Developing Knowledge-Based Strategies to Manage Plant Parasitic Nematodes in Nova Scotia Apple Orchards

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INTRODUCTION

In 2017, we explored replanted orchards with poor tree growth that was aggravated by dry weather conditions. Our investigations revealed symptoms of nematode feeding and confirmed the presence of plant parasitic nematodes, specifically root-lesion nematodes.

Plant-parasitic nematodes can cause significant crop losses. Their feeding can be directly damaging to root structures and indirectly damaging by providing entry points to other soil borne fungal and bacterial pathogens.

An integrated approach to control root-lesion nematode populations is needed for sustainable crop production in Nova Scotia. In recent years, the broad-spectrum fumigants Methyl Bromide and Telone C-17 have been withdrawn from registration, followed by an emphasis on more environmentally sustainable chemistries and integrated management practices. Knowledge of management practices in Nova Scotia that reduce plant parasitic nematodes can drive decision making to maximize productivity for horticultural crops.

Strategies of interest included cover crops and chemical nematicides. For the cover crop treatments, brown mustard and sorghum sudangrass were evaluated because of their biofumigant properties during chopping and incorporation. Brown mustard releases the chemical glucosinate and sorghum sudangrass releases the chemical dhurrin that then forms hydrogen cyanide (Kirkegaard et al, 1993). For comparison, green fallow was used as a host of root-lesion nematode and alternatively brown fallow discourages nematodes by making roots unavailable.

For the chemical treatments, Velum Prime and Movento were evaluated. Velum Prime has documented nematicidal activity through its mode of action of inhibiting nematode energy production and causing paralysis (Schleker et al. 2022). Movento has documented activity in inhibiting nematode development to reproductive maturity (Vang et al. 2016).

Multi-year trials were initiated on-farm in 2021 and 2022 to assess the impact of different strategies on reducing the population of root-lesion nematodes to manageable levels in apple orchards. The trials were monitored and evaluated in 2023 to assess the resulting crop parasitism post-treatment. We also conducted sampling to evaluate root-lesion nematode population patterns and fluctuations during the season.

GENERAL TRIAL INFORMATION

Materials and Methods

Economic threshold populations of root lesion nematodes were targeted during the selection of trial sites. For apple trees, the threshold is 40 root-lesion nematodes per 100 g of soil and 100 root-lesion nematodes per 1 g of dry root. The threshold offers a guideline for the magnitude of root-lesion nematode pressure that a crop can withstand.

Soil and root samples were analyzed for nematodes to evaluate for treatment efficacy. The soil temperature was monitored at research sites prior to the start of soil sampling. Soil sampling was initiated when soil temperature reached an average of at least 10°C. Soil samples represent a composite sample of 10 or more soil cores that were collected and combined. Feeder roots were dug using a trowel from chosen trees, for a total of 20-30 grams of roots per plot. All soil and root samples were collected within 30 centimeters from the base of the tree trunks unless otherwise noted.

TRIAL 1: APPLE TREE MULTI-YEAR COVER CROP

Introduction

The trial was set up in 2021 at a preplant orchard site. The soil type for this location was Kentville, a friable sandy loam. The chosen site had been in orchard for twenty-five years that was removed in the fall of 2020, and in 2021 it was tiled and ripped. The trial objective was to evaluate the impact of various renovation management strategies applied in year one followed by a non-host pearl millet in year two on nematode populations.

Plot Plan and Treatments

In 2021, the treatments were arranged in a randomized and replicated statistical design. The three pre-plant treatments were, 1) brown fallow/tillage (positive control), 2) brown mustard [6-8 pounds per acre] planted on August 18, 2021, and 3) PicPlus fumigant applied and tarped on October 6, 2021. Treatments were applied in full rows that were 220 feet long by 12 feet wide and replicated three times. The brown mustard was terminated at the flowering stage by chopping with a flail mower, incorporating with a disc harrow, and sealing with a weighted drum roller, all within 30 minutes from start to finish.

In 2022, pearl millet was planted at a rate of 20 pounds per acre on July 8 across the entire 2021 treatment area. Pearl millet was terminated by mowing and then tilling when it was waist-height on August 20. The orchard was established late summer by the orchard owner to rectify a missed spring planting. Therefore, the planting was done on August 23, 2022, using potted Honeycrisp trees rather than the industry standard practice of using bare root trees. In 2023, samples were taken to monitor for crop parasitism to evaluate the effectiveness of multi-year cover crops.

Data Collection and Analysis

Soil and root samples were collected on May 31 and October 5, 2023 for nematode analysis. The soil cores were sampled in the same locations as the previous year based on GPS coordinates.

Results and Discussion

In the current trial, soil analyses cannot be used to compare the efficacy of the treatments (data not shown). There is a lack of confidence in the pre-treatment external lab analysis done in 2021. Ultimately, the results were deemed erroneous after an internal lab comparison of lab approaches (PCR vs light microscopy). The importance of finding a trusted laboratory procedure was realized for all future samples.

