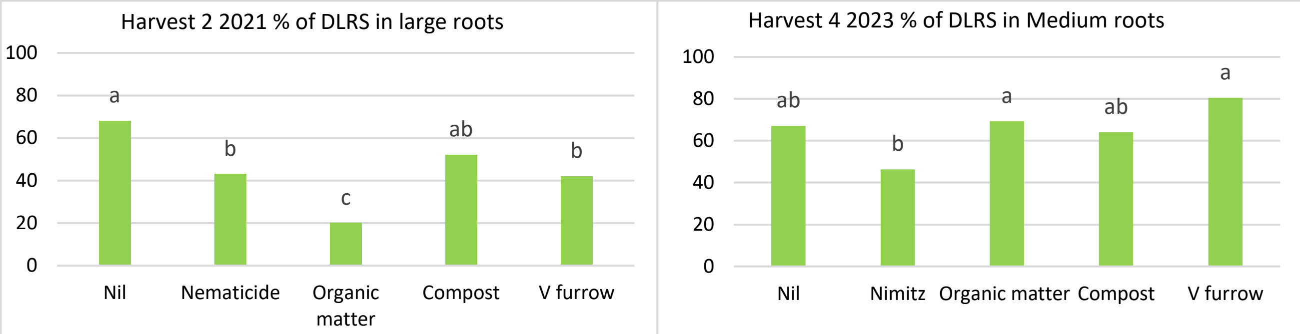


Figure 11.Incidence of DLSR at Harvest 2, left and Harvest 4, right.

Elongated Lenticels

In 2020, no treatment affected the level of Elongated lenticels. In 2021 there were some significant differences in small roots and in large unmarketable roots (figure 7). In all the small roots the Organic matter treatment had significantly more Elongated lenticels than all other treatments, while in the small roots the Organic matter treatment again had the highest percentage of Elongated lenticels although this was similar to Compost, Nematicide and Nil treatments, and only significantly different to the V furrow treatment. The large nonmarketable roots also saw some significant differences, although in this case it the Organic matter treatment was significantly lower than all treatments accept Compost. 2022, saw some treatment differences in the small sized roots with the Compost treatment having more elongated lenticels than Organic matter or V furrow treatments, but was similar to Nimitz and Nil treatments. The planting in 2023 saw no differences in the level of Elongated lenticels in any of the treatments.

Overall, the treatments did not show much effect on the level of Elongated lenticels. The occurrence of Elongated lenticels may be more related to environment and stage of growth factors.

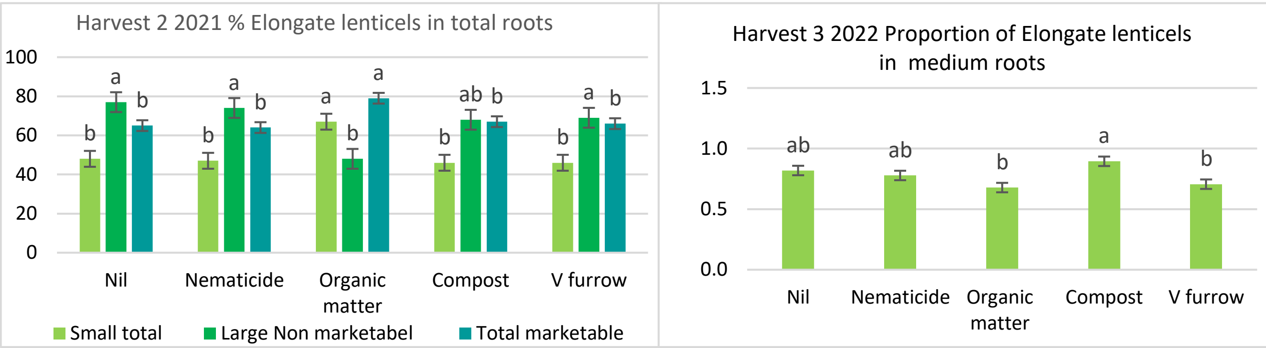


Figure 12 Incidence of Elongated lenticels at Harvest 2, left and Harvest 3, right.

Miscellaneous defects

In 2020 there was minimal occurrence of sunken lenticels in the trial. The numbers of sunken lenticels had increased in 2021, 2022 and 2023 there was not treatment affecting their occurrence. As over three years there was no treatment effect on the occurrence of sunken lenticels, their formation may be due to other factors.

Sunburn (Table 7) was not analysed 2020 and 2022 due to low numbers. In 2023 while analysed there were no significant differences between treatments and in 2021 the only treatment difference seen was in large unmarketable root category where the organic matter had significantly less sunburn than all other treatments. Overall, the level of sunburn does not appear to be affected by treatments. Concertina skin effect was not analysed in 2020, 2022 and 2023 due to low numbers of roots being affected. In 2021 only the large marketable roots showed any significant treatment differences in level of root concertina. The Organic matter and V furrow treatments had significantly less concertina than the Compost treatment. Given the lack of data, concertina would not appear to be a problem caused by any of the treatments.

There was a significantly lower incidence of broken roots in the nematicide treatments in 2021 and 2023. In the fourth harvest in 2023 there were significantly higher incidence of animal damage in Nimitz plots than all other plots except the V-furrow plots. Root constrictions were not analysed in 2020 and 2022 due to their low number. Although analysed in 2021 there was no difference between treatments. In 2023 the organic matter treatment showed significantly more root constrictions in medium sized roots than the Nil and Nimitz treatments but similar to Compost or V furrow which in turn were similar to nil and Nimitz treatments. Possibly the organic matter treatments may be more susceptible to root constrictions but there would need to be further research to prove this.

A significantly lower incidence of Longitudinal grooves was recorded in large roots grown in the Organic matter and Compost treatments in Harvest 4. There were no significant differences in previous harvests. As the 2020 and 2022 trials only had a low number of misshapen roots the data was not analysed. The level was higher in 2021 but no significant differences were seen between treatments. In 2023 there only differences seen between treatments was in the medium size roots. In this category the Nimitz treatment had significantly fewer misshapen roots than the Compost, Organic matter or V furrow treatments. Nimitz and Nil treatments were similar. There is not enough evidence to determine if the treatments have an effect on root shape.

Table 7. Other defects with significant treatments differences in 2021 and 2023.

Year	2021		2023						
Defect	Sunburn	Concertina	Broken	Broken	Animal Damage	Constrictions	Longitudinal Grooves	Longitudinal Grooves	Misshapen
Size	*Large Non-Mkt*	*Large Mkt*	*Small*	*All roots*	*Medium*	*Medium*	*Small*	*Large Non-Mkt*	*Medium*
Nil	24.6 a	4.0 ab	0.066 a	0.046 a	0.105 b	0.115 ab	0.077 b	76.4 a	0.866 ab
Nematicide	27.9 a	2.4 ab	0.014 b	0.02 b	0.094 b	0.072 b	0.178 a	72.4 a	0.789 bc
Organic matter	7.0 b*	0.0 b*	0.048 a	0.037 ab	0.163 a	0.069 b	0.075 b	43.2 b	0.761 c
Compost	29.7 a	5.7 a	0.074 a	0.057 a	0.103 b	0.171 a	0.072 b	75.0 a	0.867 ab
V furrow	23.8 a	0.0 b	0.057 a	0.039 ab	0.129 ab	0.114 ab	0.116 ab	56.6 b	0.892 a
F(4,16)	6.6	1.2	5.010	3.620	3.45	3.85	4.74	7.20	3.51
P	CR	RB	0.008	0.028	0.033	0.022	0.010	0.002	0.031
Average 95% lsd	0.03	0.02	0.0338	0.0217	0.0427	0.0609	0.0582	15.06	0.0893

** Means followed by a similar letter do not differ significantly (p>0.05)*

Extensive trial -Sustainable farming systems long term trial

Introduction

This trial was established simultaneously with the Intensive trial in November 2018 at Bundaberg Research Facility. The aim was to assess the nematode control and soil health benefits provided by farming systems that incorporate minimum tillage (pre-formed beds) as well as crop rotation and organic amendments. The extensive trial was more experimental than the intensive trial in its design with the use of pre-formed beds. The main components of this trial incorporate controlled traffic, minimum tillage, organic amendments, cover cropping with a grass legume rotation or a grass brassica rotation and mulching. The trial ran from November 2018 to June 2023.

