



Nematode Management Strategies: Grower Support for Nematode Control

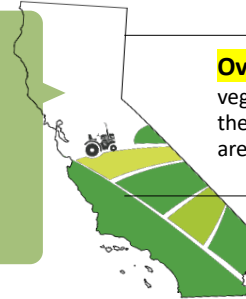
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FOOD SECURITY - Significance & Equity

CALIFORNIA is the #1 agricultural state in the nation.

Over a 1/3 of the country's vegetables and nearly 3/4 of the country's fruits and nuts are grown in California.



California is the sole producer (99 percent or more) of the following commodities: almonds, artichokes, celery, garlic, grapes, raisins, kiwifruit, melons, honeydew, nectarines, olives, peaches, pistachios, plums, walnuts

(Source: CDFA California Agricultural Statistics Review 2021-2022)

KEY PLANT PARASITIC NEMATODES (PPNs) IMPACTING AGRICULTURAL CROP PRODUCTION

PPNs seriously threaten the safety of crop and agriculture

Can result in **yield losses of 20% in a single crop** and **cost an estimated \$125 billion worth of crop losses globally each year**

What are the most economically important PPNs, and why?

- World wide distribution, extremely wide host range, their intricate relationship with host plants, and level of damage ensued by their feeding
- Limitations on the use of chemical pesticides have brought increasing interest in studies on alternative methods of nematode control.



★ **Root-knot**
Meloidogyne spp.

Root Lesion
Pratylenchus spp.

Ring
Criconebella spp.



Plant Parasitic Nematodes (PPN) Impacting California Agriculture

Fruits, nuts and vegetables continue as the state's leading crops and accounts for **56%** of the nation's non-citrus fruit and nut production and over **46%** of the nation's citrus production

The total value of all fruits and nuts produced in California roughly \$19.7 billion

Plant-parasitic nematodes affect ~35% of almond and stone fruit acreage (McKenry)



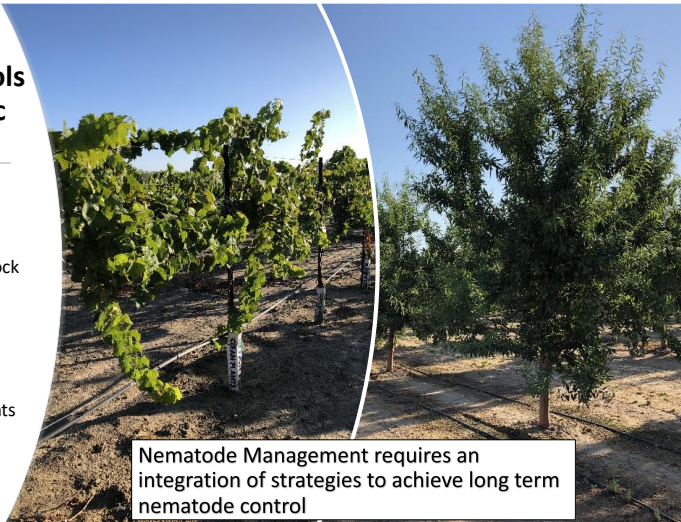
Integrated Pest Management Tools for Plant Parasitic Nematodes

Pre-plant measures:

- History of site, **soil sampling** to identify key PPNs, sanitation, rootstock selection (resistant or tolerant), fallow, crop rotation, **fumigation**

Post-plant measures:

- Sanitation, soil treatments (**contact nematicides**), symptoms (foliar and root), **soil sampling for diagnosis**



Nematode Management requires an integration of strategies to achieve long term nematode control

WHY ARE PLANT PARASITIC NEMATODES SUCH A BIG PROBLEM?

