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# Demonstrate Bio-fumigants as a Control of Nematode and Verticillium in Pota-toes and Strawberries

## Objective

To evaluate soil sampling and analyti-cal methodologies for nematodes and Verticillium sp to demonstrate the management of bio fumigant control in potatoes and strawberries.

## Summary

Root lesion nematodes have an eco-nomic impact on potato production that could be in the range of 10 per cent in Atlantic Canada. Root lesion nematodes and Verticillium sp are as-sociated with a major cause of potato yield reduction commonly referred to as Early Dying Complex (PED). Root lesion nematodes and Verticillium sp singularly and combined have similar negative impacts on a range of crops. When present, these pests can also cause significant economic losses in strawberries.

NBSCIA established mustard bio-fumigant cultivars in a field in 2019 prior to potatoes in 2020 to observe the potential as a fumigant to reduce nem-atodes and Verticillium populations. Similar treatments were established at two locations in 2020 preceding pota-toes and strawberries in 2021. The ef-fectiveness of chemical fumigation was observed in a single location in strawberries in 2020 and 2021. Canadi-an forage pearl millet was added as a potential biofumigant crop in 2021.

On average, root lesion nematode pop-ulations increased from spring to fall in each of 2019 and 2020 in the HW po-tato field and the CM strawberry field in 2020 under the mustard bio-fumigant. Root lesion nematode popu-lations were significantly reduced from the fall of 2019 to the spring of 2020 at the original HW location. Root lesion populations were reduced under oats and mustard in the Home 1 field in 2020, however there was little ob-served difference between the two crop species. Treatment effects were less conclusive in 2021, possibly impacted by the record setting temperature and rainfall throughout the growing season. Chemical fumigation with Vapam in the Sunset strawberry field clearly re-duced root lesion nematode popula-tions in 2020 and 2021.

V. dahlia increased from an average 6644 cells per gram to 23,721 cells per gram of soil under potatoes at the HW field site in the summer of 2020. Mus-tard bio-fumigant was observed to re-duce V. dahlia population in the potato and strawberry fields during the sum-mer of 2020. Oats as a cover crop did not reduce. The average cells per gram of soil for the three oat sites increased from 7701 to 9866 but decreased from 9866 to 6003 under Caliente mustard. Overall V. dahlia populations in-creased slightly throughout the 2021 season.

## Conclusion

Chemical fumigation clearly reduced root lesion nematode populations in 2020 and 2021. However, the impact of mustard bio-fumigant crops on root lesion nematode populations is less definitive, as populations were reduced under oats and mustard in 2020 and none were reported after potatoes in the fall of 2021. Nematode populations were reduced under both mustard and CFPM in 2021.

The extremely dry weather experi-enced during the growing season of 2020 may have been a factor in reduc-ing the chemical reaction of the bio-fumigant or nematodes may have re-mained below the layer of incorpora-tion of the mustard foliage. The ex-tremely wet weather experienced dur-ing the growing season of 2021 may have impacted results, as nematodes may have moved below the sample depth. Nematode populations on aver-age appear to be rebuilding in the HW field. Mustard bio-fumigant appeared to be effective in reducing V. dahlia population in the potato and strawberry fields during the summer of 2020.

Treatment effects were inconclusive in 2021.

## **Démontrer la présence de biofumigants pour lutter contre le nématode et** le Verticillium **dans les pommes de terre et les fraises**

**Objectif**

Évaluer les méthodes d'échantillonnage et d'analyse du sol pour les nématodes et Verticillium sp afin de démontrer la gestion du contrôle des biofumigants dans les pommes de terre et les fraises.

**Sommaire**

Les nématodes à lésions radiculaires ont un impact économique sur la production de pommes de terre qui pourrait être de l'ordre de 10% au Canada atlantique. Les nématodes à lésions racinaires et Verticillium sp sont associés à une cause majeure de réduction du rendement de la pomme de terre communément appelée Complexe de mort précoce (DEP). Les nématodes à lésions racinaires et Verticillium sp, seuls et combinés, ont des impacts négatifs similaires sur une gamme de cultures. Lorsqu'ils sont présents, ces ravageurs peuvent également entraîner des pertes économiques importantes pour les fraises.

L'AASCNB a établi des cultivars de biofumigants de moutarde dans un champ en 2019 avant les pommes de terre en 2020 pour observer le potentiel en tant que fumigeant de réduire les populations de nématodes et de Verticillium. Des traitements similaires ont été mis en place à deux endroits en 2020 avant les pommes de terre et les fraises en 2021. L'efficacité de la fumigation chimique a été observée en un seul endroit dans les fraises en 2020 et 2021. Le millet perlé fourrager canadien a été ajouté comme culture biofumigants potentielle en 2021.

En moyenne, les populations de nématodes à lésions racinaires ont augmenté du printemps à l'automne en 2019 et 2020 dans le champ de pommes de terre HW et le champ de fraises CM en 2020 sous le biofumigant moutarde. Les populations de nématodes à lésions radiculaires ont été considérablement réduites de l'automne 2019 au printemps 2020 à l'emplacement d'origine de HW. Les populations de lésions racinaires ont été réduites sous l'avoine et la moutarde dans le champ de la Maison 1 en 2020, mais il y avait peu de différence observée entre les deux espèces de cultures. Les effets du traitement ont été moins concluants en 2021, peut-être affectés par la température record et les précipitations tout au long de la saison de croissance. La fumigation chimique au Vapam dans le champ de fraises Sunset a clairement réduit les populations de nématodes à lésions racinaires en 2020 et 2021.

V. dahlia est passé d'une moyenne de 6644 cellules par gramme à 23 721 cellules par gramme de terre sous les pommes de terre sur le site du champ HW à l'été 2020. Un biofumigant à la moutarde a été observé pour réduire la population de V. dahlia dans les champs de pommes de terre et de fraises au cours de l'été 2020. L'avoine en tant que culture de cou-verture n'a pas diminué. La moyenne des cellules par gramme de sol pour les trois sites d'avoine est passée de 7701 à 9866, mais a diminué de 9866 à 6003 sous la moutarde Caliente. Les populations globales de V. dahlia ont légèrement augmenté tout au long de la saison 2021.

**Conclusion**

La fumigation chimique a clairement réduit les populations de nématodes à lésions racinaires en 2020 et 2021. Cependant, l'impact des cultures biofumigants à la moutarde sur les populations de nématodes à lésions racinaires est moins définitif, car les populations ont été réduites sous l'avoine et la moutarde en 2020 et aucune n'a été signalée après la pomme de terre à l'automne 2021. Les populations de nématodes ont été réduites sous la moutarde et le CFPM en 2021. Le temps extrêmement sec connu pendant la saison de croissance de 2020 peut avoir été un facteur de réduction de la réaction chimique du biofumigant ou les nématodes peuvent être restés sous la couche d'incorporation du feuillage de moutarde. Le temps extrêmement humide connu pendant la saison de croissance de 2021 peut avoir eu un impact sur les résultats, car les nématodes peuvent s'être déplacés sous la profondeur de l'échantillon. Les populations de nématodes semblent en moyenne se reconstituer dans le champ HW. Le biofumigant moutarde semblait efficace pour réduire le V. population de dahlias dans les champs de pommes de terre et de fraises pendant l'été 2020. Les effets du traitement n'étaient pas concluants en 2021.