Root samples taken in 2023 when the orchard was becoming established helped to determine levels of crop parasitism as an indication of treatment success. In the spring, there was no difference in root populations of root-lesion nematodes across the treatments, which was low at an average of 21 root-lesion per gram dry root (Figure 1). The fall sample, however, showed that the lowest total root-lesion nematode populations were within the brown fallow and PicPlus fumigant treatments.

The bare ground served as a positive control to give the expected result of discouraging nematode population growth by making roots unavailable for parasitism. Bare ground would not be a recommended practice due to other environmental concerns. The fumigant treatment appeared to prevent the build-up of nematode populations in the crop roots during the first year of growth.

Meanwhile, the brown mustard treatment allowed root-lesion populations to increase by 188% according to trends to an above-threshold level of 92 ± 39 root-lesion per gram of dry root. The roots of brown mustard are a host of the root-lesion nematode, and the success of this treatment relies on the chemical glucosinolate that is released during chopping and incorporation (Kirkegaard et al, 1993 and Bélair et al, 2007). It is possible that conditions at the time of incorporation were not ideal for glucosinolates to distribute throughout the soil to kill nematode populations. Brown mustard can be a risky treatment to attempt if the chemical benefits are not realized during termination, and the cover crop could inadvertently support nematodes.

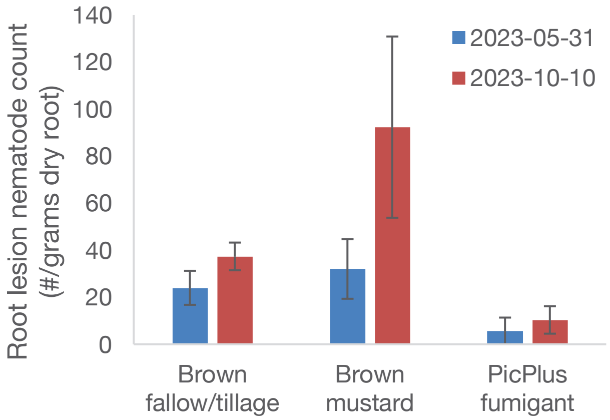

Figure 1. Average root-lesion nematode counts in apple tree roots in spring and fall. Trees were established after treatments with brown fallow, brown mustard, and fumigation in 2021, and pearl millet across treatments in 2022. N = 3.

TRIAL 2: GENERAL SUMMER PRE-PLANT COVER CROP

Introduction

The trial was initiated in 2022 at a field being prepared for orchard. The soil type was Berwick, a sandy loam. The trial objective was to evaluate the impact of various preplant cover crops applied in summer, relative to weedy fallow, on nematode populations.

Treatments

On June 24, 2022, the cover crop treatments were planted in a randomized and replicated statistical design. The four treatments were, 1) weedy fallow (negative control), 2) brown mustard [6 pounds per acre, var. Centennial], 3) sorghum-sudangrass [40 pounds per acre, var. super sugar], and pearl millet [22 pounds per acre, var. PM 101]. Treatments were applied in rows that were 180 feet long by 18 feet wide and replicated three times. The weedy fallow was mainly composed of lamb's-quarters. On August 11, the brown mustard was incorporated, and all other plots were terminated by mowing.

Data Collection and Analysis

Pre-treatment soil samples were collected on June 30, 2022 and post-treatment soil samples were collected on October 4, 2022. The following year, soil samples were collected on May 29, 2023, as apple trees were being planted. Sampling was done in the same locations as the previous year based on GPS coordinates. On October 3, 2023, once the trees had become established, another set of soil samples was collected in the same manner.

Root sampling was delayed until July 12, 2023, allowing time for the new trees to become established. Root samples were also collected on October 3, 2023.

Results and Discussion

Pre-treatment soil samples taken on June 30, 2022, showed root-lesion nematode populations that were below the threshold of 40 root-lesion nematodes per 100 grams of soil (Figure 2). Post-treatment nematode soil samples taken in the fall showed that the green fallow, sorghum sudangrass, and brown mustard allowed root-lesion populations to increase at or beyond the threshold, whereas the population stayed relatively constant in the pearl millet treatment.