The experimental trial design followed the process outlined below:

- Apply organic amendments, form beds, grow a cover crop on the beds, mulch or spray the above-ground biomass.
- Plant sweetpotato with minimum tillage and controlled traffic.
- Harvest the sweetpotato crop ensuring that all traffic was controlled during the harvesting operation.
- Re-form the beds and repeat the process.

Materials and methods

The trial followed these steps: Apply organic amendments, form beds, grow a cover crop on the beds, mulch or spray the above-ground biomass. Plant sweetpotato with minimum tillage and controlled traffic. Harvest the sweetpotato crop ensuring that all traffic was controlled during the harvesting operation. Re-form the beds and repeat the process.

The extensive trial comprised ten treatment combinations with a factorial treatment structure. There were two crop treatments (Grass/Brassica and Grass/Legume) and five amendment treatments (Double, Incorporated, Nematicide, Nil and V furrow). Each treatment was replicated four times, and the trial was designed as a randomised complete block. Nematicide treatments (Vydate) were included to determine if the sustainable farming system approach reduced RKN populations to an extent that a nematicide was no longer necessary. In the five-year trial period three commercial crops were grown and harvested

Table 8. Treatments in the Extensive trial.

	Method		Rotation Crops
Treatment 1	Nematicide	Vydate (oxamyl)	Grass/Brassica
Treatment 2	Nil	No treatment	Grass/Brassica
Treatment 3	V-furrow	Sawdust + chicken manure	Grass/Brassica
Treatment 4	Incorporated	Sugarcane mulch + chicken manure/compost	Grass/Brassica
Treatment 5	Double	Incorporated + v-furrow treatments	Grass/Brassica
Treatment 6	Nematicide	Vydate (oxamyl)	Grass/Legume
Treatment 7	Nil	No treatment	Grass/Legume
Treatment 8	V-furrow	Sawdust + chicken manure	Grass/Legume
Treatment 9	Incorporated	Sugarcane mulch + chicken manure/compost	Grass/Legume
Treatment 10	Double	Incorporated + v-furrow treatments	Grass/Legume

The same procedures used in the Intensive trial for RKN inoculation of the block, soil monitoring, planting of the commercial crop, trial maintenance, harvest and assessment were also carried out in the Extensive trial.

Amendments

After harvest of the sacrificial sweetpotato crop, the block was rotary hoed. Organic amendments were applied to the Double amendment and Incorporated amendment treatments band prior to incorporation during bed forming. Amendments were hand placed on top of the rows in a 40 cm wide central band (based on GPS tracking) using buckets (image 10). Rates for banded amendments were based on those used in previous field trials demonstrating suppression of plant-parasitic nematodes; 56 kg/14m row or plot, is equivalent to 50 t/ha. The amendments combined 22.4 kg/row of poultry manure plus 33.6 kg/row of sawdust (40/60 blend), or sugar cane mulch 25 t/ha (= 50 t/ha total). Prior to bed formation a basal fertiliser was applied, following grower practice. PRG discussions resulted in the decision not to apply any preplant soil insect chemicals (as per current grower practice), so as not to interfere with biological soil populations. After bed formation cover crops were planted, either a grass followed by a legume (20 plots), or a grass followed by a brassica species (20 plots).

Image 11 Amendments were weighed into buckets and had applied to the respective plots.

At the end of the cover crop phase a V-furrow was opened on top of the beds with a double disc opener and organic matter (poultry manure + sawdust 40/60 blend @76 L/row = 28.65 kg/row), was placed into the furrow in each of the 16 Double amendment treatments. The nematicide Vydate was applied as per label rate to the appropriate plots. The furrows were then closed by shovel, using loose soil created during the furrow opening process. It is hypothesised that newly developed roots will potentially be protected from nematode attack due to increased suppressive activity in this zone enriched with organic matter. The planting schedule can be viewed at table 7.

Image 12 Cover crops

Table 9 Extensive trial treatments and application dates

Treatment	**Incorporated amendment** Incorporated and beds formed		**Double amendment** (Incorporated + V-furrow amendment)		**V-furrow amendment** V furrow added prior to planting		**Vydate Nematicide** As per label, 18 L/ha within 7 days of planting, followed by four applications @ 2 L/ha at 14-day intervals.		**Nil/ control** No amendments or nematicides	
Rotation	Grass/Brassica	Grass/Legume	Grass/Brassica	Grass/Legume	Grass/Brassica	Grass/Legume	Grass/Brassica	Grass/Legume	Grass/Brassica	Grass/Legume
Date										
21 Nov 18	Nematode inoculation to increase populations, sacrificial sweetpotato crop planted									
14 May 19	Poultry manure + Sugarcane mulch.		**Incorporated:** Poultry manure + Sugarcane mulch.							
14 May 19	Rotary hoe and form beds									
27 May 19	White French millet									
3 Sep 19	Nemsol	Soybean A6785	Nemsol	Soybean A6785	Nemsol	Soybean A6785	Nemsol	Soybean A6785	Nemsol	Soybean A6785
15 Jan 2020			**V furrow:** Poultry manure + Sawdust		Poultry manure + Sawdust					
20 Jan 20	Planted sweetpotato crop 1 cv. Beauregard									
8 Jun 20	Harvest and assess sweetpotatoes 140 DAP									
29 Jun 20	Poultry manure + Sugarcane mulch.		**Incorporated:** Poultry manure + Sugarcane mulch.							
7 Jul 20	White French millet									
30 Nov 20	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp
25 Feb 21	Signal grass									
20 May 21	Swan oats									
21 Sept 21			**V furrow:** Poultry manure + Sawdust		Poultry manure + Sawdust					
23 Sept 21	Planted sweetpotato crop 2 cv. Beauregard									
21 March 22	Harvest and assess sweetpotatoes 179 DAP									
23 Mar 22	Poultry manure + Sugarcane mulch.		**Incorporated:** Poultry manure + Sugarcane mulch.							
23 Mar 22	Rotary hoe and form beds									
5 Apr 22	Swan oats									
28 Sept 22	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp	Nemsol	Sunn Hemp
2 Dec 22			**V furrow:** Poultry manure + Sawdust		Poultry manure + Sawdust					
6 Dec 22	Planted sweetpotato crop 3 cv. Beauregard									
24 Apr 23	Harvest and assess sweetpotatoes 139 DAP									

Soil Monitoring

Soil samples were collected at critical points in the trials, such as pre plant, post-harvest and post rotation crop. Samples were sent to the project team nematologists for nematode extraction, to the Department of Environment and Science (DES) for soil chemical and physical analysis and to GRF for extraction of soil biologicals, microarthropods and Nematode trapping fungi (NTF). Results from these samples will allow investigation into correlation between soil characteristics, RKN populations and soil biology.

Planting the commercial crop

The Intensive was planted with standardised hi spec vine tip cuttings (image 22), cultivar Beauregard at 20 cm plant spacing on the 20th of January 2020. 2 January 2021, 11 February 2022 and 15 December 2022 (Table 7).

Image 13.The Extensive trial preformed beds showing the White french millet cover crop sprayed off in preparation for planting of the commercial crop.

Image 14.Left to right, planting into the preformed beds in the Extensive trial.

Image 15.The commercial crop in the Extensive trial showing a sorghum rotation in the Intensive trial to the right.

Harvests

Harvests were conducted in June 2020 March 2022 and April 2023. After harvest, amendments were again applied to the Double and Incorporated treatments, beds were re-formed, and the next cover crop was planted as per table 7.

Results

Roots were harvested from each plot and individually graded by size (small, medium, large) and marketability (premium marketable, second marketable and non-marketable). The data form the premium and second grade marketable roots was combined into a single marketable class. Each individual root was assessed for defects and the proportion of roots in each plot affected by damage was calculated.