## **2021 Interim Report**:

1. *Project title and project number*: C1920-0201-Y3 Demonstrate Bio-fumigants as a Control of Nematode and Verticillium in Potatoes and Strawberries

2. *Project leader and collaborators*: The project team consists Ray Carmichael, MSc. Ag. and Andrew Systma, NBSCIA Club Agrologists. The collaborating farmers are Carpenter Farms Ltd Charles McIntosh and Sunset U-Pick.

3. *Summary:* Root Lesion nematodes have an economic impact on potato production that could be in the range of 10% in Atlantic Canada. Root lesion nematodes and Verticillium sp are associated with a major cause of potato yield reduction commonly referred to as Early Dying Complex (PED). Root Lesion nematodes and Verticillium sp singularly and combined have similar negative impacts on a range of crops. When present these pests can also cause significant economic losses in strawberries.

   NBSCIA established mustard bio-fumigant cultivars in a field in 2019 prior to potatoes in 2020 to observe the potential as a fumigant to reduce nematodes and Verticillium populations. Similar treatments were established at two locations in 2020 preceding potatoes and strawberries in 2021. The effectiveness of chemical fumigation was observed in a single location in strawberries in 2020 and 2021. Canadian Forage Pearl Millet was added as a potential biofumigant crop in 2021.

   The objective of this project is to evaluate soil sampling and analytical methodologies for nematodes and Verticillium sp to demonstrate the management of bio fumigant control in potatoes and strawberries

   On average, Root lesion nematode populations increased from spring to fall in each of 2019 and 2020 in the HW potato field and the CM strawberry field in 2020 under the mustard bio-fumigant. Root lesion nematode populations were significantly reduced from the fall of 2019 to the spring of 2020 at the original HW location. Root lesion populations were reduced under oats and mustard in the Home 1 field in 2020, however there was little observed difference between the two crop species. Treatment effects were less conclusive in 2021, possibly impacted by the record setting temperature and rainfall throughout the growing season. Chemical fumigation with Vapam in the Sunset strawberry field clearly reduced Root lesion nematode populations in 2020 and 2021.

   V. dahlia increased from an average 6644 cells per gram to 23,721 cells per gram of soil under potatoes at the HW field site in the summer of 2020. Mustard bio-fumigant was observed to reduce V. dahlia population in the potato and strawberry fields during the summer of 2020. Oats as a cover crop did not reduce. The average cells per gram of soil for the three oat sites increased from 7701 to 9866 but decreased from 9866 to 6003 under Caliente mustard. Overall V. dahlia populations increased slightly throughout the 2021 season.

   Initial soil health sampling data established benchmark procedures for future work.

4. *Introduction:* There are no statistically validated estimates in Canada of yield losses in potatoes due to nematodes, however in the United States, it is estimated that 10% of the potato crop is lost annually because of nematodes, and it is reasonable to assume that this percentage is also applicable to Canada and the Atlantic region. The most important nematode parasite of potatoes in the northeastern United States and in eastern Canada is the root lesion nematode,

Pratylenchus penetrans. Several other root lesion nematode species attack potatoes but are not important or have not been detected in the Atlantic region.

Since nematodes usually attack underground plant parts, there are no reliable foliar symptoms to signify that nematodes may be the major cause of poor growth and reduced tuber yields in potatoes. In roots, injury by nematodes may be detected by the presence of lesions, cysts or galls. After a few weeks, however, roots are attacked by other pathogens such as bacteria and fungi (Verticillium sp.), and the original damage by nematodes may not be obvious. Consequently, nematode damage has often been attributed to other factors. Root lesion nematodes invade and migrate in potato roots, though tubers are sometimes invaded when nematode populations are very high. Root lesion nematodes and Verticillium sp are associated with a major cause of potato yield reduction commonly referred to as Early Dying Complex (PED).

Adult females lay eggs in roots or soil. Second stage juveniles hatch from the eggs, invade roots, and develop through the third and fourth stages to adults. Second, third, and fourth stage juveniles, as well as adult males and females are all capable of invading and migrating through roots. A life cycle takes 20 to 60 days to complete, and depends mostly on the condition of the host and on soil temperature. Maximum damage occurs in sandy soils, since these nematodes prefer this type of soil, and also because sandy soils are suited for potato culture. Above-ground symptoms caused by high populations of root lesion nematodes are sometimes falsely attributed to lack of water or nutrients.

Fumigant nematicides are an expedient way to control nematodes. The major disadvantage of chemical control is the cost of fumigants and the need for specialized equipment. Planting is delayed by three or four weeks if fumigants are applied in the spring. In addition, there is the possibility that residues may be left in tubers or may contaminate groundwater. Soil fumigants also are not discriminating in the organisms they control and may destroy beneficial soil life as well as the target pests.

A soil health analysis including parameters that measure microbial or biological activity could provide some comparison of the impact of chemical and biofumigant treatments. The soil health analysis conducted by PEI Analytical Laboratories provided a measure of soil respiration and biological nitrogen availability.

Microbes, including bacteria and fungi, play a critical role in regulating the carbon cycle and mineralizing nutrients, turning them into plant-available forms. Soil microbes also influence tilth (soil structure) and help protect crops against pests and disease. As the name implies, the soil respiration test assesses microbial activity by measuring the release of carbon dioxide ($CO_2$) from the soil. $CO_2$ respiration is a by-product of microbial metabolism, which includes mineralizing nutrients and breaking down residues. This test is a good indicator of overall microbial activity. The value reported for the soil respiration test is in milligrams of $CO_2$ per gram of dry soil. The higher the value - the better.

Nitrogen is stored in the soil in two forms – one is immediately plant available (inorganic), and the other (organic) is tied-up in a variety forms (i.e. in organic matter, microbial organisms, plant and root residues, etc.). Nitrogen becomes plant available when it is broken down (also known as mineralized) into an “inorganic” form, and can then be actively taken up by plant roots. This breakdown process occurs by microbes metabolizing these compounds and releasing nitrogen into a plant available form. This process is driven by microbes and is dependent on soil temperatures and moisture levels.

To measure how well your soil can provide plant-available nitrogen during the growing season, the biological nitrogen availability is tested by taking a dry, relatively inactive soil and exposing it to optimum moisture and temperature conditions over two weeks. This allows microbial activity to resume and the amount of nitrogen that gets mineralized into plant-available forms can be measured. The amount of plant-available (inorganic) nitrogen that is mineralized during this period is reported and the higher the value – the better. This test was adapted for use specifically for PEI producers by the Atlantic Soil Health Lab in Truro, NS.

Mustard is a well understood bio fumigant. Its bio fumigation properties have been studied for a number of years and scientists have developed a method to fully use these properties. Mustard has been shown to control a variety of soil borne pests. These include Verticillium spp., Rhizoctonia spp., Fusarium spp., Pythium spp., Sclerotinia spp., common scab and a range of nematodes. The use of mustard as a bio fumigant has also shown a decrease in damage caused by wireworm. However, using a bio fumigant non-cash crop results in lost income for the year and significant input costs which can approximate the cost of chemical fumigants.