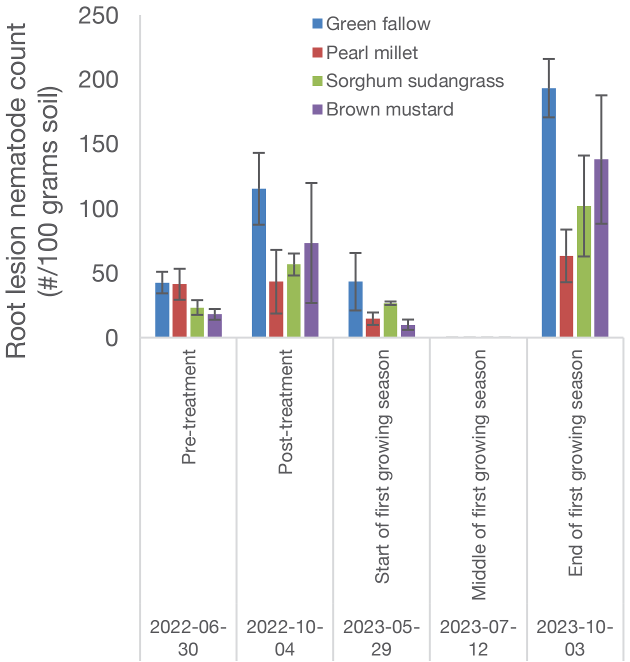

Figure 2. Average root-lesion nematode counts in soil during the trial period from pre-treatment on June 30, 2022 to the end of the first growing season on October 3, 2023 following pearl millet, sorghum-sudangrass, brown mustard or green fallow. N = 3

During the year of crop establishment, the fall soil samples again showed relatively higher soil root-lesion populations than the spring samples of the same growing season (Figure 2). The relative treatment differences were the same in 2023 as in 2022 but in 2023 showed a higher magnitude of soil root-lesion nematodes, perhaps due to the presence of the crop and attraction to the root system of the tree row.

Compared with pre-treatment soil, all treatments had an increase in soil root-lesion population by the end of the first growing season in 2023 after crop establishment. The greatest increase in root-lesion nematode populations from pre- to post-treatment was in the brown mustard treatment by 645%, followed by 387% after sorghum sudangrass, 375% after green fallow, and 73% after pearl millet (Figure 2).

Our work to date has shown that brown mustard can have the unintended consequence of supporting root-lesion nematode when conditions on the farm are uncontrollable, suggesting that brown mustard may not be a straightforward or practical approach to management in Nova Scotia unless the ideal conditions can be achieved.

Pearl millet is expected to be a non-host of the root-lesion nematode and therefore would have discouraged root-lesion presence in the root zone prior to crop establishment. The pearl millet showed success in limiting growth of the root-lesion population but cannot be counted on to reduce the population to below-threshold levels.

Samples taken on July 12, 2023 in summer showed no detectible root-lesion in the soil but a high presence in the roots (Figure 2 and Figure 3). The greatest pressure in the roots was observed in the sorghum sudangrass treatment at 1379 ± 138 root-lesion per gram dry root and the green fallow at 1007 ± 464 root-lesion per gram dry root followed by the brown mustard at 555 ± 355 root-lesion per gram dry root and the pearl millet at 250 ± 155 root-lesion per gram dry root (Figure 3).

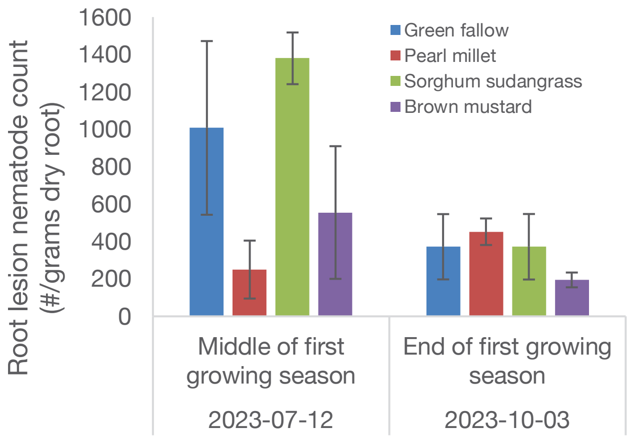

Figure 3. Average root-lesion nematode counts in apple tree roots (#/grams dry root) in the middle of the first growing season on July 12, 2023 and at the end of the first growing season on October 3, 2023 following pearl millet, sorghum-sudangrass, brown mustard or green fallow (negative control). N = 3

Therefore, based on current results in the pre-plant and planting year, only the pearl millet treatment appeared to positively impact nematode populations relative to the green fallow control. Conversely, brown mustard would be recommended with caution to avoid worsening the root-lesion soil population.

TRIAL 3: APPLE POST-PLANT RESCUE TREATMENT

Introduction

In 2022, the trial was established in a young two-year-old orchard of Honeycrisp on Supporter 4 rootstock. Trees were spaced at 3.4 meters (11 feet) between rows and 0.8 meters (2.5 feet) between trees and issues with poor tree growth were already apparent. The soil type was Middleton, a loam at 0-15 centimeters and clay loam at 15-25 centimeters. The trial objective was to evaluate the impact of post-plant chemical treatments on a young apple tree planting with nematode pressure. Further, summer versus spring treatment timing were compared.