The plot proportions were initially analysed using a generalised linear mixed model (GLMM) assuming a binomial distribution and complementary log-log link function. However, the models often did not converge and therefore a generalised linear model (GLM) was fitted. The replicate effect was fitted as the first term in the model followed by a single treatment factor representing the 10 treatments. Each combination of size and marketability was analysed independently. This does not allow for any differences between size classes to be determined but allows for a simpler interpretation of the treatment effects. A simple contrast was also fitted to investigate an overall effect of crop. This was investigated further by fitting the factorial treatment structure in the model. Data from extra small and small roots was combined to form the small category, small medium-, medium- and medium-large root data was combined into the medium category and large and jumbo roots were combined to form the large category.

Root weights

In 2020 in both the grass/brassica and grass/legume treatments in the Incorporated plots produced significantly higher yields than all other treatments. In the grass/brassica plantings the Double and V furrow treatments were similar in yield although lower than the Incorporated treatment. In both plantings the Nil treatment produced the lowest yield, significantly so in the grass/brassica planting and similar to the nematicide treatment in the grass/legume planting.

In 2022 results were reversed in that the highest yielding treatment was the Nil treatment, significantly better in the grass/brassica plantings and equal to the V furrow and significantly better than the other treatments in the grass/legume plantings. In both the grass/brassica and grass/legume plantings the Nematicide, Double and Incorporated treatments were significantly lower. In 2023 another reverse occurred with Double, Incorporated and V furrow treatments being the best yielding treatments in both plantings. Nil and nematicide treatments were the lowest yielding treatments.

The yield results are variable over time. Given the complex nature of soils and soil biology there may well be need for extended trial periods to see the true benefits of these treatments. At this early stage it is only possible to say that the Incorporated, Double and V furrow treatments performed best in two out of three plantings.

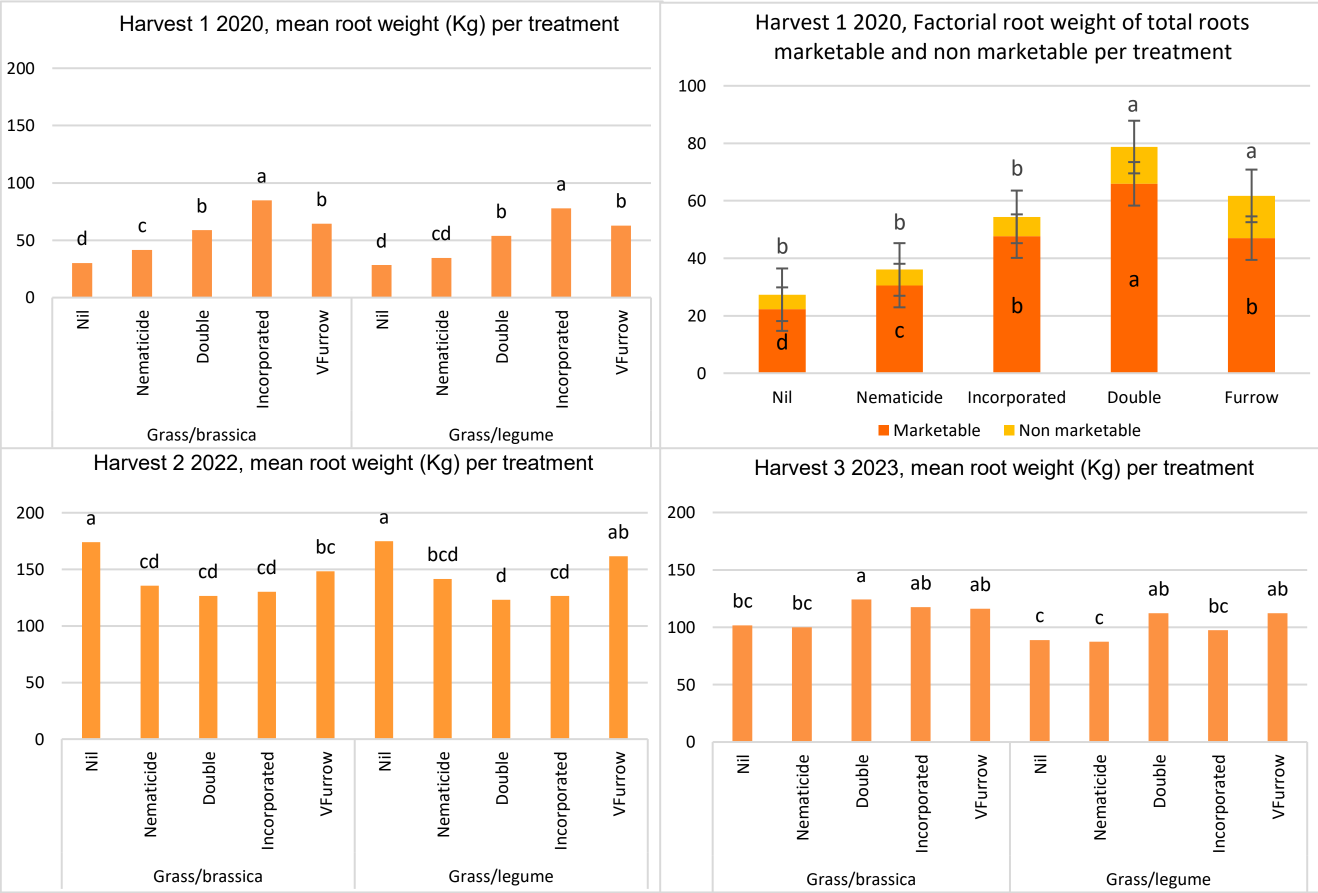


Figure 16 Extensive trial root weights across all harvest.

Root numbers

The root count data was analysed using a GLM but assumes a Poisson distribution and a log link function. In 2020, the Incorporated and V furrow treatments in the grass/brassica & grass/legume treatments had the highest root numbers. In the factorial analysis, the Double amendment produced the highest number of roots with the Nil treatment plots producing the lowest number of roots.

In 2022, the Nil treatment produced the highest number of roots in the grass/brassica plots and the double, Incorporated and V furrow plots in the grass/legume treatments produced the most roots High counts were recorded for double, incorporated and V furrow in the Grass/legume treatment crop. A somewhat similar trend was seen in 2023, however there were no significant differences between treatments in the number of total roots produced.