Determining if **nematodes** are involved in a plant growth issue is difficult because few nematodes cause distinctive diagnostic symptoms



Significant damage is below ground, give rise to nonspecific symptoms (general decline, stunting, poor plant growth), their presence frequently ignored

Sound diagnosis should be based on these key factors:

Foliar symptoms

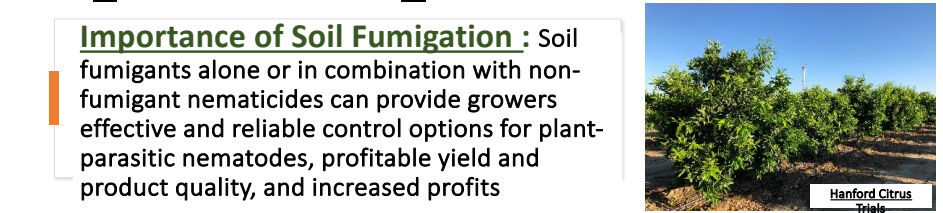
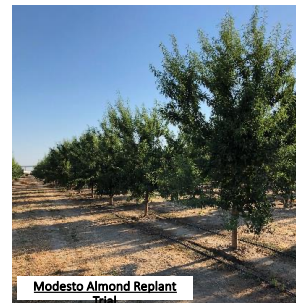
Root Symptoms

Field History

Laboratory Analysis

Provide valuable clues to the identity of nematode and other pest problems-previous crop, susceptibility?

Collection of plant roots and soil is required to confirm the presence of nematodes



TRICAL
DIAGNOSTICS
NEMATOLOGY
PROGRAM:
HELPING GROWERS
DIAGNOSE
NEMATODE ISSUES

To make management decisions, it is critical to know what plant parasitic nematodes are present and population estimates

★ Soil Sampling is Key!

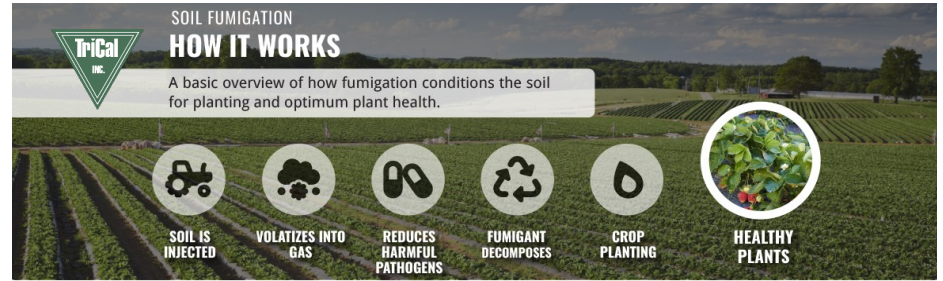
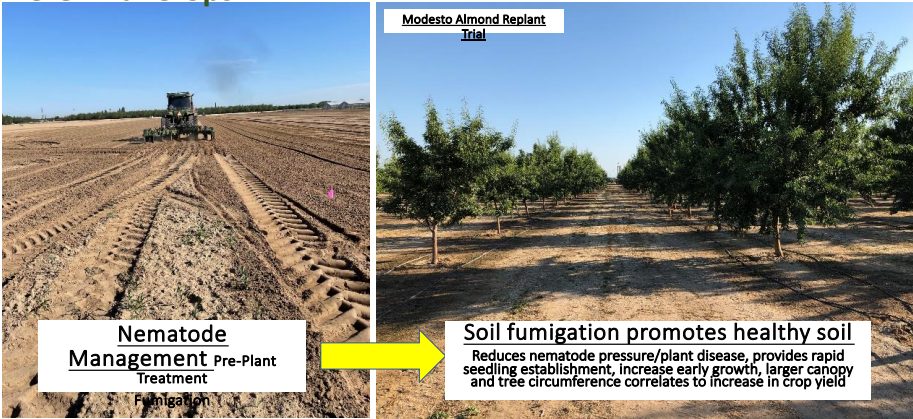
- The # of nematodes in the soil analysis can give some indication about the damage potential
- If nematode pest is detected and replanting orchard with tolerant or susceptible rootstock it is important to **fumigate!**

Pre Treatment: Soil fumigation is a key management tool for growers to reduce nematode populations to a level where serious crop damage will not result.



Importance of Soil Fumigation : Soil fumigants alone or in combination with non-fumigant nematicides can provide growers effective and reliable control options for plant-parasitic nematodes, profitable yield and product quality, and increased profits

Nematode Management: Pre-Plant Control is Vital for Perennial Crops



A basic overview of how fumigation conditions the soil for planting and optimum plant health.