Treatments

In 2022, the treatments were applied in a randomized design with fourteen-tree plots for post-plant chemical treatments, being the number of trees between in-row posts. The seven treatments were located at the start of a tree row and plots were replicated three times, with each replication being arranged in parallel orchard rows. The first plot of fourteen trees was left unused as a buffer at the beginning of each row. The seven treatments are listed in Table 1.

Table 1. Treatment list for two-year old Honeycrisp on S.4 rootstock.

	Year of Treatment	Treatment	App Method	Rate	Number of Apps	App Timing
1	NA	Untreated	-	-	-	-
2	Summer 2022	Velum Prime	Trickle irrigation	500 mL/ha	1	App A July 8, 2022
3		Movento 240 SC	Foliar	585 mL/ha	1	App A July 8, 2022
4		~~*Velum Prime~~ ~~Movento 240 SC (application error)~~	~~Trickle irrigation~~ ~~Foliar~~	~~500 mL/ha~~ ~~585 mL/ha~~	~~1~~ ~~1~~	~~App A July 8, 2022~~ ~~App B July 5, 2022~~
5	Spring 2023	Velum Prime	Trickle irrigation	500 mL/ha	1	App C May 22, 2023
6		Movento 240 SC	Foliar	585 mL/ha	1	App D June 8, 2023
7		Velum Prime Movento 240 SC	Trickle irrigation	500 mL/ha 585 mL/ha	1 1	App C May 22, 2023 App D June 8, 2023

*Note: Due to an application error, the combination treatment of Velum Prime + Movento was removed from the analysis in summer 2022.

Velum Prime was applied using trickle chemigation with one trickle line. Treatment of Velum Prime targeted mid-May during active root growth and after soil temperatures reached 10°C. Movento must be applied post-bloom according to the label, so treatment targeted immediately post-bloom.

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Movento was applied with a Maruyama MD155 gas-powered backpack sprayer with a nozzle setting of 3. Trees were sprayed with an average water volume of approximately 255 mL/tree – equivalent to 1000 litres per hectare.

Data Collection and Analysis

Soil and root samples for the summer treatments were collected pre-treatment on July 7, 2022 and post-treatment on October 3, 2022. The following year, soil and root samples were collected on July 12, 2023, six weeks after the foliar Movento application. Fall soil and root samples were collected from the same tree locations on October 4, 2023.

Trunk diameters were measured on June 8 and October 11, 2023. On the middle three trees in each plot a line was painted 10 cm above the graft union. Trunk diameter was measured at the top of this line, measuring both between tree and between row on each trunk to produce an average diameter. The diameter measurements were then used to calculate trunk cross-sectional area (TCSA).

Results and Discussion

Pre-treatment nematode soil samples taken on July 7, 2022, had an average of 11 root-lesion nematodes per 100 grams of soil and 4 root-lesion nematodes per gram of dry root across the trial area and there was no statistical difference among the starting populations within the treatments. The threshold of 40 root-lesion nematodes per 100 grams of soil was not met but root-lesion nematodes were present.

Following the summer 2022 treatments, post-treatment nematode soil samples taken on October 3, 2022, did not have statistically significant differences between the treatments (Figure 4). Nematode soil populations increased over time for all treatments and neared or exceeded the threshold. The following season, populations showed a decrease after winter die-off of root-lesion nematodes. By October 4, 2023, there were no significant differences between the treatments and limited root-lesion nematode population growth by season's end even in the untreated control. Similarly, after the spring-applied treatments, the root-lesion populations did not increase to fall population levels that were observed the prior season (Figure 4).

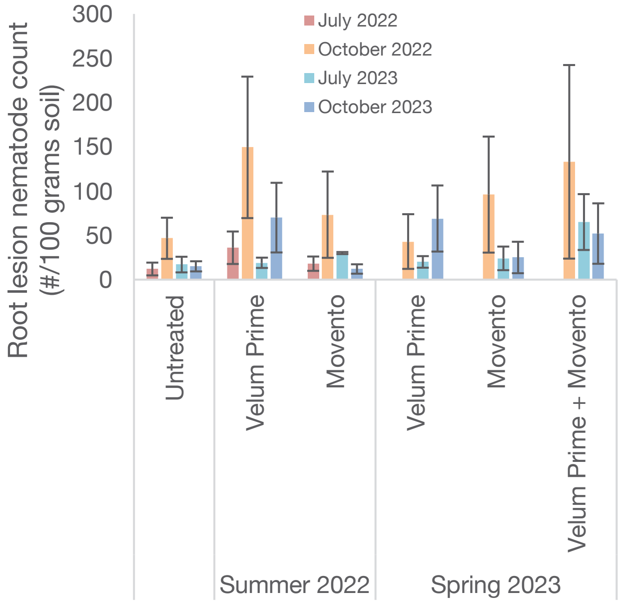

Figure 4. Summer 2022 treatment application timings of July 5, 2022 and July 8, 2022 and spring application timings of Velum Prime on May 22, 2023 and Movento on June 8, 2023. Average root-lesion nematode counts in soil (#/100 grams soil) pre-treatment and post-treatment with application of Velum Prime, Movento, and Velum Prime + Movento. N =3