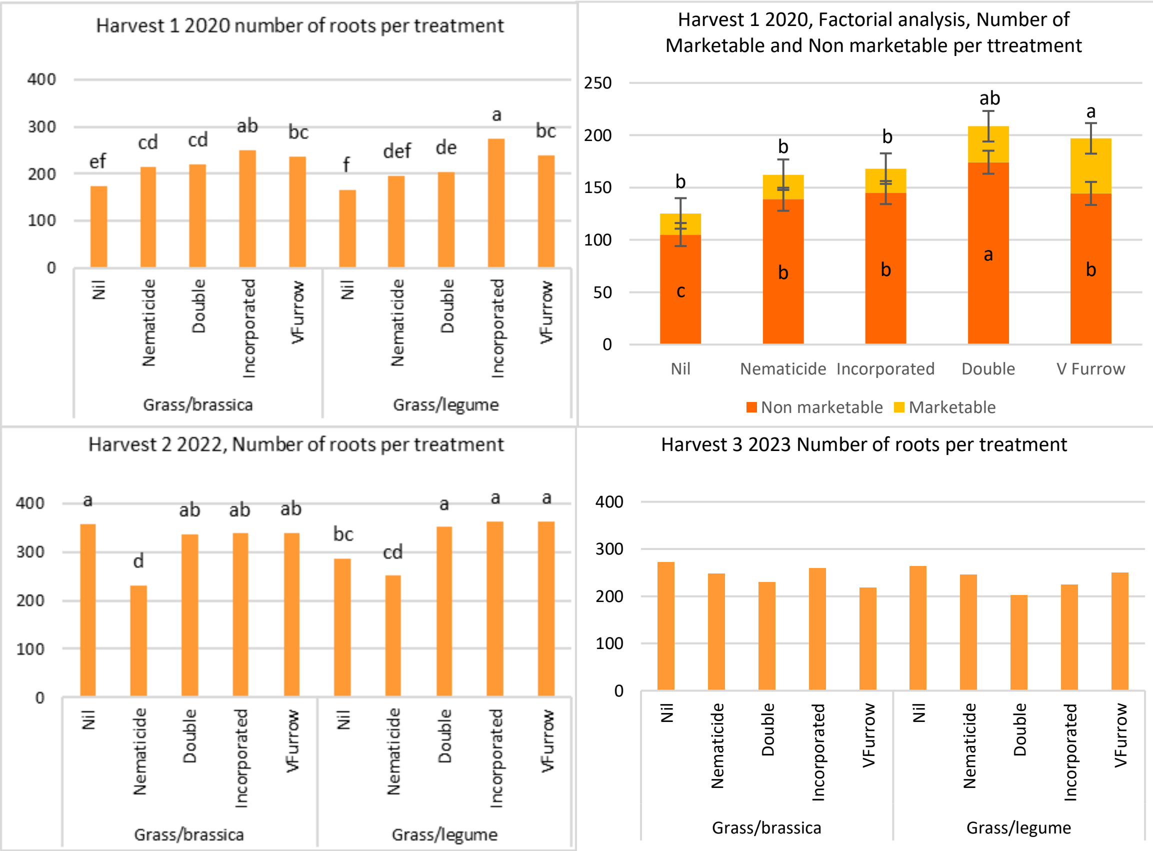


Figure 17 Extensive trial total no of roots per treatment for all harvest.

Nematode related lesions

Results are reported as a percentage of all roots (marketable and non-marketable) on the overall incidence for each size class and the sizes combined (Total roots). Incidence data was been analysed using a generalised linear model with a Binomial distribution and complementary log-log link with means, standard errors (se) and average 95% least significant differences shown.

Raised Pimples

In 2022 there were significant differences between treatments in the marketable second roots across all size grades. The mean incidence of raised pimples was highest in the Nil and Vydate treatments, in both cover crop planting regimes along with the Incorporated treatment with the grass/legume rotation.

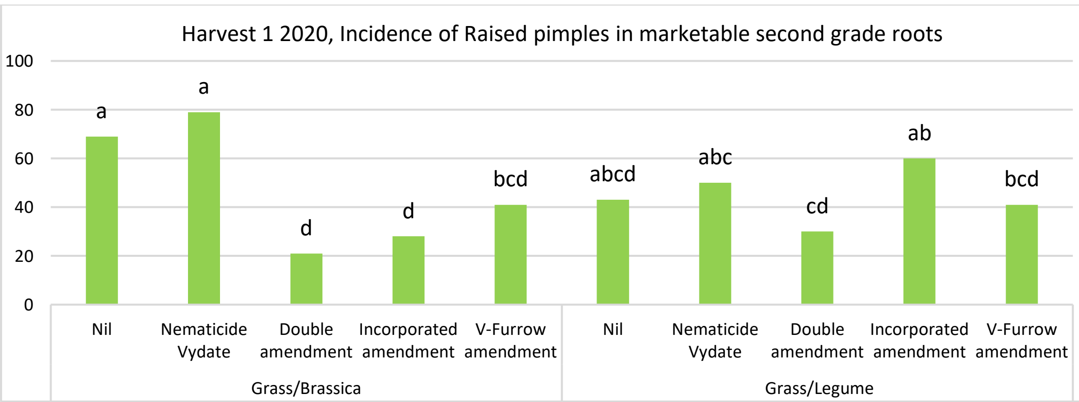


Figure 18. Occurrence of Raised pimples in marketable second grade roots in harvest 1.

A similar trend to that observed in 2020 was apparent in the second harvest in 2022 with significant differences in the incidence of raised pimples in both marketable and non-marketable medium sized roots. The proportion of raised pimples was highest in both marketable and unmarketable roots in the Nematicide and Vydate treatments followed by unmarketable roots in Nil treatment of the Grass/brassica treatment.

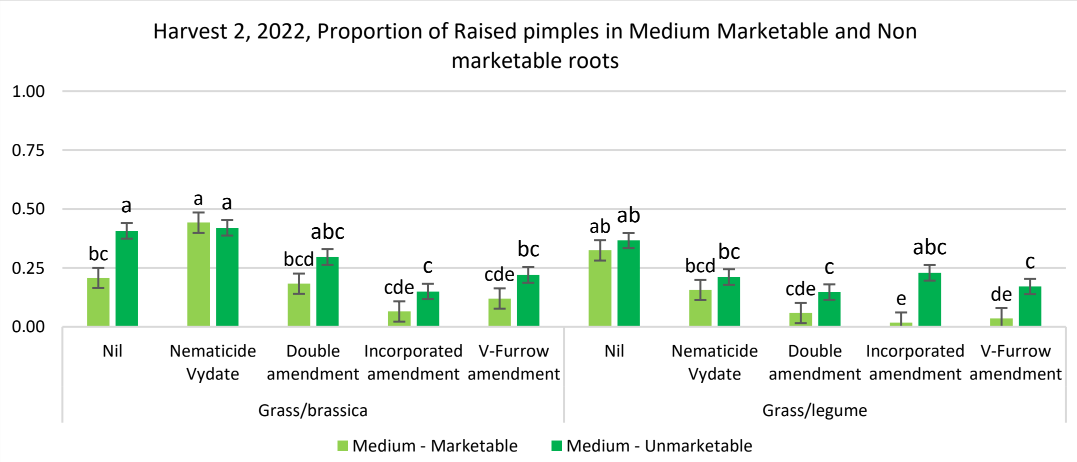


Figure 19. Proportion of Raised pimples in Medium marketable and Nonmarketable roots in harvest 2.

At the third harvest in 2023, the grass/legume Nil treatment produced roots with the highest incidence of raised pimples (Total roots) followed by nematicide treatment. The V Furrow and double amendments with Grass/brassica cover crops had the lowest incidences. The same significant differences were observed in the Medium sized category (data not shown).

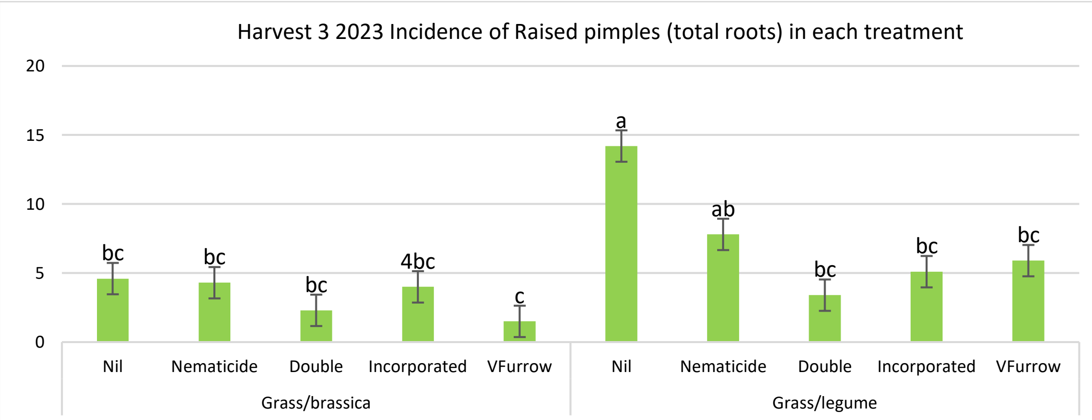


Figure 20.Incidence of Raised pimples in each treatment in Harvest 3.

Black Pimples

In 2020 roots in the grass/legume Nematicide treatments had the highest mean proportion of black pimples followed by the Nil treatment (also grass/legume) and the Nematicide and Incorporated grass/brassica treatments. All treatments generally had a high incidence of black pimples. The V furrow in both treatment crops recorded the lowest incidence.