Compounding the situation is finding crops that complement the potato crop in regards to soil health and disease cycles while providing an economic benefit. Pearl millet also has properties that control root lesion nematodes and can act as a green manure crop to improve soil health in the break years of potato rotations. Pearl millet following a mustard crop could potentially further reduce Root lesion nematodes.

The bio fumigant (mustard) crop must be cut and incorporated into the soil not more than 60 days after planting and before the crop goes to seed. While there is time to establish a second crop the cutting and incorporation will conflict with potato harvest. The use of a millet crop following the mustard crop may eliminate the need to cut and incorporate a second mustard crop during potato harvest while still having an impact on the nematode population.

5. *Project Objective(s):* To evaluate soil sampling and analytical methodologies for nematodes and Verticillium sp to demonstrate the management of bio fumigant control in potatoes and strawberries.

6. *Project Deliverable(s):*
   1. The level of Root lesion nematode and Verticillium sp. in the field prior to establishing the bio fumigant crop and levels at seasons end.
   2. Management of the break crop by the producer to control the nematode and virus population in the field, as well as improving soil organic matter and acting as a nutrient sink.
   3. A cost benefit comparison between bio fumigation and chemical fumigation.

7. *Material and Methods*: The collaborating producer (Carpenter Farms) indicated that one of their potato fields exhibited poor growth in sections of the field in 2017.Soil samples from a Carpenter Farms' field (HW) in the fall of 2018 identified higher levels of Root Lesion Nematode in sections of the field where the crop production was reduced compared to the "newer" area. (Appendix Table 1). Because Potato Early Die (PED) symptoms are not expressed uniformly throughout a field. All soil sample sites were geo-referenced.

   Replicated bio-fumigant treatments of Mighty, Attack and Centennial mustard were established in 2019 in the HW field as reported in C1920-0201 Demonstrate Bio-fumigants as a Control of Root Lesion Nematode. Pearl Millet, Sorghum Sudan grass and oats were planted as cover crops following incorporation of the mustard bio fumigant species. Samples from the geo-referenced locations were collected in the spring and fall of 2019, 2020 and fall of 2021 (Appendix Tables 1 & 2).

A second field location (Home-8) was identified and six geo-referenced sample sites were established in the fall of 2019.The field was split with Caliente mustard and oats and seeded June 5, 2020. Both crops were chopped, prior to mustard seed formation and incorporated on July 22, 2020. A second crop of each species was replanted on August 27, 2020. Soil samples from the geo-referenced locations were collected in the fall of 2019, spring of 2020, prior to planting the mustard and oat crop, spring of 2021, prior to planting the potato crop and in the fall of 2020 and 2021 and assessed for nematodes and Verticillum sp. (Appendix Tables 3 & 4).

A third site was established in Home 8 in the spring of 2021 and split to compare Canadian Forage Pearl Millet (CFPM) with Caliente mustard. Three geo-referenced sample sites were located in each crop species as illustrated in Appendix Figures 1. A similar side by side comparison with geo-referenced sample sites was established in a second field site CampMid. Samples were collected from each field location in the spring and fall of 2021 and assessed for nematodes and Verticillum sp. (Appendix Tables 3 &4).

Biomass imagery from Climate Fieldview was monitored throughout the 2021 season to identify potential visual symptoms of PED for Carpenter Home 8 and HW fields (Appendix Figures 2).

Spring and fall samples for nematode and Verticillium sp. identification were collected from two strawberry farm sites identified in 2020. As a comparison one of the strawberry farm cooperators has a history of chemical fumigation and one field site was treated with a chemical fumigant in 2020 and 2021. (Appendix Tables 5 & 6)

A number of samples for soil health analysis were collected from selected geo-referenced sites from across all locations for observation of potential correlation between soil health parameters and nematode and Verticillium sp. occurrence (Appendix Tables 7 & 8)

Experience from the initial work in 2019 identified variance between laboratory methodologies and interpretation of results regarding critical levels for both nematodes and Verticillium spp.. To eliminate this variance all nematode evaluations were conducted by the University of Guelph, Agriculture and Food Laboratory and soil scans using qPCR technology for DNA identification of Verticillium sp. were undertaken at Agricultural Certification Service.

Basic soil health analysis conducted by PEI Analytical Laboratories (https://www.princeedwardisland.ca/en/information/agriculture-and-land/pei-soil-health-test-how-to-interpret-your-results) was initiated this year.

8. *Results and Discussion*:

Fall sample results for 2021 for nematode and Verticillium sp.for the Carpenter HW field with all historical values are presented in Appendix Tables 1 and 2, attached. Root-lesion population as reported were depressed in the spring of 2020 prior to the potato crop and subsequent to the biofumigant treatments of 2019. Populations increased during 2020with potatoes and again in 2021 under the oat crop. However considerably lower than the levels reported throughout the 2019 crop season.

Verticillium dahliae cells per gram of soil increased during the same three crop seasons. V dahlia populations increased in the HW field planted to potatoes in 2020. The number of cells per gram of soil were observed to be similar between the fall of 2019 and the spring of 2020 but exhibited a large increase during the 2020 growing season and increased again in 2021 under oats. Suggesting that V dahlia populations may be capable of rebuilding quickly with a susceptible host such as potatoes.

Spring and fall nematode populations for 2019, 2020 and 2021 for all Carpenter field sites and others are presented in Appendix Table 3, attached. Observed variance is considered to be within the limits of random error due to timing and the absence of replication. In the fall of 2021 Root-lesion nematode counts were 0 for the three sample sites with oats in 2020 compared to Caliente mustard with 20 nematodes per kg of soil in the fall of 2021. On average the three sample sites treated with Canadian Forage Pearl Millet demonstrated a greater reduction in Root-lesion nematode counts per kg of soil than the three sites with Caliente mustard.

The exact sample locations and biomass ratings from Climate Fieldview are illustrated in Appendix Figures 2.

Spring and fall Verticillium sp cells per gram of soil for 2019, 2020 and2021 for all Carpenter field sites and others are presented in Appendix Table 4, attached

Mustard bio-fumigant was observed to reduce V. dahlia population in the potato and strawberry fields during the summer of 2020. Oats as a cover crop did not reduce V. dahlia. The average cells per gram of soil for the three oat sites in the field Home 8-1, 2, and 3 increased from 7701 to 9866 under oats but decreased from 9866 to 6003 under Caliente mustard( Sites 4,5,and6). Verticillium dahliae concentrations increased in each treatment under potatoes in 2021, somewhat greater in the Caliente mustard treatment.

With Verticillium qPCR testing, the level of Verticillium species in soil is quantified directly by the extractable DNA from soil samples. For practical purposes, this is converted into an estimate of the number of cells per gram of soil based upon the known DNA content of Verticillium dahliae. The quantity of Verticillium DNA as reported is not atypically very high or low compared to representative Verticillium-positive samples in New Brunswick potato rotations. How these DNA concentrations relate to infection risk, symptom expression and possible yield reduction in the field, however, likely depends on many factors.

