5TH INTERNATIONAL STRAWBERRY CONGRESS

Wednesday

Parallel Session 2: Integrated Pest Management

Sustainable soil fumigation

Program over 3 years with Nemasol™ (metam-sodium 510 g/l) on strawberry in Huelva, Spain

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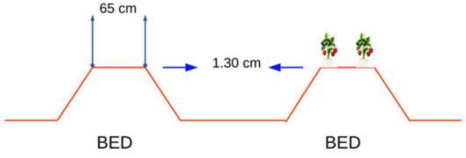
Why this study? Context and objectives

Strawberry cultivation in Huelva

- Total surface area: 6.295 ha, employed workforce: 160.000 people, regional GDP:11%
- Intensive monoculture system
  - No rotation possible (economic constraints and polyphagous pests)
  - Dependence on soil disinfestation



EU fumigant restrictions

- 1,3-dichloropropene, chloropicrine
- Limitations of use for MITC generators (3 years, dose)

Need for durable solution

- Test the efficacy of Nemasol over 3 years, with and without post-planting nematicides and biological agents
- Assess the impact on yield
- Evaluate soil food-web resilience

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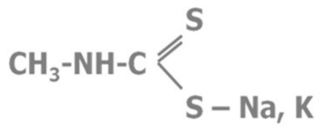
Nemasol™ active ingredient



metam *sodium, potassium*

Application in soil

Chemigation

Soil injection

Soil incorporation

Start decomposing in methyl-isothiocyanate (MITC)

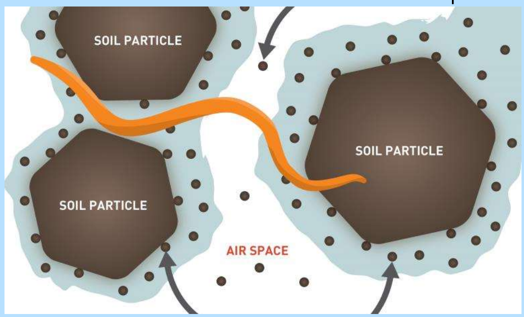
metam *methyl isothiocyanate*

300 L/ha 86 kg/ha

MITC is highly soluble in water and is present in the 3 phases of the soil matrix: soil - air - water

- MITC is the major gaseous active metam decomposition product
- MITC shows solubility and volatility characteristics suitable for soil disinfectant purposes exploiting the porosity of the soil
- A large part of MITC in soil is in the form of solution in water
- MITC movement/diffusion in soil operates mainly with water

MITC in soil air phase



MITC adsorbed on soil particles

MITC in soil water solution

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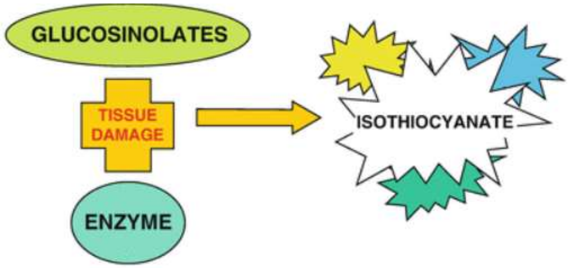
Nemasol - technology inspired by nature

The real active ingredient of Nemasol (metam sodium 510 g/l) is methyl isothiocyanate (MITC). MITC is a compound present in nature.

In nature, glucosinolates (GLSs) are metabolites of plants in the order Brassicales and the family Capparaceae, which are stored in the S-cells' vacuoles. After plant tissue damage, the enzyme myrosinase stored in contiguous cells is released. When plant cells are ruptured, the GSLs and myrosinase come into contact and are hydrolyzed in the presence of water to release various products, including isothiocyanate (ITC)
(Vig et al., 2009). ITCs have a wide range of biocidal characteristics and are acutely toxic to a variety of pests and pathogens (Chew, 1987*)*.



Some commonly used biofumigant crops and their respective GSLs and ITCs

Common name	Glucosinolates	Isothiocyanate
Brown mustard (*Brassica juncea*)	Sinigrin	2-propenyl-ITC (= allyl-ITC)
White mustard (*Sinapis alba*)	Sinalbin	4-hydroxybenzyl-ITC
Radish (*Raphanus sativus*)	Glucoraphenin	4-methylsulfinyl-3-butenyl--ITC
Rocket (*Eruca sativa*)	Glucoerucin	4-methylthiobutyl-ITC
Caper (*Capparis spinosa*)	Glucocapparin	Methyl-ITC