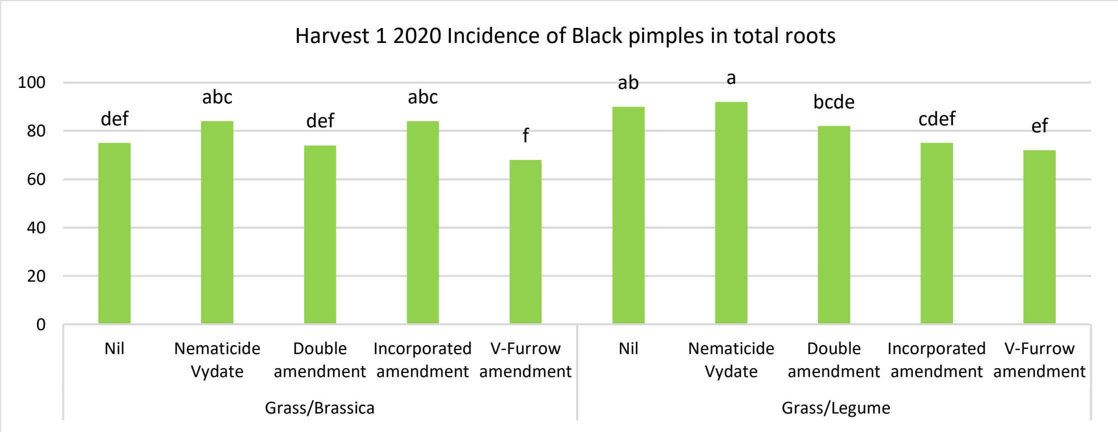


Figure 21. Incidence of Black pimples in total roots in first harvest in 2020.

In 2022, the highest mean incidence of black pimples occurred in the grass/brassica Nematicide and Double amendments and the Nematicide and Nil treatments with grass/legume cover crops.

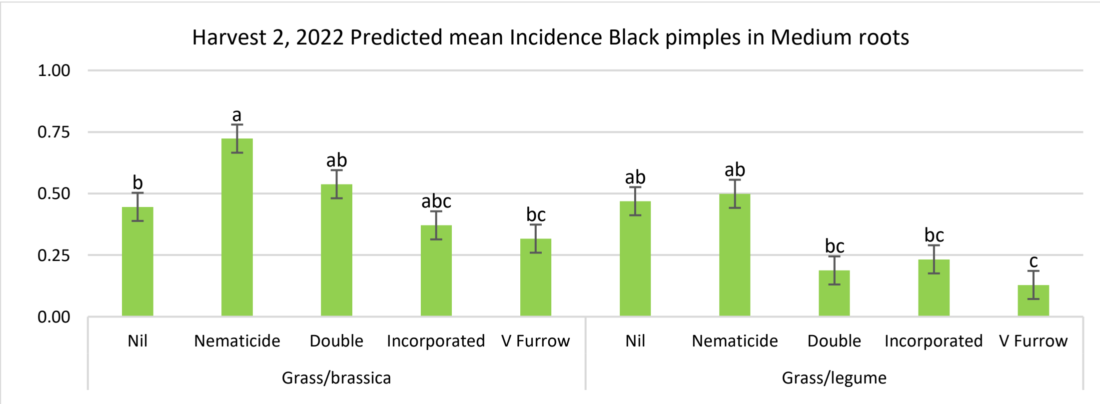


Figure 22. Predicted mean incidence of black pimples in Medium sized roots in harvest 2.

Conversely in 2023 as nematode numbers diminished across the trial, , there were significant differences in the severity rating for black pimples observed on roots with the double amendments in the grass/legume plots producing the most severe occurrences. However, this was not significantly different to the V furrow (grass/legume) and both the Double and Incorporated grass/brassica treatments.

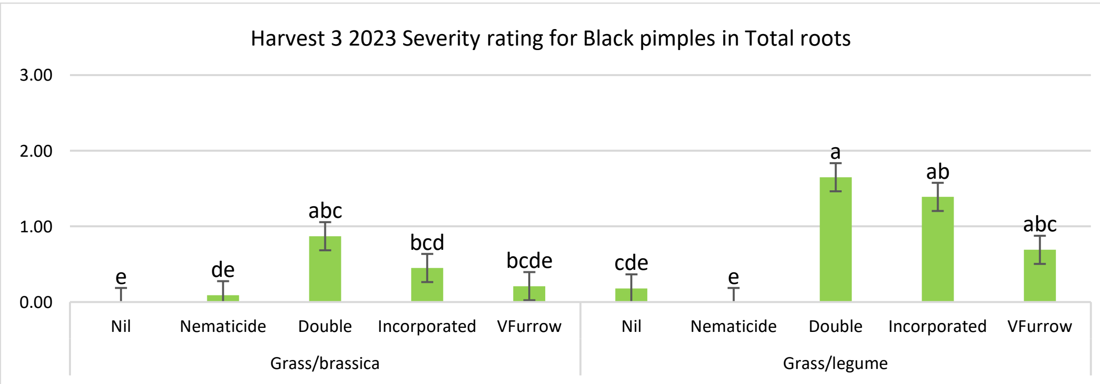


Figure 23. Severity analysis, mean count of Black pimples in each treatment in 2023.

Barnacles

There were no significant differences in the first harvest. In 2022, the highest incidence of Barnacles was recorded in the Nil grass/legume treatments, followed by Nematicide treatments in both cover crop treatments (grass/brassica and grass/legume).

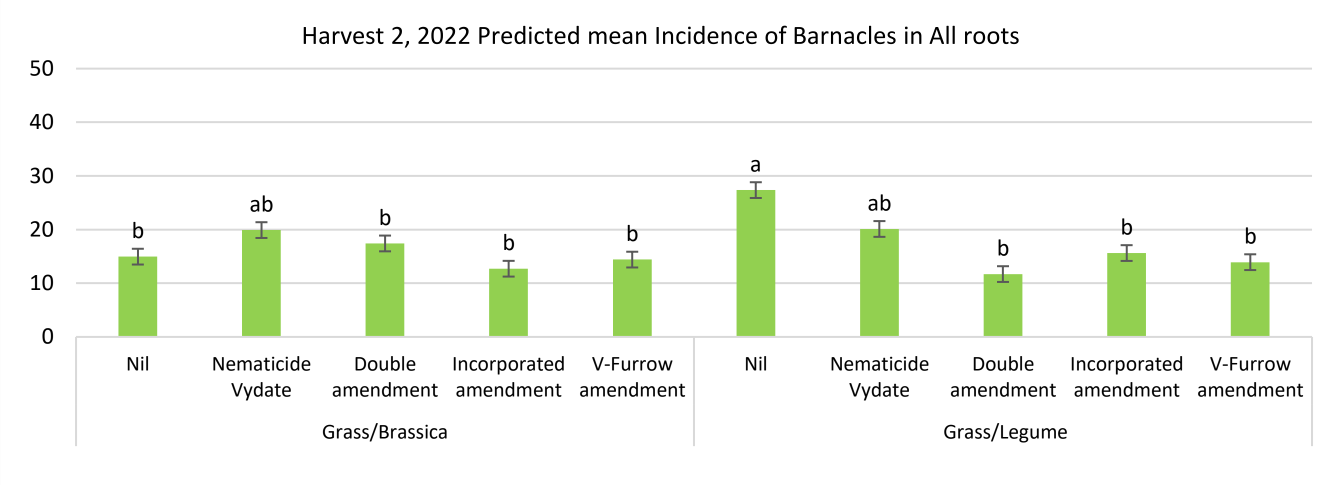


Figure 24 Incidence of Barnacles in the second harvest in 2022.

In 2023, roots grown in the grass/brassica Double amendment and Incorporated grass/legume treatments were the most severely affected by Barnacles.