A series of greenhouse experiments recently completed by Agricultural Certification Services determined that tuber yield of greenhouse-grown Russet Burbank potato plants was reduced by 50% at V. dahliae inoculum levels of 0.035 ng/g soil, compared to control plants not exposed to V. dahliae in the soil; this increased to 75% reduction in tuber yield at 0.123 ng/g soil. Given that the values recorded lay close to the conditions of the ACS greenhouse experiment, the potential for substantial infection and yield reduction exists.

The ACS experiment did not determine a safe lower limit of Verticillium DNA that does not cause tuber yield reduction compared to the control. Literature values of Verticillium DNA levels in soil corresponding to crop outcomes are rare for potatoes, but in other susceptible crops, DNA levels as low as 0.003 ng/g soil can cause detectable levels of plant infection. The DNA levels (ng/g of soil) reported for all samples are in excess of the suggested low limit of 0.003ng/g.

Soil samples were collected from several other field locations to provide reference values for nematode and Verticillium infestation levels in commercial fields.

Nematode populations for 2020 and 2021 in strawberry field sites are reported in Appendix Table 5, attached. The Root-lesion populations for the CM samples sites are inclusive and variable, demonstrating real trend. Chemical fumigation clearly reduced Root lesion nematode populations in the strawberry fields in 2020 and 2021.

Verticillium sp concentrations for 2020 and 2021 in strawberry field sites are reported in Appendix Table 6, attached. A very low level of Verticillium dahliae was reported in only one sample site in the fall 2020 and 2021 but not the spring of 2021.

Soil health Verticillium sp and Root-lesion nematodes results are illustrated in Appendix Figures 7 & 8, attached. This is a very preliminary look at potential relationships between soil health parameters and the occurrence of Verticillium and Root-lesion nematodes, as such is impossible to draw any conclusions. It is worth noting that two parameters related to soil biological activity Respiration and Biological Nitrogen Activity should slight increase during the growing season.

9. *Conclusions*:

Chemical fumigation clearly reduced Root lesion nematode populations in 2020 and 2021. However, the impact of mustard bio-fumigant crops on Root lesion nematode populations is less definitive, as populations were reduced under oats and mustard in 2020 and none were reported after potatoes in the fall of 2021. Nematode populations were reduced under both mustard and CFPM in 2021.The extremely dry weather experienced during the growing season of 2020 may have been a factor in reducing the chemical reaction of the bio-fumigant or nematodes may have remained below the layer of incorporation of the mustard foliage. The extremely wet weather experienced during the growing season of 2021 may have impacted results, as nematodes may have moved below the sample depth. Nematode populations on average appear to be rebuilding in the HW field. Mustard bio-fumigant appeared to be effective in reducing V. dahlia population in the potato and strawberry fields during the summer of 2020. Treatment effects were inconclusive in 2021.

Utilizing the same laboratory for nematode and Verticillium sp identification and geo-referenced sampling sites increases the confidence of treatment effects observed over time. However, given the range of variability observed from year to year and location to location further work is required to validate the effectiveness of mustard and CFPM as bio-fumigant treatments. The data presented suggests that V dahlia populations may be capable of rebuilding quickly with a susceptible host, such as potatoes.

10. *Required next steps*:

Further testing at multiple sites is required to compare the efficacy and cost of crop bio fumigant treatments with registered chemical treatment such as Chloropicrin, Veleum Prime and Elatus to control nematode and Verticillium species.

These data collected should also be supported with Soil Health Analysis provided by PEI Analytical Laboratories (PEIAL, of particular interest would be any correlation with OM, Soil Respiration, Biological Nitrogen Availability and soil texture.

11. *Communication:*
The data generated by this project will be analyzed and reported in the NBSCIA annual report and used at producer meetings, and local association meetings when requested.

*12. Intellectual Property:*
There are no intellectual properties involved with this project.

## Appendix Tables: C1920-0201-V3 Demonstrate Bio-fumigants as a Control of Nematode and Verticillium in Potatoes and Strawberries

**Appendix Table 1: Carpenter Farms Number of Nematodes/kg of Dried Soil**

| | | Fall 2018 | 25-Jun-19 | | 26-Sep-19 | | | 5-Jun-20 | | 30-Oct-20 | | | 29-:Sep-21 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plot | Treatment Crop | Root-lesion | Root-lesion | Other | Root-lesion | Other | 2020 Crop | Root-lesion | Other | Root-lesion | Other | 2021 Crop | Root-lesion | Other |
| HW-1 | Mighty | 1440 | 1800 | 6301 | 12341 | 32369 | Potatoes | 40 | 0 | 520 | 0 | Oats | 340 | 0 |
| HW-2(new) | Attack | 420 | 1768 | 5894 | 1549 | 19204 | Potatoes | 260 | 0 | 560 | 0 | Oats | 1300 | 0 |
| HW-3 | Attack/Cent | 980 | 3143 | 6601 | 3990 | 19338 | Potatoes | 200 | 0 | 100 | 0 | Oats | 300 | 0 |
| HW-4 | Centennial | 980 | 1261 | 4414 | 4494 | 40147 | Potatoes | 220 | 0 | 180 | 0 | Oats | 360 | 0 |
| | **Average** | **955** | **1993** | **5803** | **5594** | **27165** | | **180** | **0** | **340** | **0** | | **575** | **0** |

**Appendix Table 2: Carpenter Farms Number of Verticillium Cells per gram of Soil***

| | | 16-Oct-19 | | | | | 5-Jun-20 | Report Date: | 16-Jul-20 | | 28-Oct-20 | | Report Date: | 9-Dec-20 | | 5-Oct-21 | | Report Date: | Dec 17-21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *V. dahliae* | | *V. albo-atrum* | | | *V. dahliae* | | *V. albo-atrum* | | *V. dahliae* | | *V. albo-atrum* | | | *V. dahliae* | | *V. albo-atrum* | |
| **Plot** | **2019 Crop** | **DNA ng/g soil** | **cells per gram soil*** | **DNA ng/g soil** | **cells per gram soil*** | **2020 Crop** | **DNA** ng/g soil | **cells per** gram soil* | **DNA** ng/g soil | **cells per** gram **soil*** | **DNA ng/g** soil | **cells per gram soil*** | **DNA ng/g** soil | **cells per** gram soil* | **2021 Crop** | **DNA ng/g** soil | **cells per** gram **soil*** | **DNA ng/g soil** | **cells per gram soil*** |
| HW-1 | Mighty | 0.33 | 9030 | 0 | 0 | Potatoes | 0.263 | 7199 | 0 | 0 | *0.612* | *16767* | *0.014* | *381* | Oats | **0.667** | **18283** | **0.000** | **0** |
| HW-2(new) | Attack | 0.16 | 4434 | 0 | 0 | Potatoes | 0.084 | 2310 | 0 | 0 | *0.191* | *5226* | *0.031* | 845 | Oats | 1.059 | 29022 | 0.000 | 0 |
| HW-3 | Attack/Cent | 0.19 | 5201 | 0.32 | 8778 | Potatoes | 0.26 | 7121 | 0.001 | 18 | *1.92* | 52599 | *0.09* | *2470* | Oats | 0.967 | 26496 | 0.000 | 0 |
| HW-4 | Centennial | 0.1 | 2842 | 0.09 | 2519 | Potatoes | 0.363 | 9948 | 0 | 0 | 0.741 | *20293* | *0.078* | *2142* | Oats | 0.980 | 26852 | 0.095 | 2608 |
| | **Average** | **0.20** | **5377** | **0.10** | **2824** | | **0.243** | **6645** | **na** | **na** | **0.866** | **23721** | **0.053** | **1460** | | **0.918** | **75164** | **0.024** | **na** |