MITC has broad-spectrum activity on weed seeds, fungi and nematodes

Control of fungi

Control of weeds

Control of nematodes

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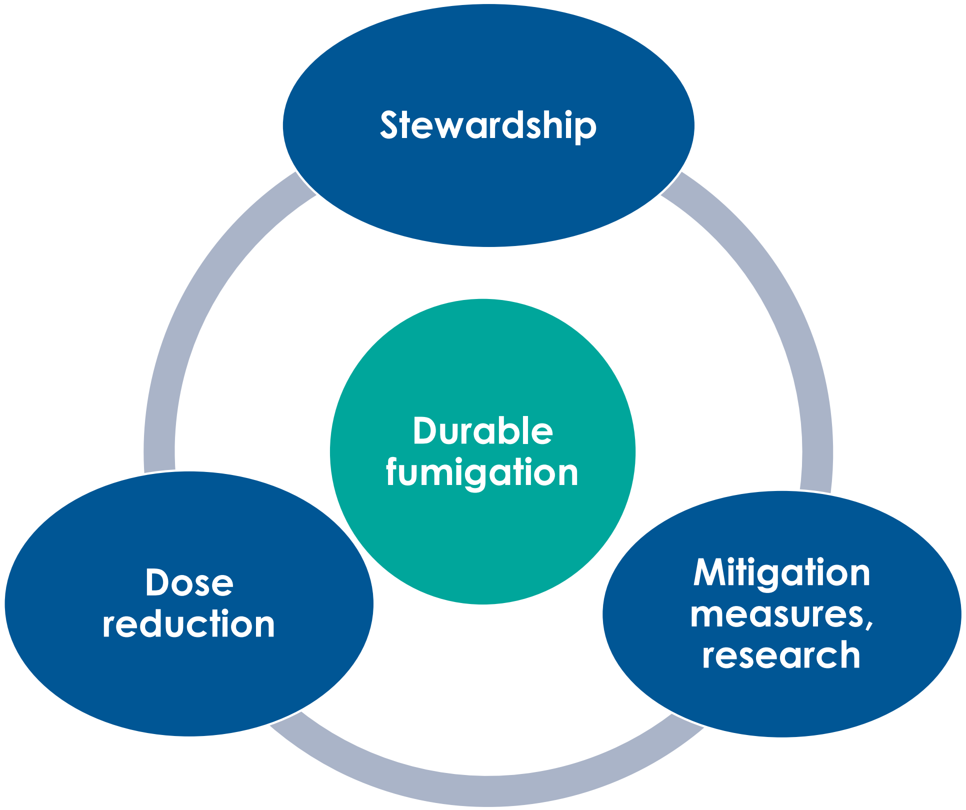
Durable fumigation



BENEFITS:

- **For the grower:** cost effectiveness, soil fertility restoration, more safety with stewardship programs
- **For the community:** contribution to sustainable food production, no residues, soil conservation

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Experimental design

Programs over 3 years, in experimental farm of IFAPA El Cebollar (Huelva)

TREATMENTS		2023/24	2024/25	2025/26
Control		-	-	-
Nematicide + biologicals in post-planting		V + Bio	Cedroz + Bio	V + Bio
MeNa 300 L	**alone**	MeNa 300	-	-
	+ nematicide + biologicals post-planting	MeNa 300 + V + Bio	Cedroz + Bio	Herbie 5000 kg/ha in August + Cedroz
MeNa 150 L	**alone**	MeNa 150	-	-
	+ nematicide + biologicals post-planting	MeNa 150 + V + Bio	Cedroz + Bio	Herbie 5000 kg/ha in August + Cedroz

Application of fumigant under TIF on 15 September 2023
Planting of var. ‘Rociera’ on 20 October
Pre- and post-planting treatments with V (Velum) x2
Post planting treatments with Bio (*Bacillus* + *Trichoderma*) x6

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Samplings and assessments

Soil samples at P0, Pi and Pf

- Abundance and biomass of nematodes (*Pratylenchus penetrans*, free living nematodes), identification
- *Macrophomina phaseolina* (sclerotia /g soil), *Trichoderma* and *Fusarium* spp. (CFU/g soil)

Nematode-based indices

- Trophic network (CI, BI, EI, SI)
- Maturity indices (Mi, MI 2-5, ∑MI, PPI)
- Analysis of trophic roles

Henderson-Tilton efficacy

Weekly harvest, vigor, weeds

Yield

- Cumulated early and final yield (g/plant)