1. Fumigants are injected as liquids into the soil to control harmful insects, nematodes, weeds, bacteria, fungi, and diseases that have invaded a field.
2. The fumigant volatizes into gas diffusing through the soil air space, radiating out from the points of injection.
3. The treatment significantly reduces the harmful pathogens and rebalances the native beneficial soil microbe population, conditioning it for planting.
4. The fumigant decomposes rapidly in the soil; and some fumigants, like Chloropicrin, actually biodegrade into plant nutrients.
5. Crop planting takes place in the newly conditioned soil.
6. Healthy plants are able to maximize their water and nutrient use and grow to full yield potential with no uptake of fumigant into the plant root or residue on the plant.

TriCal: IMPORTANCE OF FUMIGATION



Fumigated orchard soil:

- Rapid seedling establishment
- Increases early growth
- Earlier and larger yields
- Increases orchard longevity



Non-fumigated orchard soil:

- Slower seedling establishment
- Sluggish early growth
- Delayed and smaller yields
- Shorter orchard longevity

FUMIGATION HELPS MANAGE A BROAD SPECTRUM OF SOIL-BORNE PATHOGENS:



TRICLOR™



- ✓ Prunus Replant Disorder
- ✓ Nematodes
- ✓ Phytophthora
- ✓ Root Rot

CO-APPLICATION



- ✓ Telone is the industry standard pre-plant nematocidal.
- ✓ TriClor is the industry standard fungicide.
- ✓ Products can be co-applied or as a stand alone.

TELONE II

- ✓ Nematode control and Prunus Replant Disease mitigation
- ✓ Greater crop uniformity leading to more efficient use of fertilizer and water
- ✓ Greater production



Agriculture Division of DowDuPont™

TriCal/TCD Nematology Program R&D Field Trials

Helping growers diagnose nematode issues and provide support on IPM decisions.

- Pre-plant measures
- Fumigation
- Post plant treatment, nematicides

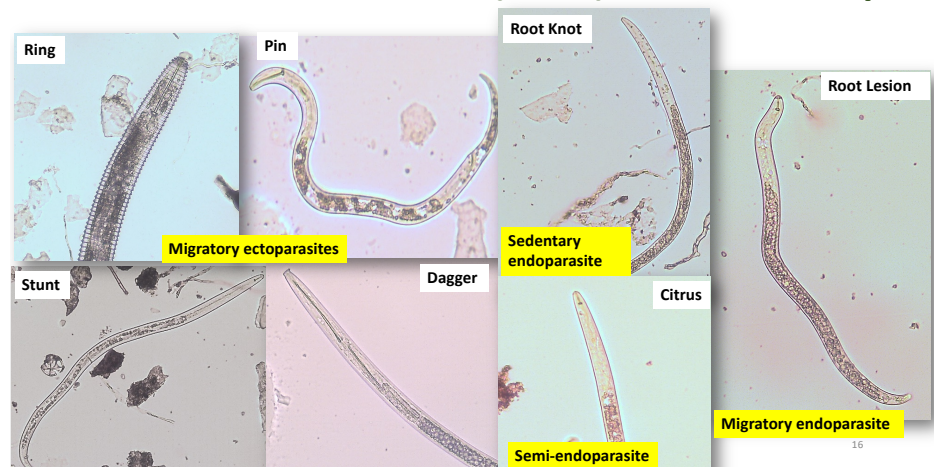
Established multiyear field trials evaluating the performance of **Telone-1,3D** and **Chloropicrin** on key perennial crops

- Walnut, Almond, Grape, Citrus, Peach

Conduct thorough investigation on plant parasitic nematode (PPN) evaluations pre/post fumigation, post planting through the seasons to determine nematicidal efficacy of the fumigants/nematicides and monitor tree growth