Root populations of root-lesion nematode generally stayed constant in 2022, except for the increase observed in the Velum Prime treatment that was accompanied by large sample variation (Figure 5). In 2023, there was a trend toward increases in the root-lesion root population for all treatments and less so for the untreated control (Figure 5). Velum Prime and Movento appeared to trend toward increases in root root-lesion nematode populations, but the variation was wide.

It is unclear why a trend toward more root-lesion in the root system would exist after chemical treatment. Velum Prime was expected to have nematicidal activity through its mode of action of inhibiting nematode energy production and causing paralysis (Schleker et al. 2022). Movento was expected to inhibit nematode development to reproductive maturity (Vang et al. 2016). It could be possible that there was an issue with the chemical distribution or targeted application timing.

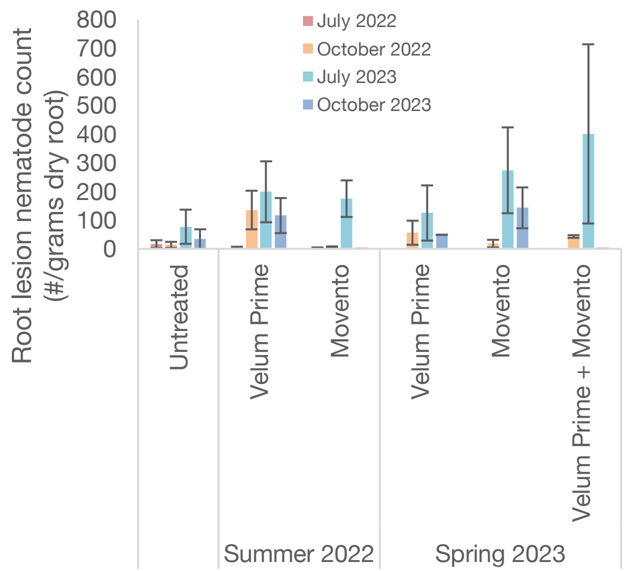

Figure 5. Summer 2022 treatment application timings of July 5, 2022 and July 8, 2022 and spring application timings of Velum Prime on May 22, 2023 and Movento on June 8, 2023. Average root-lesion nematode counts in apple roots (#/gram dry root) pre-treatment and post-treatment with application of Velum Prime, Movento, and Velum Prime + Movento. N =3

Although the effect of the treatments on the soil and root populations of nematodes was unclear, the trunk cross sectional area (TCSA) that represents tree productivity in terms of wood mass over a season shows interesting trends. The untreated trended toward the smallest growth of TCSA at 22.1%, whereas the individual treatments with Movento and Velum Prime had marginally more growth of TCSA from 26.9% to 37.1% (Figure 6). There was no benefit to combining Movento and Velum Prime.

Based on the root-lesion results, there are no clear promising effects of the summer or spring application of Velum Prime and Movento chemical treatments. The TCSA data suggests that there may be a marginal benefit to tree health from the individual application of Velum Prime and Movento during summer or spring application.

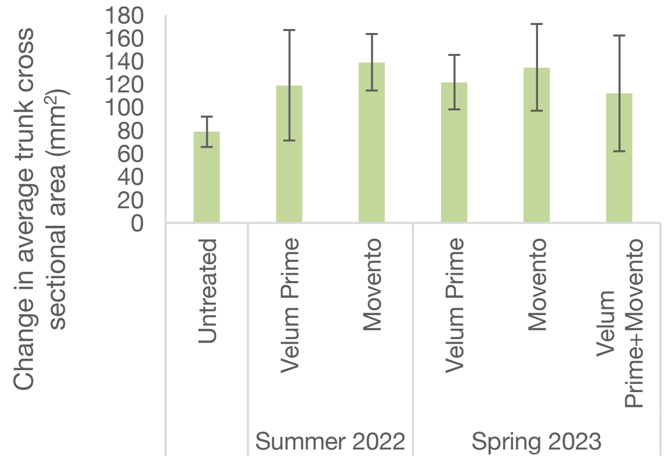

Figure 6. The change in average trunk cross sectional area (mm^2) after summer 2022 and spring 2023 treatment applications. Initial trunk diameter was measured on June 8, 2023, and final diameter was measured on October 11, 2023. N = 3

The timing of root birth in apple trees can vary from year to year with active growth occurring in spring or late summer (Eissenstat et al. 2006). The summer and spring applications of nematicides may help to protect the roots during active root growth, depending on when root growth occurs in any given year. Additionally, the summer application may target nematodes that congregate in the root systems.