'cells per gram soil estimate based on known DNA size of V. dahliae genome = 36.5 fg/cell

## Appendix Table 3: 2019-2021 Nematodes/kg of Dried Soil

| | Oct.16,2019 | | | 2020 | June 5,2020 | | | Oct 30,2020 | | | 2021 | May 17, 2021 | | | Sept. 29, 2021 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Plot* | Root-lesion | Spiral | Pin | *Crop* | Root-lesion | Spiral | Pin | Root-lesion | Spiral | Pin | Crop | Root-lesion | Spiral | Pin | Root-lesion | Spiral | Pin |
| Home8-1 | 3680 | 260 | 0 | Oat | 760 | 0 | 0 | 0 | 60 | 0 | Potato | 80 | 0 | 0 | 0 | 40 | 0 |
| Home8-2 | 1680 | 80 | 0 | Oat | 1220 | 80 | 0 | 160 | 0 | 0 | Potato | 40 | 0 | 0 | 0 | 0 | 0 |
| Home8-3 | 1400 | 0 | 0 | Oat | 200 | 20 | 0 | 140 | 0 | 0 | Potato | 60 | 0 | 0 | 0 | 0 | 20 |
| **Average** | **2253** | **113** | **0** | | ***727*** | **33** | **0** | **100** | **20** | | **Average** | **60** | **0** | **0** | 0 | 13 | 7 |
| Home8-4 | 500 | 0 | 0 | Caliente | 1060 | 60 | 0 | 60 | 20 | 0 | Potato | 20 | 0 | 0 | 0 | 20 | 0 |
| Home8-5 | 1340 | 120 | 20 | Caliente | 240 | 20 | 100 | 240 | 120 | 0 | Potato | 20 | 0 | 20 | 0 | 0 | 60 |
| Home8-6 | 440 | 0 | 120 | Caliente | 520 | 40 | 0 | 80 | 0 | 140 | Potato | 20 | 0 | 60 | 60 | 0 | 20 |
| **Average** | **760** | **40** | **47** | | **607** | **40** | **33,** | **127** | **47** | | | **20** | **0** | **27** | **20** | **7** | **27** |
| Home8-7 | na | na | na | | na | na | na | no | na | no | CFPM | 4360 | 60 | 0 | 80 | 0 | 0 |
| Home8-8 | na | na | na | | na | na | na | na | no | na | CFPM | 5120 | 300 | 0 | 280 | 0 | 0 |
| Home8-9 | na | na | na | | na | na | na | na | no | na | CFPM | 2400 | 20 | 0 | 140 | 0 | 0 |
| | | | | | | | | | | | **Average,** | **3960** | **127** | **0** | **167** | **0** | **0** |
| Home8-10 | na | na | na | | na | na | na | na | na | na | **Caliente** | 10400 | 40 | 0 | 2480 | 20 | 0 |
| Home8-11 | na | na | na | | na | na | na | na | na | na | **Caliente** | 2680 | 60 | 0 | 960 | 0 | 0 |
| Home8-12 | na | na | no | | na | na | na | na | na | na | **Caliente** | **16000** | 60 | 0 | 1060 | 0 | 0 |
| | | | | | | | | | | | **Average** | **9693** | **53** | **0** | **1500** | **7** | **0** |
| CampMidl | na | na | na | | na | na | na | na | na | na | **Caliente** | **2560** | **0** | 0 | 20 | 0 | 0 |
| CampMid2 | na | na | na | | na | na | na | na | na | na | **CFPM** | **560** | **0** | **0** | **40** | | |
| | | | | | | | | | | | **Average** | **1560** | **0** | **0** | **30** | **0** | **0** |
| Max-1 | no | no | na | | no | na | na | na | na | na | **Oats** | na | na | na | 620 | 0 | 0 |
| Max-2 | na | na | nor | | no | no | na | na | na | na | Oats | na | na | na | 120 | 0 | 0 |
| | | | | | | | | Oct 30,2020 | | | Client **ID** | | | | Dec 8,2021 | | |
| Home6 | na | na | na | Caliente | na | na | na | 200 | 0 | 0 | 101 10 FOF-103V | | | | 3200 | 40 | 20 |
| Paul 47 | na | na | na | Alfalfa/grass | na | na | na | 360 | 300 | 0 | D1 10 FOF-104V Nov 2nd | | | | 4280 | | 40 |
| Paul 48-1B | na | na | na | Barley/under | na | na | na | 20 | 0 | 0 | A2 10 FOF-102V Nov 1st | | | | 4360 | | |
| Paul 48-2B | na | na | na | Barley/under | na | na | na | 20 | 0 | 0 | A2 10 FOF-106V Nov 3rd | | | | 3480 | 20 | 860 |
| KT-1 | na | na | na | Soybean | na | na | na | 2180 | 0 | 0 | A3 10 FOF-105V Nov 3rd | | | | 1100 | | 80 |
| BP-1 | na | na | na | Potato | na | na | na | 1760 | 0 | 20 | A3 10 FOF-101V Nov ?1st | | | | 980 | | 100 |
| | | | | | | | | | | | A3 10 FOF-109V Nov 10th | | | | 280 | | 20 |
| | | | | | | | | | | | A4 10 FOF-107V Nov 3rd | | | | 2400 | 40 | 20 |
| | | | | | | | | | | | A4 10 FOF-108V Nov 3rd | | | | 1940 | | 20 |

## Appendix Table 4: Verticillium sp. qPCR Results Summary All Years All Sites Carpenter

Organism(s): Verticillium dahliae, Verticillium albo-atrum

'cells per gram soil estimate based on known DNA size of V. dahliae genome - 36.5 fg/cel