Plant Parasitic Nematodes (PPNs) that infect crops

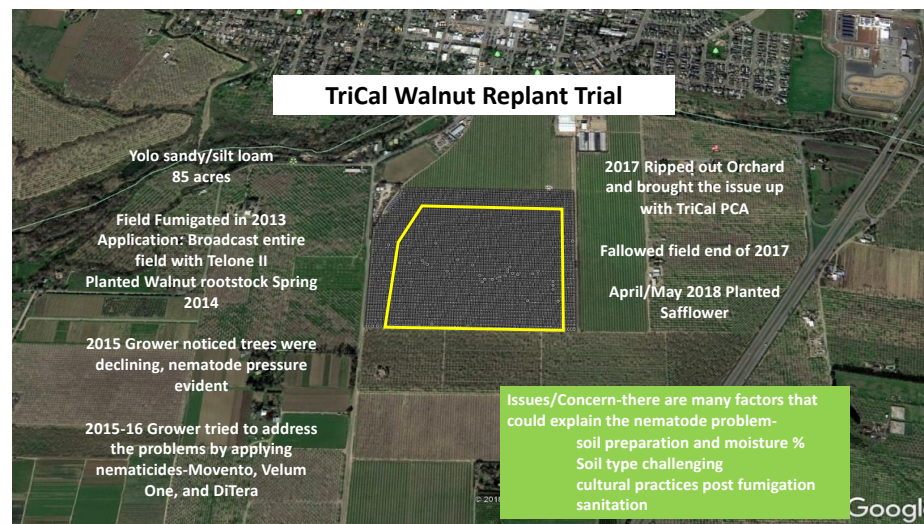


COMMON MISCONCEPTION: SOIL FUMIGATION KILLS EVERYTHING IN THE SOIL

FALSE

- Pre-Plant Soil Fumigation resets the soil microbiology, creating competition for different organisms and creates positive soil biome shifts, not decimation.

- Pre-Plant Soil Fumigation is specific reduces the bad and increases the good.
- Saprophytic bacteria and fungi, which live off non-living, decaying organic matter, increase after fumigation. Saprophytes play major roles in soil nutrient cycles, and also support soil structure, promote plant growth and are involved in natural, biological control of some soil-borne pathogens.



Treatments

Trt 1: Grower Standard Walnut Replant Trial: Fumigated Fall 2018 for Orchards

Non-tarped Broadcast
John Deere (18" inj. depth)
1.3D @ 33.7 GPA (max rate)

Trt 2: Replant Disorder Treatment (all non-tarped)

Non-tarped, John Deere (18" inj. depth)
Broadcast 1.3D @ 33.7 GPA, plus
Strip (tree row) PIC @ 200 lbs/acre

Trt 3: Replant Disorder Treatment (non-tarped but with tree-row strip tarp)

John Deere (18")
Non-tarped, broadcast 1.3D @ 33.7 GPA,
co-applied PIC @ 200 lbs/acre at 18" with
TIF strip down tree row

Trt 4: Replant Disorder Treatment (broadcast tarped)

John Deere (18" inj. depth)
Broadcast 1.3D @ 33.7 GPA, plus
Strip-applied (tree row) PIC @ 200 lbs/acre,
Broadcast TIF

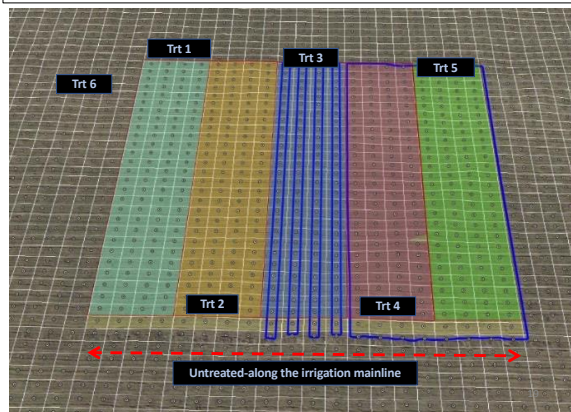
Trt 5: The "Armillaria treatment"

John Deere, non-tarped, 18", broadcast
co-application of 1.3D @ 33.7 GPA and
PIC @ 200 lbs/acre, followed by Cat DAE, PIC at
150 lbs/acre at 12", broadcast TIF

Trt 6: McKenry Recommendation

Non-tarped, broadcast
1.3D @ 33.7 GPA
Bussing shank: split depth at 18-in and 36-in

A demo replant trial was installed to evaluate 6 different one-acre fumigation treatments in 2018.