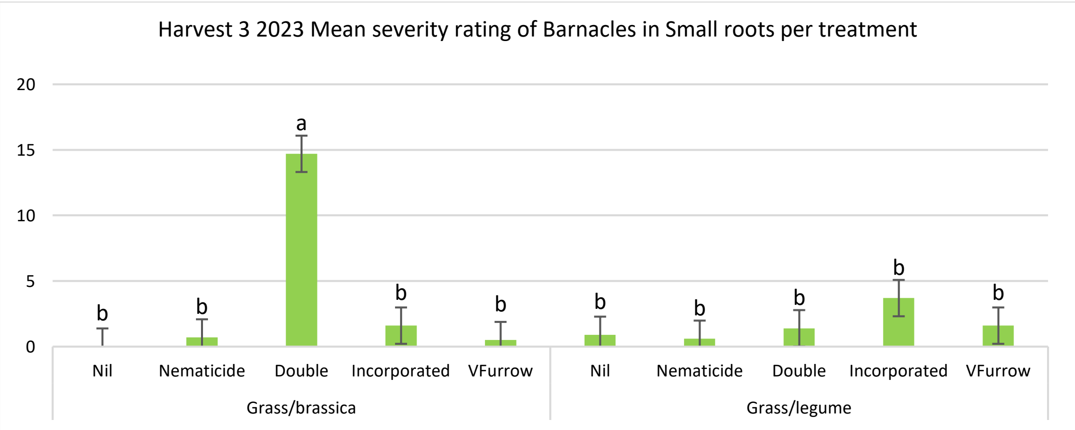


Figure 25. Severity rating of Barnacles in the third harvest in 2023.

Insect damage

Insect Damage (wire worm, white grub and weevil). There were no significant differences between the treatments for the proportions of roots with insect damage in 2020, therefore roots were considered to have insect damage if they were affected by either wire worm, white grub or weevil at the 2022 assessment. The contrasts between the two crops were all non-significant and the GLM found no significant differences between the amendments.

Wireworm

At the third harvest in 2023, the most severe wireworm damage occurred in the Incorporated and Double amended plots across total roots and in all size grades, (Small, Medium and Large).

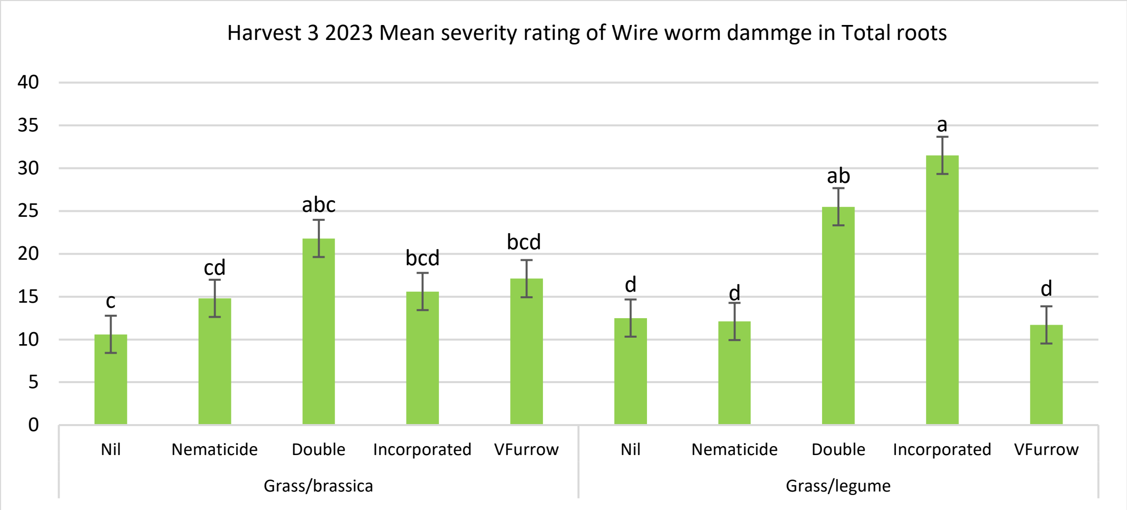


Figure 26. Mean severity of wireworm damage in Harvest 3, 2023.

White grub

The presence of white grub in total roots was highest in the Nil and V furrow treatment in both the grass/brassica and grass/legume treatments and lowest in the Incorporated amendments in both cover crop treatments.

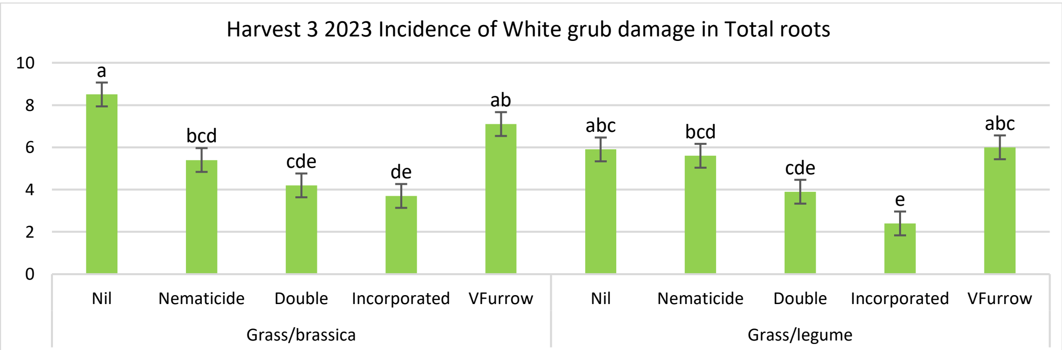


Figure 27 White grub damage in total roots, Harvest 3, 2023.

Sweetpotato weevil

A high incidence of weevil damage was observed in the Nil, Double and Incorporated amendments in the grass/brassica treatments as well as the Double, Incorporated and V furrow amendments in the grass/legume treatments. The Nil and Nematicide treatment in the grass/legume plots had the lowest incidence of weevil damage.

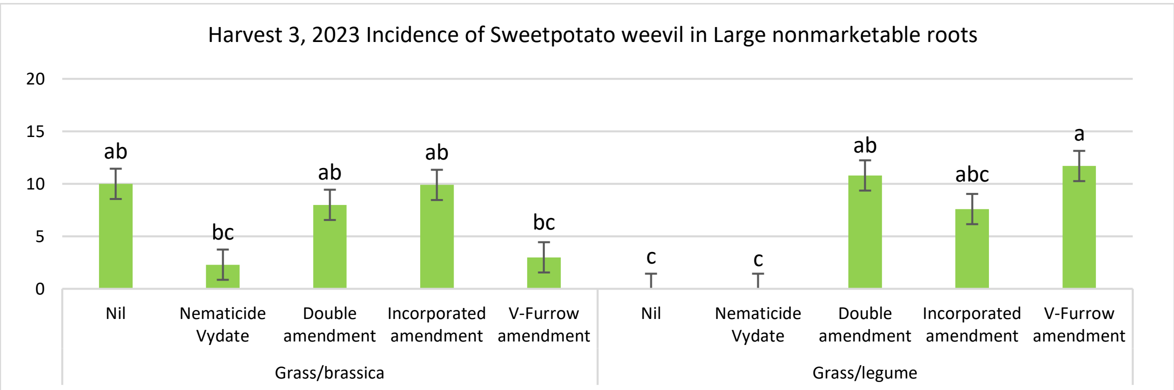


Figure 28 Sweetpotato weevil by treatment in Harvest 3.

Symphilids

Roots gown in the Nil treatment in Grass/legume plots had highest Symphilid damage rating. Symphilids damage was not recorded in any previous harvests.