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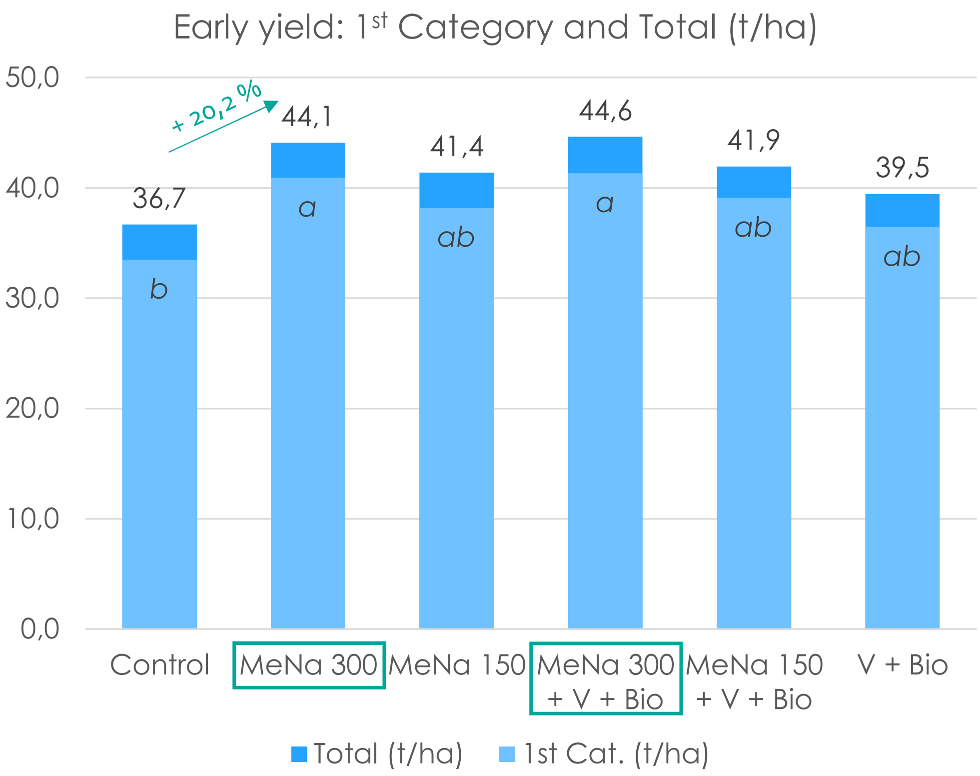
Early yield



Early harvests from 15 January to 2 April 2024

- Significant differences between treatments were observed. MeNa 300 and MeNa 300 + V + Bio yielded significantly more than the Control
- The application of V + Bio after the MeNa treatment did not significantly improve yields
- No significant differences were detected in the percentages of second-category produce

MeNa 300 and MeNa 300 + V + Bio produced statistically significant increases in early harvest of 20.2% and 22.5%, respectively

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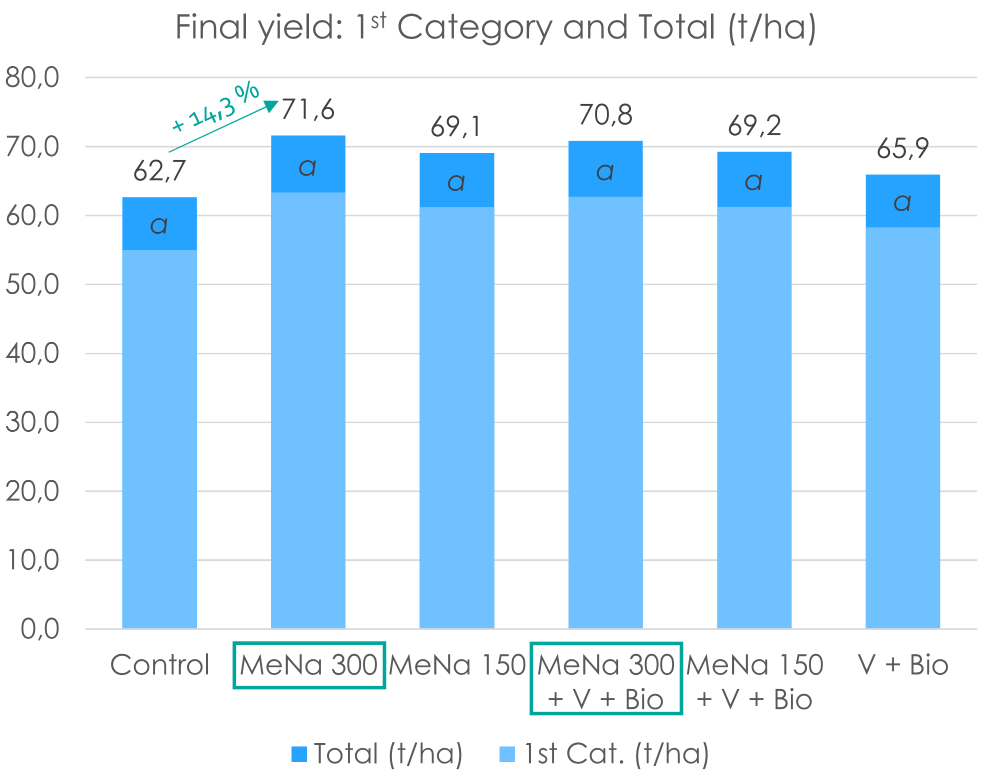
Final yield