| | *V. dahliae* | | *V. albo-atrum* | | | *V. dohlioe* | | *V. albo-atrum* | | *V. dahliae* | | *V. albo-atrum* | | | *V. dahliae* | | *V. olbo-atrum* | | *V. dahliae* | | *V. albo-atrum* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Client ID | **DNA** ng/g soil | cells per | DNA ng/g soil | cells per gram soil' | 2020 Crop | DNA ng/g soil | cells per gram soil' | DNA ng/g soil | cells per gram soil' | DNA ng/g soil | cells per gram | DNA ng/g soil | cells per gram soil* | 2021 Crop | DNA ng/g soil | cells per gram soil' | DNA ng/g soil | cells per gram soil | **DNA** ng/g soil | cells per gram soil' | DNA ng/g soil | cells per gram soil' |
| Sample Date: | 16-Oct-19 | | | | | 5-1un-20 | | | | 28-Oct-20 | | | | | 18-May-21 | | | | 5-Oct-21 | | | |
| Horne8.1 | 0.32 | 8776 | 0.00 | 0 | Oat | 0.23 | 6293 | 0 | 0 | *0.424* | *11616* | *0* | *0* | Potato | 0.113 | 3097 | 0.000 | 0 | 0.181 | 4958 | 0.138 | 3792 |
| Horne8.2 | 0.93 | 2594 | 0.08 | 2113 | Oat | 0.242 | 6621 | 0 | 0 | *0.283* | *7746* | *0* | *0* | Potato | 0.089 | 2429 | 0.000 | 0 | 0.147 | 4027 | 0.250 | 6847 |
| Home8.3 | 0.35 | 9636 | 0.00 | 0 | Oat | 0.372 | 10190 | 0.001 | 40 | *0.374* | *10237* | *0* | *0* | Potato | 0.178 | 4884 | 0.000 | 0 | 0.106 | 2917 | 0.131 | 3582 |
| **,4erage** | **0.53** | **7002** | **0.03** | **704** | | **0.28** | **7701** | **0.00** | **13** | **0.36** | **9855** | **0** | **0** | **Average** | **0.13** | **3470** | **0.00** | **0** | **0.14** | **3967** | **0.17** | **4740** |
| Home8.4 | 0.42 | 11324 | 0.06 | 1690 | Caliente | 0.288 | 7890 | 0.004 | 103 | *0.214* | *5868* | *0* | *0* | Potato | 0.121 | 3326 | 0.000 | 0 | 0.679 | 18610 | 0.290 | 7951 |
| Hornet-5 | 0.47 | 12937 | 0.00 | 0 | Caliente | 0.294 | 8067 | 0 | 0 | *0.257* | *7029* | *0* | *0* | Potato | 0.184 | 5050 | 0.000 | 0 | 0.426 | 11682 | 0.184 | 5036 |
| Home8.6 | 0.40 | 10841 | 0.00 | 0 | Caliente | 0.408 | 11165 | 0.004 | 111 | *0.187* | *5112* | *0* | *0* | Potato | 0.138 | 3780 | 0.000 | 0 | 0.309 | 8460 | 0.140 | 3847 |
| **Average** | **0.43** | **11701** | **0.02** | **563** | | **0.33** | **9041** | **0.00** | **71** | **0.22** | **6003** | **0.0** | **0** | **Average** | **0.15** | **4052** | **0.0** | **0** | **0.47** | **12918** | **0.20** | **6511** |
| Home8-7 | na | na | na | na | | na | na | na | na | na | na | na | na | CFPM | **0.113** | **3105** | **0.000** | **0** | **0.067** | **1848** | **0.000** | 0 |
| Home8-8 | na | na | na | na | | na | na | na | na | na | na | na | na | CFPM | **0.052** | 1424 | **0.000** | **0** | **0.103** | **2834** | **0.000** | **0** |
| Home8-9 | na | na | na | na | | na | na | na | na | na | na | na | na | CFPM | 0.069 | 1885 | **0.000** | 0 | 0.078 | 2129 | 0.000 | 0 |
| | | | | | | | | | | | | | | **Average** | **.0.08** | **2138** | **0.00** | **0** | **.08** | **2270** | **0.00** | **0** |
| Home8 10 | na | na | na | na | | na | na | na | na | na | na | na | 113 | Caliente | 0.113 | 3089 | 0.000 | 0 | 0.046 | 1249 | 0.000 | 0 |
| lior»e8-11 | na | na | na | na | | na | na | na | na | na | na | na | na | Caliente | 0.036 | 981 | 0.000 | 0 | 0.097 | 2671 | 0.000 | 0 |
| Rome8-12 | na | na | na | na | | na | na | na | na | na | na | na | na | Caliente | 0.028 | 764 | 0.000 | 0 | 0.117 | 3212 | 0.000 | 0 |
| | | | | | | | | | | | | | | **Average** | **.06** | **1612** | **0.00** | **0** | **.09** | **2377** | **0.00** | **0** |
| CampMidi | na | na | na | na | | na | na | na | na | na | na | na | na | Caliente | 0.164 | 4497 | 0.000 | 0 | **0.162** | **4436** | **0.000** | **0** |
| campmid2 | na | na | na | na | | na | na | na | na | na | na | na | na | CFPM | 0.275 | 7524 | 0.000 | 0 | 0.206 | 5654 | 0.000 | 0 |
| | | | | | | | | | | | | | | **Average** | **0.22** | **6010** | **0.00** | **0.00** | **.18** | **5045** | **0.00** | **0** |
| Max 1 | na | na | *na* | na | | na | na | na | na | na | na | na | na | Oats | na | na | na | na | 496 | 40988 | 0.025 | 693 |
| Max *2* | ny | na | na | na | | lid | na | na | na | na | na | na | na | Oats | na | na | na | na | .455 | 12454 | 0.000 | 0 |
| | | | | | | | | | | | | | | **Average** | **na** | **na** | **na** | **na** | **0.98.....** | **26721** | **.01** | **346.63** |

| **Farm of the Future** | ***V. dahliae*** | | ***V. albo-atrum*** | |
|---|---|---|---|---|
| | **DNA ng/g soil** | **cells per gram soil"** | **DNA ng/g soil** | **cells per gram soil'** |
| **Client ID** | Sample Date: | | 12-Nov-21 | |
| **D1 10 FOF-103V** | 0.081 | 2225 | 0.060 | 1637 |
| **DI 10 101-104V Nov 2nd** | 0.193 | 5300 | 0.000 | 0 |
| **A2 10 FOF•102V Nov 1st** | 0.074 | 2029 | 0.000 | 0 |
| **A2 10 FOF 106V Nov 3rd** | 0.112 | 3062 | 0.000 | 0 |
| **A3 10 FOF-105V Nov 3rd** | 0.186 | 5099 | 0.000 | 0 |
| **A3 10 FOF•101V Nov ?1st** | 0.144 | 3949 | 0.000 | 0 |
| **A3 10 FOF•109V Nov 10th** | 0.248 | 6802 | 0.000 | 0 |
| **A4 10 FOF-107V Nov 3rd** | 0.103 | 2820 | 0.021 | 587 |
| **A4 10 FOF•108V Nov 3rd** | 0.111 | 3046 | 0.117 | 3206 |

Source: Agricultural Certification Service Inc.

## Appendix Table 5: Strawberry Fields Nematodes/kg of Dried Soil

| Field | Crop | June 5,2020 Root-lesion | June 5,2020 Spiral | June 5,2020 Pin | Oct 30,2020 Root-lesion | Oct 30,2020 Pin | Oct 30,2020 Knot |
|---|---|---|---|---|---|---|---|
| CM-1 | Caliente | 300 | 0 | 0 | 380 | 0 | 0 |
| CM-2 | Pacific Gold | 60 | 0 | 0 | 900 | 0 | 0 |
| CM-3 | Timothy-Clover | na | na | na | 280 | 4380 | 0 |
| CM-4 | | | | | | | |
| CM-5 | | | | | | | |
| CM-6 | | | | | | | |
| Jordie | Strawberry | na | na | na | 600 | 0 | 520 |
| Blueberry field | Strawberry | na | na | na | 80 | 0 | 0 |
| Wrong Way | Strawberry | na | na | na | 20 | 0 | **0** |
| Hill | Strawberry | na | na | na | 640 | 0 | 60 |
| | | PreFumigant | | | PostFumigant | | |
| Blueberry | Strawberry | 140 | 0 | 60 | 20 | 0 | 0 |