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TRIAL 4: SEASONAL NEMATODE SAMPLING

Introduction

The evaluation began in 2022 at two sites. A weedy fallow site of 0.2 ha at the end section of a field was selected on a site with a history of vegetable production, and the soil type was Kingsport, a sandy soil. The site contained legumes and weeds.

Another site was chosen with established orchard on a Pelton soil type, a loam. Five trees were designated in the plot area that would be monitored over time. The trial objective was to evaluate the nematode population in soil and roots over time to help determine the parasite load at points in time in Nova Scotia.

Data Collection and Analysis

Compared to the 2022 season, changes were implemented in 2023 to improve the sequential sampling procedure. Sample timings were limited to spring, summer and fall in favour of sampling in triplicate on individual sample dates to account for variability instead of more frequent sampling.

To compare the results from 2022 and 2023, the 2022 data was simplified to focus on the main message of seasonal effect. In doing so, the 2022 data for five summer samples (4 July, 18 July, 4 August, 15 August, 29 August) and five fall samples (12 September, 23 September, 11 October, 24 October, 7 November) were pooled and averaged. Graphs of the data were made for descriptive purposes using the averages and standard errors representing the multiple dates for 2022 and three replicates for 2023. The error bars for 2022 data illustrate the amount of variation among dates within a season. The error bars for 2023 data illustrates the analytical variation.

Green fallow site:

Soil samples were collected in triplicate on May 19, July 21, and September 21, 2023. At the first sample timing, three sets of ten flags were randomly placed throughout the sampling area and GPS coordinates were recorded for each flag location to enable repeat sampling in the summer and fall. For each replicate, one soil core was collected at each flag and combined to create a composite sample of ten soil cores. Three separate composite samples were taken for the triplicate analysis.

Established orchard site:

Soil and root samples were collected in triplicate on May 30, July 21, and September 21, 2023. At the first sample timing, three flags (one for each replicate) were randomly placed near the base of each of the five trees. At each sample timing fifteen soil cores were collected for each replicate (three per tree) and combined to create composite samples. Feeder roots were dug from around the base of each tree, combining 20-30 grams of roots into a composite sample for each replicate. All soil and root samples were collected within 30-60 centimeters from the base of the tree trunks.

An additional investigation was included in 2023 to explore the population dynamics within a total 100 cc soil volume. In summer and fall, the feeder roots were extracted directly from the soil cores to determine what percentage of the total parasitic nematode population was in the roots versus the soil.

Results and Discussion

The spring months of April and May in the Annapolis Valley ranked as the fifth driest in the last 111 years. The spring sample was taken in late May during the drought period and the ground at the site was dry and hard. Beginning in June, above-average rainfall led to abnormally wet growing conditions, especially by the fall sample period. Therefore, the spring and fall sample results do not represent typical conditions and multiple years of evaluation are recommended to develop an average representation of seasonal nematode populations.

Green fallow site:
Based on the weather conditions in 2023, the soil root-lesion parasite load was observed to be highest during the fall sample period (Figure 7). Starting populations in the spring were at 20 ± 3 root-lesion per 100 grams of soil, stayed relatively constant in summer, and increased by a factor of 8-times by fall to 159 ± 42 root-lesion per 100 grams of soil. In spring the parasite load was considered below the economic threshold but by fall at the same location the population exceeded the threshold of 40 root-lesion per 100 grams of soil. An increase in the parasite load throughout the growing season is consistent with the expected multiplication of a parasite on a host plant.

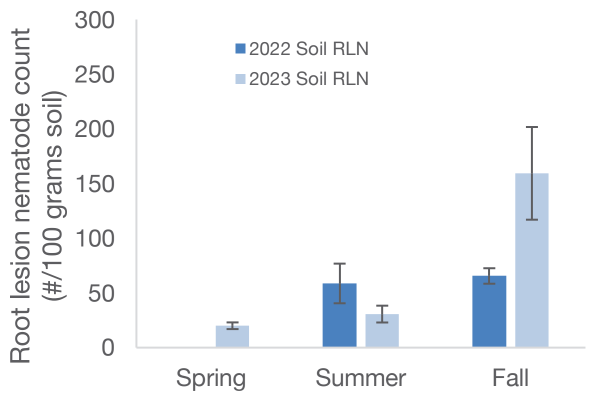

Figure 7. Seasonal soil samples of root lesion nematode at a green fallow site during 2022 and 2023. The 2022 data for five summer samples (4 July, 18 July, 4 August, 15 August, 29 August) and five fall samples (12 September, 23 September, 11 October, 24 October, 7 Nov) were pooled and averaged (spring data not available). The error bars for 2022 data illustrate the amount of variation among dates within a season. The 2023 data includes three replicates, and the error bars represent the analytical variation.