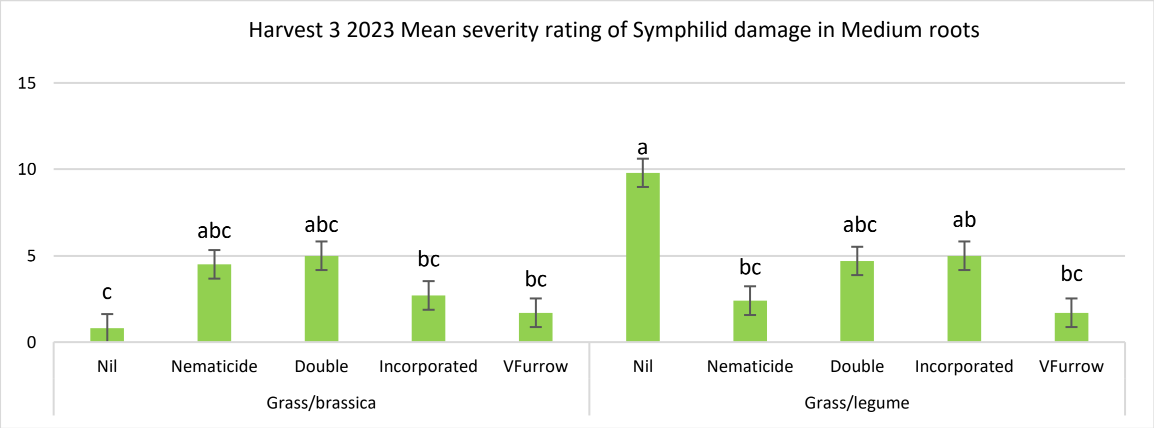


Figure 29. Incidence of Symphilids in Medium roots.

Bacterial and fungal lesions

Geotrichum sour rot

The Double, Incorporated and V furrow amendments in both the grass/brassica and grass/legume regimes produced roots with the highest severity rating of Geotrichum sour rot in 2023.

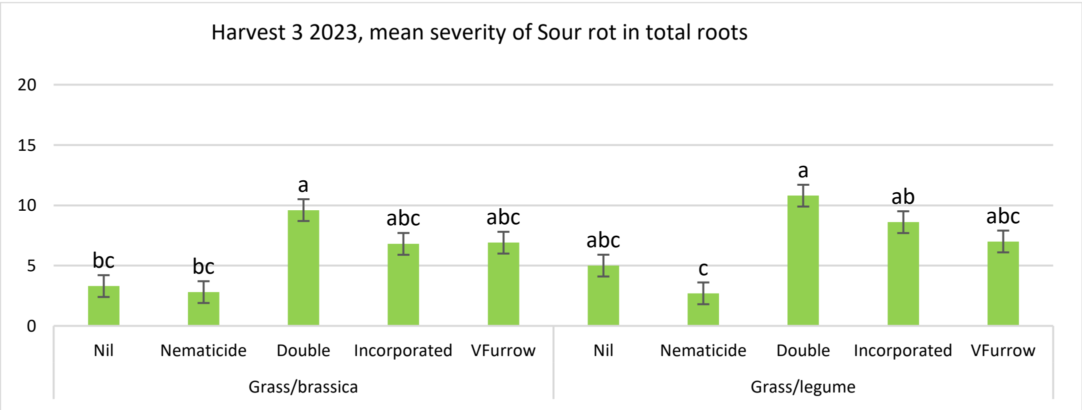


Figure 30 Incidence of Sour rot in Total roots.

Streptomyces Soil Rot (Pox), Streptomyces ipomoeae

Incidence of Soil pox is generally high for double, incorporated and V furrow for both treatment crops.

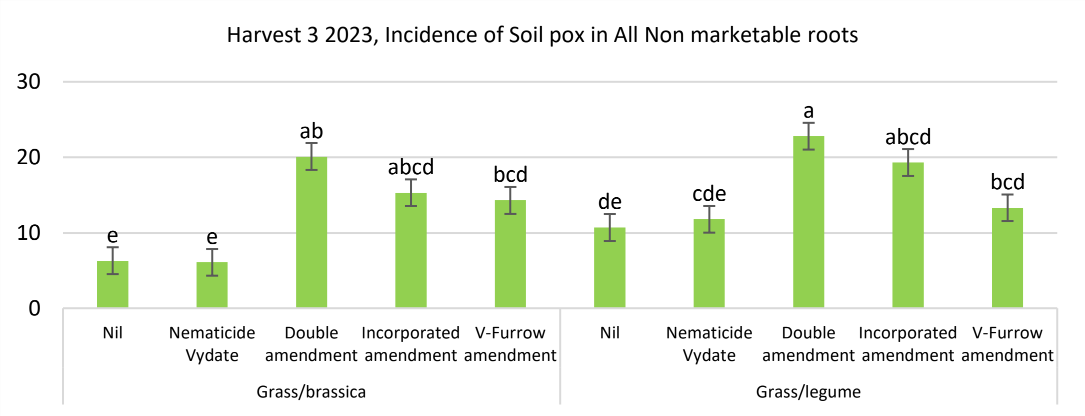


Figure 31 Incidence of Soil pox in 2023.

Severity presence of Soil pox in harvest 3 was generally highest in the Double, Incorporated and V furrow amendments for both crop treatments. Severity was the same in both total, and medium and large root sizes.

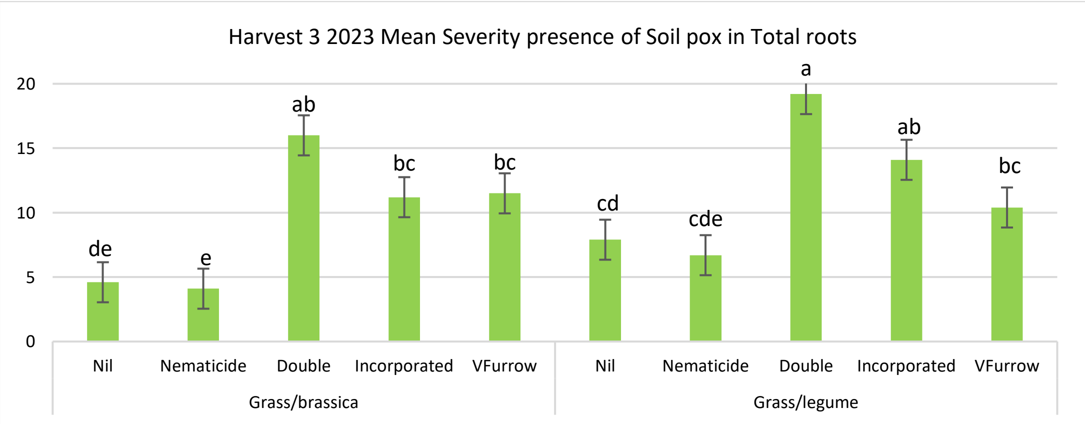


Figure 32 Severity of Soil pox in harvest 3, 2023.

Other defects

Darkened lateral root scars (DLSR)

There were no significant differences in the 2020 harvest. In 2022, the Nil and Nematicide treatments for both cover crops were had the highest incidence of DLSRs. There was no significant difference between the amendments within the grass/legume treatments.

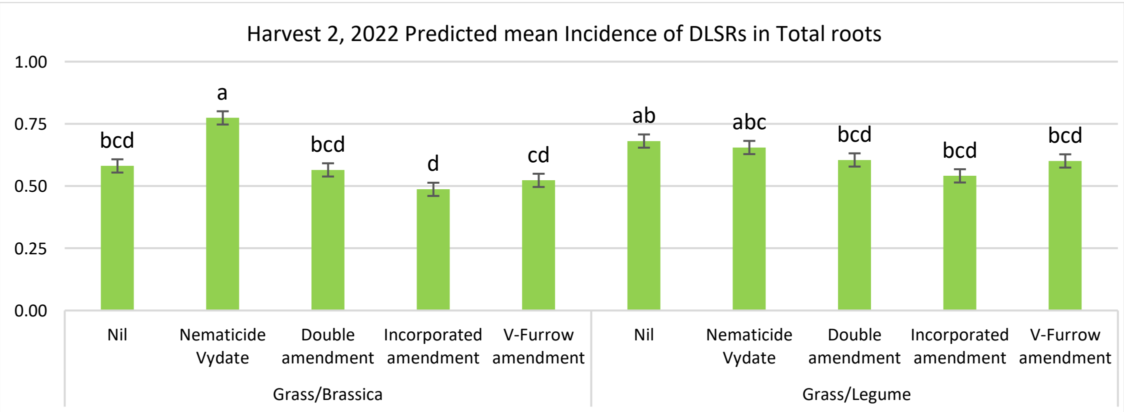


Figure 33. Incidence of DLSRs in 2022.