| Field | Crop | May 17,2021 Root-lesion | May 17,2021 Pin | May 17,2021 Knot | Oct 4,2021 Root-lesion | Oct 4,2021 Pin | Oct 4,2021 Knot |
|---|---|---|---|---|---|---|---|
| CM-1 | Oats/clover | 200 | 0 | | 180 | 160 | |
| CM-2 | Oats/clover | 940 | 0 | | 900 | 20 | |
| CM-3 | Strawberry | 1660 | 1460 | | 400 | 1280 | |
| CM-4 | CFPM | 280 | 0 | | 140 | 80 | |
| CM-S | Mustard/oats | 700 | 0 | | 520 | 0 | |
| CM-6 | Mustard/oats | 1600 | 20 | | 800 | 140 | |
| Field | Crop | Oct 26,2021 -PreFumigant | | | Nov 15,2021-PostFumigant | | |
| Beside Hill | | 1200 | 20 | 60(Dagger) | 40 | | 20 |
| By SprayTank | | 120 | | 180(Knot) | 20 | 0 | 0 |
| Raspberry | | 180 | | | 220 | 0 | 0 |

## Appendix Table 6: Verticillium sp. qPCR Results Summary All Years All Berry Sites

**Verticillium qPCR results**

Organism(s): Verticillium dahliae, Verticillium albo-atrum

*cells per gram soil estimate based on known DNA size of V. dahliae

| Client ID | *V. dahliae* DNA ng/g soil | *V. dahliae* cells per gram soil* | *V. albo-strum* DNA ng/g soil | *V. albo-strum* cells per gram soil* | *V. dahliae* DNA **ng/g** soil | *V. dahliae* cells per gram soil* | *V. olbo-atrum* DNA **ng/g** soil | *V. olbo-atrum* cells per **gram** | 2021 Crop | *V. dahliae* DNA **ng/g** soil | *V. dahliae* cells per **gram soils** | *V. albo-strum* DNA **ng/g** soil | *V. albo-strum* cells per **gram soil*** | *V. dahliae* DNA **ng/g** soil | *V. dahliae* cells per **gram soil*** | *V. albo-atrum* DNA **ng/g** soil | *V. albo-atrum* cells per **gram soil*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Date: | 5-Jun-20 | | 28-Oct-20 | | | | | | | 18-May-21 | | | | 5-Oct 21 | | | |
| CM1 | 0.035 | 958 | 0 | 0 | *0* | *0* | *0* | *0* | Oats/clover | 0.000 | 0 | 0.000 | 0 | 0.011 | 291 | 0.000 | 0 |
| CM2 | 0.01 | 261 | 0 | 0 | *0* | *0* | *0* | *0* | Oats/clover | 0.000 | 0 | 0.000 | 0 | 0.020 | 548 | 0.000 | 0 |
| CM-3 | | | | | *0.093* | 2555 | *0* | *0* | Strawberry | 0.000 | 0 | 0.000 | 0 | 0.071 | 1935 | 0.000 | 0 |
| CM-4 | | | | | | | | | CFPM | 0.000 | 0 | 0.000 | 0 | 0.017 | 455 | 0.000 | 0 |
| CM-5 | | | | | | | | | Mustard/oats | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 |
| CM-6 | | | | | | | | | Mustard/oats | 0.000 | 0 | 0.000 | 0 | 0.129 | 3547 | 0.000 | 0 |
| | | | | | | | | | | | | | | **Oct 26,2021 -PreFumigant** | | | |
| | | | | | | | | | | | | | By Spray Tanks | 0.000 | 0 | 0.000 | 0 |
| | | | | | | | | | | | | | Beside Hill | 0.000 | 0 | 0.000 | 0 |
| | | | | | | | | | | | | | Raspberry | 0.000 | 0 | 0.000 | 0 |
| | | | | | | | | | | | | | | **Nov 15,2021-PostFumigant** | | | |
| | | | | | | | | | | | | | Beside Hill | 0.000 | 0 | 0.000 | 0 |
| | | | | | | | | | | | | | Sprayer | 0.000 | 0 | 0.000 | 0 |
| | | | | | | | | | | | | | Raspberry | 0.000 | 0 | 0.000 | 0 |

## Appendix Table 7: 2021 Soil Health, Verticillium dahliae and Root-lesion Nematode Summary

| DATE_RECD | FIELD_ID | Date | %SAND | %SILT | %CLAY | TEXTURE | OM | ACTIVE_C | RESPIRATION | AG_STABILITY | BNA | pH | P_INDEX | C:NRATIO | %C | %N | *V. dahliae* cells/gram soil* | | Root-lesion/kg of soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May 17 &18, 2021 | Spring | | | | | | | | | | | | | | | | | | |
| | Sept. 29 & Oct 5, 2021 | Fall | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | spring | fall | spring | fall |
| 5-May-21 | Cbell Mid 1 Caliente | Spring | 22.6 | 59.9 | 17.5 | Silt Loam | 3 | 349 | 0.36 | 27.1 | 19.7 | 6.4 | 14.62 | 9.16 | 1.74 | 0.19 | 4,497 | | 2560 | |
| 4-Oct-21 | CbellMid1 Caliente | Fall | 25.8 | 55.7 | 18.5 | Silt Loam | 3 | 403 | 0.47 | 34.6 | 25.5 | 6.2 | 15.51 | 8.29 | 1.74 | 0.21 | | 4,436 | | 20 |
| 5-May-21 | Cbell Mid 2-CFPM | Spring | 23.5 | 60.1 | 16.4 | Silt Loam | 2.6 | 467 | 0.32 | 26.9 | 18.1 | 6.4 | 18.17 | 8.39 | 1.51 | 0.18 | 7,524 | | 560 | |
| 4-Oct-21 | CbellMid2-CFPM | Fall | 21.6 | 59.3 | 19.1 | Silt Loam | 2.6 | 358 | 0.42 | 25 | 23.4 | 6 | 15.6 | 7.95 | 1.51 | 0.19 | | 5,654 | | 40 |
| | | | | | | | | | | | | | | | | | | | | |
| 5-May-21 | Home 8 8- CFPM | Spring | 18.1 | 63.4 | 18.5 | Silt Loam | 4.8 | 585 | 0.41 | 28.6 | 23.7 | 6 | 8.06 | 11.12 | 2.78 | 0.25 | 1,424 | | 5120 | |
| 4-Oct-21 | Home 8 8- CFPM | Fall | 20.7 | 59.2 | 20.2 | Silt Loam | 4.7 | 591 | 0.47 | 26.4 | 44.2 | 6.1 | 6.53 | 9.75 | 2.73 | 0.28 | | 2,834 | | 280 |
| 5-May-21 | Home 8 11 Caliente | Spring | 17.6 | 63.1 | 19.2 | Silt Loam | 4.7 | 569 | 0.4 | 27.9 | 29.4 | 6.1 | 10.02 | 10.5 | 2.73 | 0.26 | 981 | | 2680 | |
| 4-Oct-21 | Home 8 11 Caliente | Fall | 18.7 | 61.3 | 20 | Silt Loam | 4.4 | 601 | 0.51 | 26.6 | 34 | 6.1 | 11.39 | 9.11 | 2.55 | 0.28 | | 2,671 | | 960 |
| | | | | | | | | | | | | | | | | | | | | |
| 4-Oct-21 | Max 1 | Fall | 25.4 | 57.7 | 16.9 | Silt Loam | 4.7 | 489 | 0.54 | 47.2 | 19.5 | 6.2 | 6.87 | 9.41 | 2.73 | 0.29 | | 40,988 | na | 620 |
| 4-Oct-21 | Max 2 | Fall | 21.9 | 58.6 | 19.5 | Silt Loam | 4.9 | 548 | 0.43 | 49.1 | 29.2 | 6.5 | 6.29 | 9.16 | 2.84 | 0.31 | | 12,454 | na | 120 |
| | | | | | | | | | | | | | | | | | | | | |
| 4-Oct-21 | HW 1 | Fall | 26.4 | 53.7 | 19.9 | Silt Loam | 4.3 | 460 | 0.4 | 26.4 | 6.4 | 6.4 | 8.52 | 9.58 | 2.49 | 0.26 | | 18,283 | | 340 |
| 4-Oct-21 | HW 2 | Fall | 25.8 | 55.3 | 18.9 | Silt Loam | 4.8 | 503 | 0.67 | 35.9 | 31.9 | 7.1 | 5.18 | 10.69 | 2.78 | 0.26 | | 29,022 | | 1300 |
| 4-Oct-21 | HW 3 | Fall | 23.7 | 55.4 | 20.9 | Silt Loam | 4.9 | 471 | 0.62 | 39.6 | 24.9 | 6.1 | 7.45 | 10.14 | 2.84 | 0.28 | | 26,496 | | 300 |
| 4-Oct-21 | HW 4 | Fall | 24.3 | 56 | 19.7 | Silt Loam | 5.3 | 508 | 0.49 | 46.5 | 33.5 | 6.5 | 6.82 | 10.96 | 3.07 | 0.28 | | 26,852 | | 360 |