There were no clear trends in 2022 and data from spring 2023 was unavailable to show how populations might have changed over time. Furthermore, the site was tilled in the spring of 2022 and then planted with clover and invaded by weeds to create green fallow. No tillage occurred in 2023 so the plants and parasites might have been better established during the second year.

Established orchard site:
Based on the weather conditions in 2023, the soil root-lesion parasite load was observed to be highest during the fall sample period (Figure 8). Starting populations in the spring were at 45 ± 8 root-lesion per 100 grams of soil, followed by a slight decrease in measurable summer populations. The fall sample relative to the spring sample increased by a factor of almost 5x to 212 ± 50 root-lesion per 100 grams of soil. Again, the seasonal sampling seems to illustrate a multiplication of the parasite load by the end of the season.

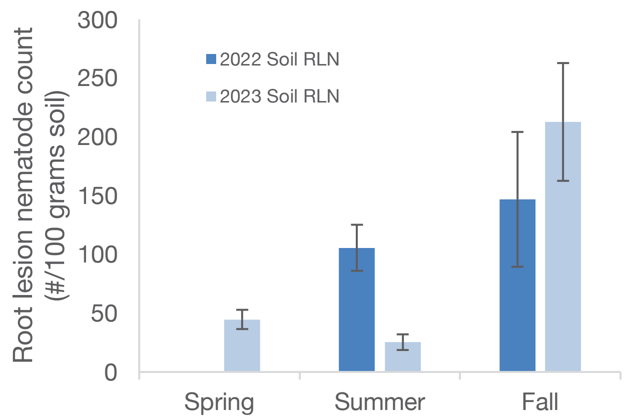

Figure 8. Seasonal soil samples of root lesion nematode at a mature orchard site during 2022 and 2023. The 2022 data for five summer samples (4 July, 18 July, 4 August, 15 August, 29 August) and five fall samples (12 September, 23 September, 11 October, 24 October, 7 Nov) were pooled and averaged (spring data not available). The error bars for 2022 data illustrate the amount of variation among dates within a season. The 2023 data includes three replicates, and the error bars represent the analytical variation.

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A similar pattern was observed in 2022 and 2023 for the root population of root-lesion nematodes (Figure 9). Root populations of root-lesion were relatively high in the summer at a time when soil populations were relatively low. The migratory nematodes may congregate in the root systems during Nova Scotia summer conditions. In fall, the root populations decreased at a time when soil populations increased. Either the nematodes migrate from root systems or fine root turnover contributes to fewer feeding sites.

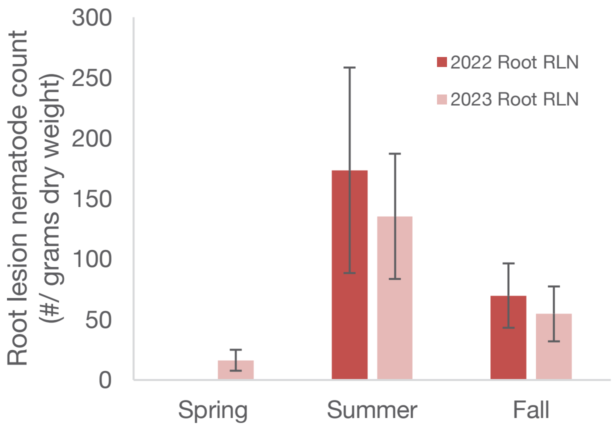

Figure 9. Seasonal root samples of root lesion nematode at a mature orchard site during 2022 and 2023. The 2022 data for five summer samples (4 July, 18 July, 4 August, 15 August, 29 August) and five fall samples (12 September, 23 September, 11 October, 24 October, 7 Nov) were pooled and averaged (spring data not available). The error bars for 2022 data illustrate the amount of variation among dates within a season. The 2023 data includes three replicates, and the error bars represent the analytical variation.

In the separate investigation of the proportion of nematodes in the soil versus root portion of a total 100 cc soil volume, the results are consistent with the seasonal trends in soil and root populations (Figure 10). The summer sample on July 21 had 22% root-lesion in roots (92 ± 28 root-lesion) and the remaining 78% in soil (330 ± 59 root-lesion). The fall sample on September 21 shifted to have 7% in roots (18 ± 6 root-lesion) and 93% in soil (258 ± 14 root-lesion). These results lend further support to the suggestion that under Nova Scotia growing conditions, there is a relatively higher root-lesion presence in roots during summer.

With a 93% presence in the soil fraction of a fall sample, the soil sample represents the total nematode population, and a soil sample would be adequate for management and diagnostic purposes. If there is an issue being diagnosed in summer, a root sample should also be recommended. Furthermore, management practices such as chemical drenches that target the soil population should avoid summer application unless they will be absorbed into roots. Foliar chemical treatments that are systemic including nematicidal activity in the root system of the plant may be most effective as a summer application.