The 2023 harvest followed a similar trend to the previous harvest with significant differences in nonmarketable small roots. The lowest incidence of DLSRs occurred in the V furrow grass/brassica and Incorporated grass/legume plots.

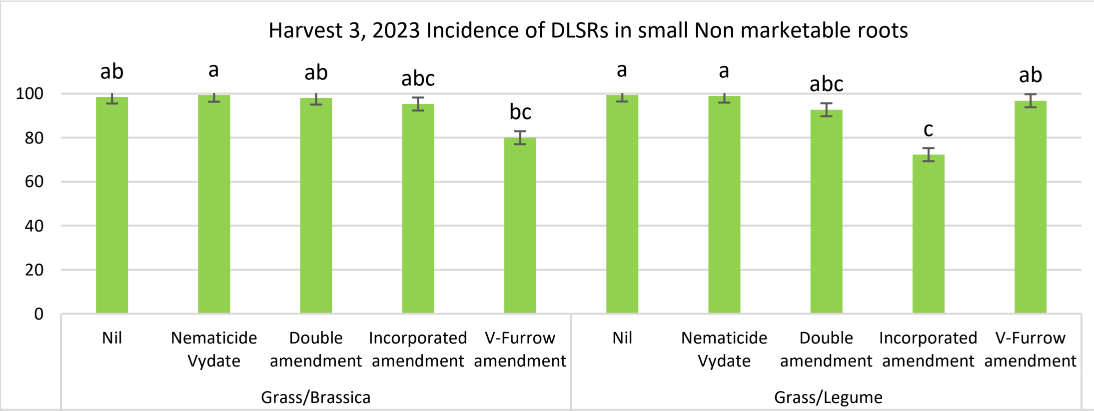


Figure 31. Incidence of DLSRs in 2023.

Miscellaneous defects

Generally, all treatments in the grass/brassica cover crop had a higher mean severity of Misshapen roots (Table 10), compared to grass/legume with the exception of the Double and V furrow amendments. The Nil and Nematicide treatments in the grass/legume cover crop and the Nematicide treatment in the grass/brassica cover crop had a significantly lower mean severity than all other treatments except the grass/legume, Incorporated treatment. This is in contrast to the grass/brassica, Incorporated treatment which had the highest severity rating. Further research needs to be conducted to determine if this severity is actually a treatment effect.

The mean severity of Elongated lenticels was not aligned to the cover crop type. The Double amendments in both cover crops were significantly higher than the Nil and Nematicide treatments in the grass/brassica, and the Nematicide and V furrow treatments in the grass/legume crop. This contrasts with the Nil grass/legume which had the highest severity of Elongated lenticels. Again, further research needs to be conducted to determine if this severity is actually a treatment effect or a spatial and assessment effect.

There were few significant differences in Sunken lenticel severity ratings between treatments, with the main difference being the grass/brassica, Nil treatment significantly better than grass/brassica, Incorporated and V furrow and grass/legume. The Grass/brassica, Nil treatment had the lowest severity rating, however this difference was not significant from some other treatments.

The grass/brassica, Double amendment had the highest incidence of Veining. This was significantly higher than all other treatments except for the grass/brassica, Nematicide and V furrow amendments in the grass/legume treatment. The grass/brassica, Nil treatment had the lowest incidence of Veining.

The highest mean severity of Veining was recorded for the grass/brassica, Double amendment. This was significantly higher than all other treatments except for the Double and Incorporated grass/legume treatments. The Grass/brassica, Nil treatment had the lowest severity rating, however not significantly different from some other treatments.

Table 10. Mean severity rating for total roots for misshapen, elongated & sunken lenticels & veining.

Defect		Misshapen	Elongated lenticels	Sunken lenticels	Veining
Size		Total roots	Total roots	Total roots	Total
Severity rating		High	High	High	Present
Crop	Amendment	Mean	Mean	Mean	Mean
Grass / brassica	Nil	26.8 bc	0.0 d	0.13 c	0.00 c
	Nematicide	20.5 e	0.39 cd	0.53 bc	0.63 b
	Double	25.8 bc	1.29 ab	0.59 bc	2.24 a
	Incorporated	32.0 a	0.94 abc	1.09 ab	0.39 bc
	VFurrow	28.6 abc	0.48 bcd	0.87 ab	0.55 bc
Grass / legume	Nil	17.9 e	1.56 a	0.52 bc	0.20 bc
	Nematicide	19.8 e	0.00 d	0.53 bc	0.21 bc
	Double	30.0 ab	1.53 ab	1.41 ab	0.96 ab
	Incorporated	20.5 de	1.00 abc	1.82 a	0.93 ab
	VFurrow	24.6 cd	0.29 cd	0.52 bc	0.82 b
F		11.66	5.54	2.63	4.23
p		<0.001	<0.001	0.005	0.002
Average 95% lsd		4.25	0.824	0.85	0.84

When the total roots (small, medium and large) were assessed for Longitudinal grooves (Table 11), the incidence in the Double amendment in both cover crop types was significantly less than that in the grass/brassica Nil and Nematicide and grass/legume Nematicide, which had the highest incidence of all treatments. When the medium roots were analysed separately, this pattern was more evident, with the Double amendment in both cover crops and the grass/brassica, Incorporated amendment being significantly better than in all Nil and Nematicide amendments.

Table 11. Mean incidence of longitudinal grooves in medium and total roots.

Defect		Longitudinal grooves	
Size		Medium	Total
Severity		Present	Present
Crop	Amendment	Mean	Mean
Grass /brassica	Nil	35.7 a	24.0 ab
	Nematicide	36.1 a	25.2 a
	Double	11.3 c	10.3 cd
	Incorporated	10.6 c	11.7 bcd
	VFurrow	28.8 ab	24.6 abc
Grass /legume	Nil	37.6 a	22.3 abc
	Nematicide	36.9 a	24.6 a
	Double	12.8 bc	6.8 d
	Incorporated	25.3 abc	22.3 abc
	VFurrow	22.6 abc	18.2 abc
F		3.43	2.33
p		0.006	0.047
Average 95% lsd		16.96	13.82

When severity of Longitudinal grooves (Table 12), was analysed, the results were similar to the incidence reporting, with the grass/legume Double amendment treatment being significantly better than all Nil and Nematicide treatments.These results could be useful in informing future projects which would investigate causes in the occurrence and severity of defects observed during this experiment.

Table 12. Mean severity of longitudinal grooves in medium, large and total roots for all treatments.

Defect		Longitudinal grooves					
Size		Medium	Medium	Large	Large	Total	Total
Severity		Low	Medium	Medium	High	Low	Medium
Crop	Amendment	Mean	Mean	Mean	Mean	Mean	Mean
Grass /brassica	Nil	16.2 bcde	15.6 a	7.6 abc	4.4 abcd	11.6 abc	9.3 a
	Nematicide	29.2 a	6.9 abc	16.4 a	1.5 bcd	18.4 a	6.4 ab
	Double	8.8 de	2.0 bcd	2.6 bc	0.0 d	8.0 bc	2.1 bc
	Incorporated	8.3 e	1.8 cd	8.4 ab	0.5 cd	8.1 bc	2.9 bc
	VFurrow	20.2 abc	7.9 abc	6.4 abc	3.3 abc	17.7 a	5.8 ab
Grass /legume	Nil	29.9 a	6.4 bc	16.8 a	0.9 bcd	16.7 a	4.9 ab
	Nematicide	26.3 ab	8.6 ab	19.9 a	9.3 a	15.9 a	6.7 ab
	Double	11.9 cde	0.6 d	0.8 c	0.4 cd	5.9 c	0.5 c
	Incorporated	19.1 abc	5.8 bcd	11.8 ab	5.1 ab	14.3 ab	6.4 ab
	VFurrow	17.6 bcd	4.4 bcd	8.3 ab	1.6 bcd	13.3 ab	3.8 abc
F		4.87	2.95	3.13	3.72	2.71	2.32
p		<0.001	0.014	0.010	0.004	0.025	0.048
Average 95% lsd		10.25	6.91	11.90	4.34	8.13	5.28

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