ROOT LESION NEMATODE: MIGRATORY ENDOPARASITIC



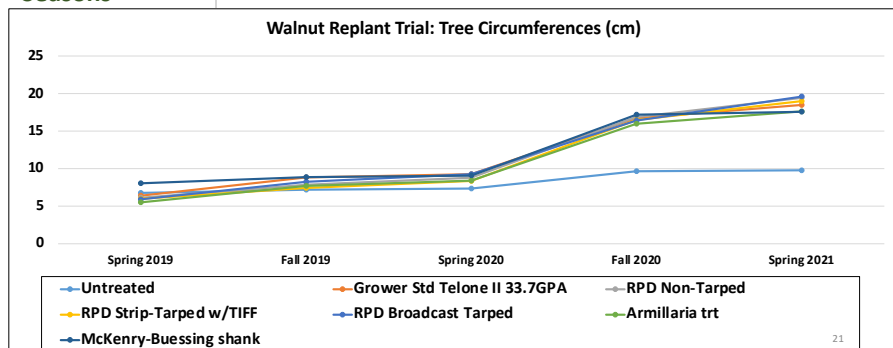
Root lesion nematode roughly 1/64 inch (0.5 mm) long.



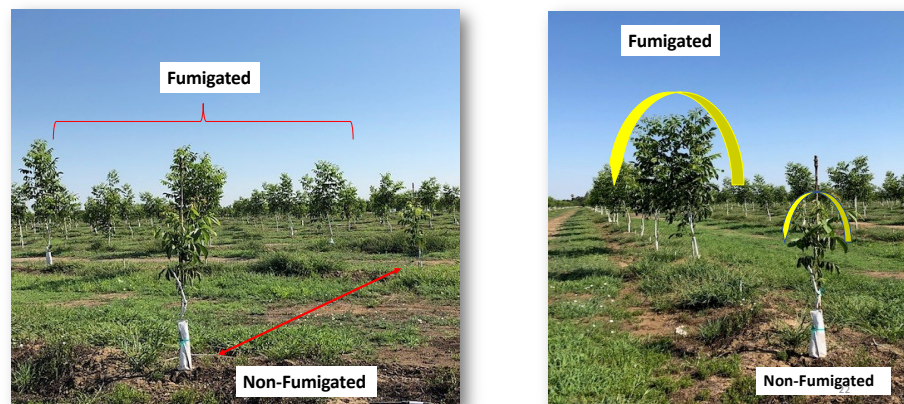
In California, root lesion nematode is wide-spread in walnut producing areas, estimated to be present in roughly 85% of walnut orchards

Walnut Replant Trial: Monitor Tree Growth Through the Seasons

- All fumigant treatments displayed significantly greater growth rates compared to Untreated
 - No substantial growth differences between fumigant treatments
- Spring 2021:** The fumigant treatments demonstrated **80-85% increase** in tree growth (cm) compared to untreated control

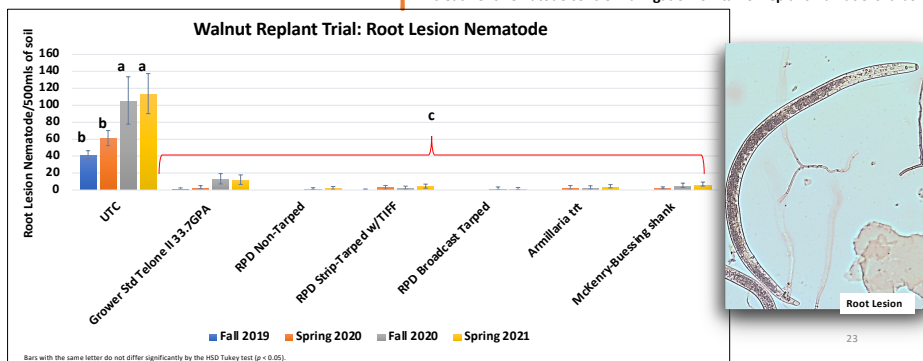


Walnut Replant Trial: Observed Tree Growth Differences (Spring 2020)