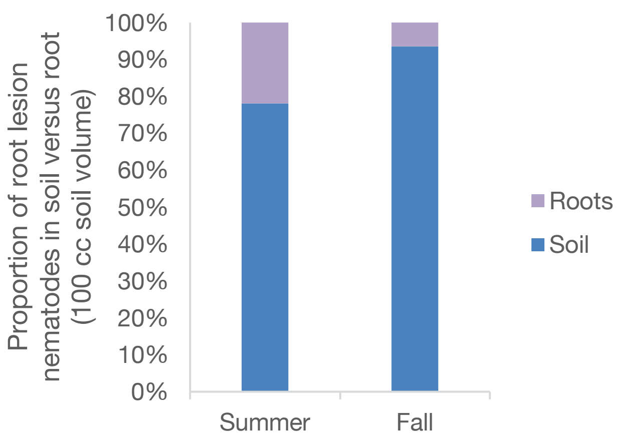

Figure 10. The population dynamics within a 100 cc volume of soil sampled from a mature orchard in summer and fall. The feeder roots were extracted directly from the soil cores to determine what percentage of the total parasitic nematode population was in the roots versus the soil.

Spring root and soil samples in 2023 returned low root-lesion populations. This may suggest that spring samples are misrepresentative of the actual carrying capacity of root lesion nematodes in a horticultural system. Spring samples appear to be difficult to interpret because the multiplication factor can be unpredictable. Fall samples represent the highest seasonal population and may provide the most valuable information for pre-plant decision-making.

GENERAL CONCLUSIONS

Cover Crops

Our work to date has shown that brown mustard can have the unintended consequence of supporting root-lesion nematodes when conditions on the farm are uncontrollable and the chemical benefits during termination are not realized. Brown mustard may not be a straightforward or practical approach to management in Nova Scotia unless the ideal conditions can be achieved. Currently, brown mustard is a risky treatment to attempt.

Pearl millet is expected to be a non-host of the root-lesion nematode and our results in Nova Scotia support this claim. Using pearl millet prior to crop establishment discouraged root-lesion presence and multiplication. The pearl millet showed success in limiting growth of the root-lesion population but cannot be counted on to reduce the population to below-threshold levels.

Chemical Treatments

Based on the root-lesion nematode results, there are no clear promising effects of Velum Prime and Movento chemical treatments as rescue treatments in a young orchard setting. However, the data on trunk cross sectional area suggests that there may be a marginal benefit to tree health from the individual application of Velum Prime and Movento during summer or spring application. The repeated or multi-year use of these products was not tested.

Root-Lesion Patterns and Seasonal Fluctuations

Spring populations of root-lesion nematodes showed a decrease through winter die-off, then magnification by the fall, altogether producing a strong natural cycle throughout the season. This may suggest that spring samples are misrepresentative of the actual carrying capacity of root lesion nematodes in a horticultural system. Spring samples appear to be difficult to interpret because the multiplication factor can be unpredictable. If a grower wants to know the carrying capacity of their field, spring nematode sampling is discouraged.

Across all trials, populations of root-lesion nematodes were typically higher in fall relative to spring populations. An increase in the parasite load throughout the growing season is consistent with the expected multiplication of a parasite on a host plant. Fall samples represent the highest seasonal population and may provide the most valuable information for pre-plant decision-making.

Another interesting pattern is that root populations of root-lesion nematode were relatively high in the summer at a time when soil populations were relatively low. The migratory nematodes may congregate in the root systems during Nova Scotia summer conditions. With a 93% presence in the soil fraction of a fall sample, the soil sample represents the total nematode population, and a soil sample would be adequate for management and diagnostic purposes. If there is an issue being diagnosed in summer, a root sample should also be recommended. Foliar chemicals that are systemic with nematicidal activity in the root system of the plant may be effective as a summer application.

Sample Variability

Sample variability is a challenging issue with the study of root-lesion nematodes. To limit sample variation, locations were flagged to revisit each time a composite sample was taken. For the sequential sampling, sampling was done in triplicate for a more robust representation of the overall population. Limiting variation helped to identify trends in the data. However, sample variation and seasonal variation still limited the conclusions that could be made.

Our difficulty in studying nematodes and the influence of management practices reinforces how difficult it is for growers to monitor and manage this plant parasitic pest. It is recommended that when growers are using nematode soil samples to evaluate the impact of an on-farm management strategy or demonstration that they consider taking samples in triplicate to average their results. Furthermore, growers should flag or GPS mark a location for taking before and after samples.

When using nematode soil samples to make management decisions, a single sample should be representative of the population level relative to the threshold. Our triplicate testing showed variations but in all cases the samples were well above threshold.

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