## Appendix Table 8: 2021 Soil Health, Verticillium dahliae and Root-lesion Nematode Summary

| FIELD_ID | %SAND | %SILT | %CLAY | TEXTURE | OM | ACTIVE_C | RESPIRATION | AG_STABILITY | BNA | pH | P_INDEX | C:NRATIO | %C | %N | | Sample Date: Oct 5,2021 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | Root-lesion /kg of Dried Soil | Root-lesion/kg of Dried Soil | V. dahliae cells pergram soil* | | Soil Health Date |
| CM 4 | 25.7 | 57 | 17.3 | Silt Loam | 4.8 | 715 | 0.52 | 50.8 | 28.7 | 6.2 | 15.6 | 10.3 | 2.78 | 0.27 | CM-4 | 280 | | 0 | | May 17,20 |
| CM-4 | 36.2 | 46.6 | 17.2 | Loam | 4.9 | 569 | 0.5 | 52.9 | 49.4 | 5.9 | 15 | 11.36 | 2.84 | 0.25 | | | 140 | 455 | | Oct 4,2021 |
| CM 5 | 27.2 | 55.1 | 17.7 | Silt Loam | 4.6 | 678 | 0.51 | 61 | 29.3 | 6.1 | 15.7 | 9.89 | 2.67 | 0.27 | CM-5 | 700 | | 0 | | May 17,20 |
| CM-5 | 35.7 | 50.3 | 14 | Silt Loam | 5.4 | 612 | 0.7 | 65.5 | 45.2 | 6 | 16.9 | 11.59 | 3.13 | 0.27 | | | 520 | 0 | | Oct 4,2021 |
| **Average:** | **31.2** | **52.25** | **16.55** | | **4.925** | **643.5** | **0.5575** | **57.55** | **38.15** | **6.05** | **15.8** | **10.785** | **2.855** | **0.265** | | **Oct 26,2021 - PreFumigant** | **Nov 15,2021- PostFumigant** | **Oct 26,2021 - PreFumigant** | **Nov 15,2021- PostFumigant** | |
| Beside Hill | 70.9 | 19.1 | 10 | Sandy Loa | 3.6 | 541 | 0.57 | 69.5 | 21.8 | 6.5 | 6.4 | 13.06 | 2.09 | 0.16 | Beside Hill | 1200 | 40 | 0 | 0 | Oct 28,202 |
| Spray Tank | 68.8 | 21.7 | 9.6 | Sandy Loa | 2.8 | 369 | 0.45 | 76.8 | 27.3 | 5.6 | 1.89 | 10.12 | 1.62 | 0.16 | By Spray Tanks | 120 | 20 | 0 | 0 | Oct 7,2021 |
| Raspberry | 73.7 | 18.2 | 8 | Sandy Loa | 4.2 | 498 | 0.81 | 88.3 | 29.9 | 4.9 | 15.9 | 11.62 | 2.44 | 0.21 | Raspberry | 180 | 220 | 0 | 0 | Oct 28,202 |

**Appendix Figures 1: C1920-0201-Y3 Demonstrate Bio-fumigants as a Control of Nematode and Verticillium in Potatoes and Strawberries**

Carpenter Home 8

Carpenter HW & Maxine

Carpenter Campbell

McIntosh Strawberry

Sunset U-pick Strawberry

# Appendix Figures 2; CLIMATE FIELDVIEW Image Summary

Geo-referenced Sample Locations

May 14, 2021

2021
Field Health
540
Area (%)
High Biomass
32.4%
9.7%
27.6%
30.3%
0%
Low Biomass
540
True Color
Recenter
Region
Google
Map data ©2022 Imagery ©2022 , CNES / Airbus, Maxar Technologies, USDA Farm Service Agency
Terms of Use
Report a map error

July 13, 2021


2021
Field Health
540
Area (%)
High
Biomass
29.1%
10.8%
29.6%
30.6%
0%
Low
Biomass
540
True Color
Recenter
Region
Google
Map data ©2022 Imagery ©2022 , CNES / Airbus, Maxar Technologies, USDA Farm Service Agency
Terms of Use
Report a map error

July 23, 2021


2021
Field Health
540
Area (%)
High Biomass
0%
33.7%
33.9%
32.4%
0%
Low Biomass
540
True Color
Recenter
Region
Google
Map data ©2022 Imagery ©2022 , CNES / Airbus, Maxar Technologies, USDA Farm Service Agency
Terms of Use
Report a map error

Aug 14, 2021

2021
Field Health
540
High Biomass
Area (%)
0%
39.2%
31.6%
14.9%
14.2%
Low Biomass
540
True Color
Recenter
Region
Google
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Sept. 8, 2021


2021
Field Health
540
Area (%)
High Biomass
9.7%
30.5%
26.8%
33%
0%
Low Biomass
540
True Color
Recenter
Region
Google
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Sept.21, 2021


2021
Field Health
540
Area (%)
High Biomass
0%
24.6%
36%
7.3%
32.1%
Low Biomass
540
True Color
Recenter
Region
Google
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Oct.11, 2021

2021
Field Health
540
Area (%)
High Biomass
0%
31.1%
33%
35.9%
0%
Low Biomass
540
True Color
Recenter
Region
Google
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