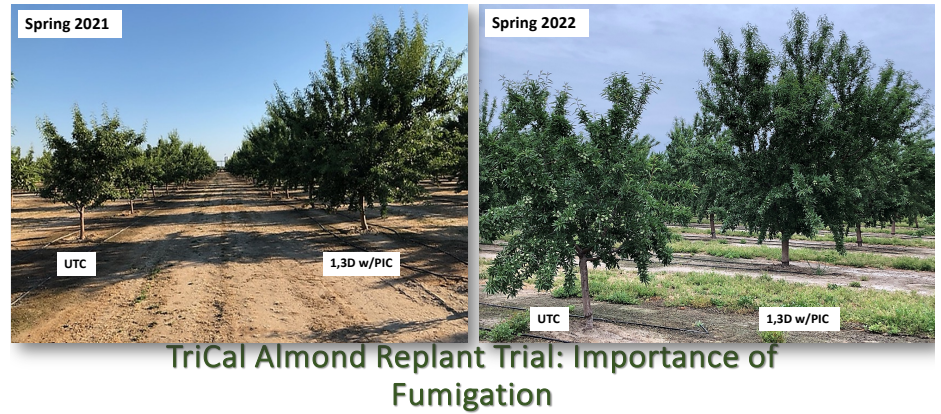
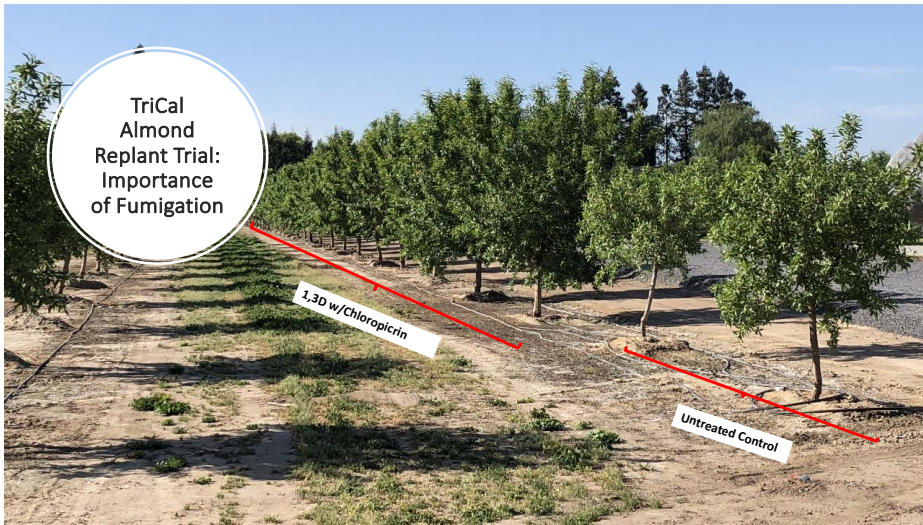
TriCal Walnut Replant Trial: Evaluate Root Lesion Nematode Through the Seasons

- 45 DAT and Spring 2019 (post fumigation):** root lesion was not detected in the fumigant treatments
- UTC:** Fall and Spring seasons illustrate an increase in root lesion juveniles and adults (*P. vulnus* & *P. thorneii*)
- Fumigant treatments continue to demonstrate consistent trend in **root lesion suppression through the seasons**
- The data we have collected over 3 yrs highlights the importance of pre-treatment nematode control: fumigation is vital for replant walnut orchards



What we've learned from this trial

- Soil preparation is key for successful fumigant application:** Break up heavy soil textured clods after tilling, can hold moisture, harbor root lesion, and prevent fumigant penetration
- Soil moisture:** Heavier soils that hold moisture pose problems, if moisture is too high fumigation will not be as effective
- RL dispersal/movement/sanitation:** root lesion can move by field equipment/tools, soil from one field to another, wind, water, and nematode infested plant material
- ★ **Walnut rootstock (VX211) source of re-infection:** documented and PCR confirmed the presence of *P. vulnus* and *P. thorneii* recovered from the rootstock tissue (**30% infection rate**)



1,3D with Chloropicrin demonstrated **33% increase in tree growth** compared to untreated control. Increase in tree circumference correlates to larger canopies as we see in fumigated trees vs nonfumigated trees.

➤ Showcases early root establishment, early growth, larger and fully canopies compared to untreated trees. 26

Non-fumigant Nematicides

Non-fumigant nematicides are nonvolatile toxic chemicals that can be applied prior to planting, at planting, or after planting through soil drenching, drip irrigation, or spraying onto the crop foliage to reduce population densities of nematodes and protect crops from damage



These products are grouped into 2 categories:

- Contact nematicides: killing nematodes in the soil by direct exposure
- Systemic: killing nematodes while they feed from plant roots

When applied to the soil, non-fumigant compounds are dispersed by movement in soil water.

Vydate® L
INSECTICIDE/NEMATICIDE

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| Trade Name | Active Ingredient | Toxic Activity | Manufacturer |
|-------------------|-------------------|------------------------|--|
| Vydate (L, C, LV) | Oxamyl | Nematicide/Insecticide | Corteva Agriscience™, Agriculture Division of DowDuPont™ |
| Nimitz | Fluensulfone | Nematicide | Adama |
| Velum Prime | Fluopyram | Nematicide/Fungicide | Bayer CropScience |
| Mocap 15G | Ethoprop | Nematicide/Insecticide | AMVAC Chemical Corporation |
| Mocap EC | Ethoprop | Nematicide/Insecticide | AMVAC Chemical Corporation |
| Movento | Spirotetramat | Nematicide/Insecticide | Bayer CropScience |
| Counter 20G | Terbufos | Nematicide/Insecticide | AMVAC Chemical Corporation |
| Salibro** | Fluazaindolizine | Nematicide | Corteva Agriscience™, Agriculture Division of DowDuPont™ |

Nematode Integrated Management Program:
Trial research examining long term nematode suppression through the seasons

A management program providing key solutions for growers: Pre/post treatment applied at an early stage in plant growth will help offer additional crop protection, promote root health, offer time for young trees to establish, and most importantly providing sustainability for growers.

TriCal Walnut Replant Trial (Winters, Ca): Investigate management solutions for growers

Root lesion nematode, *Pratylenchus vulnus*

Trial highlights how critical pre-treatment fumigation is for walnut replants, the difficulty of eliminating a PPN once it is established in a field and the importance of providing integration of strategies to maintain suppression

- Spring 20-21: showed significant reduction in root lesion pressure across all fumigant and nematode management program treatments compared to UTC
- Spring 22: UTC showed substantial increase in root lesion density 2 years post
 - All treatments continue to demonstrate significant decrease vs untreated, especially nematode management program of Telone + Salibro compared to competitor product Velum One

TriCal Walnut Replant Trial: Root Lesion Nematode Pressure

| Treatment | Spring 2020 | Spring 2021 | Spring 2022 |
|-------------------------------|-------------|-------------|-------------|
| Grower Std + Salibro 2lbs/ac | ~10 | ~10 | ~10 |
| Grower Std + Velum One | ~10 | ~10 | ~10 |
| McKenry-Telone II Bueasing... | ~10 | ~10 | ~10 |
| RPD Telone+TriClor@200lbs | ~10 | ~10 | ~10 |
| Grower Std-Telone @ 33.7GPA | ~10 | ~10 | ~10 |
| Untreated | ~10 | ~10 | ~180* |



TriCal TriClor Peach Trial (Turlock, CA): Evaluate Nematode Management Program

Spring 20-22: Observed significant increase in tree growth and durable suppression of PPNs among TriClor alone and the management program vs untreated and nematocide alone

TriCal Peach Trial (Turlock, Ca): Average Total PPN Pressure

| Treatment | Spring 2021 | Spring 2022 |
|-------------------------|-------------|-------------|
| Untreated | ~200 (bc) | ~750 (a) |
| TriClor | ~150 (c) | ~450 (b) |
| TriClor + Movento/Velum | ~100 (c) | ~350 (bc) |
| Movento/Velum | ~100 (c) | ~450 (ab) |

TRICLOR PEACH REPLANT TRIAL (TURLOCK, CA) SPRING 2022 UPDATE

- Multi-year trial was established in Fall 2019 to evaluate performance of TriClor and to examine nematode management program for growers (post plant nematicides-Velum One/Movento)
 - Collaboration with Bayer CropScience
- Fumigant treatment: TriClor 200 lbs/ac tarped with TIF, treated 10.5 ac (17.9 ft rows)
- Conducted pre/post fumigation nematode evaluation over 5 seasons:
 - Pre fumigation-detected moderate pressure of root knot, root lesion, stunt, and stubby root-key pests of stone fruits



THANK YOU!