Total cumulated yield up 21st May 2024

- No significant differences were observed between treatments
- Numerical increases were observed compared to the untreated control in all treatments. The treatments MeNa 300 (14,3%), MeNa 300 + V + Bio (14%), and MeNa 150 + V + BIOC (approximately 11%) stand out
- No significant differences were detected in the percentages of second-category produce

MeNa 300 and MeNa 150, with or without V + Bio, produced numerical increases in total production over the full season of 11–14%

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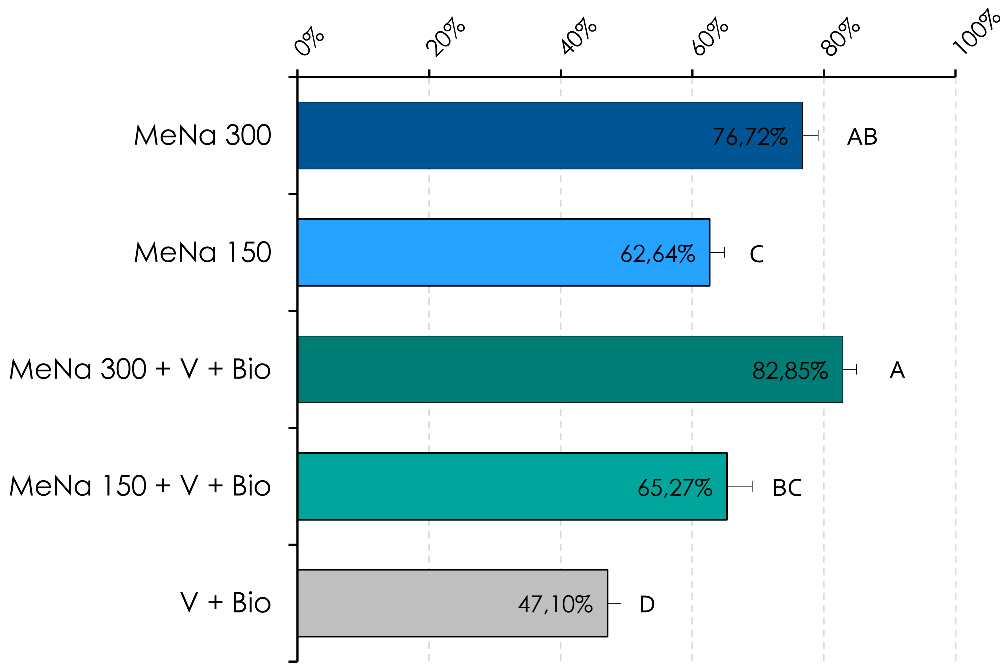
Plant-parasitic nematode control

P. penetrans **Henderson-Tilton Nematicidal Efficacy**



Count of *P. penetrans* /250g soil	P0	Pi	Pf
Control	66	46	243
MetamNa300	44	8	149
MetamNa150	49	14	154
MetamNa300+Velum+Bio	44	5	131
MetamNa150+Velum+Bio	57	14	184
Velum+Bio	61	26	212

Pratylenchus penetrans **was the sole plant-parasitic nematode identified in the soil samples.**

- The abundance (nematodes per 250 g of soil) decreased in all treatments between P0 (52 ± 4) and Pi (25 ± 3). It increased significantly in all treatments at Pf (172 ± 18) following nematode's reproduction in the roots of the crop.
- The combination MeNa 300 + V + Bio was the most effective in reducing populations of P. penetrans (83%), comparable to the treatment with only MeNa 300 (77%).
- MeNa 300 was more effective (77%) than MeNa 150 (62%), while the treatment V + Bio was the least efficient (47%)

MeNa 300 was the main effective treatment; adding V + Bio did not produce a statistically significant incremental effect (trend)

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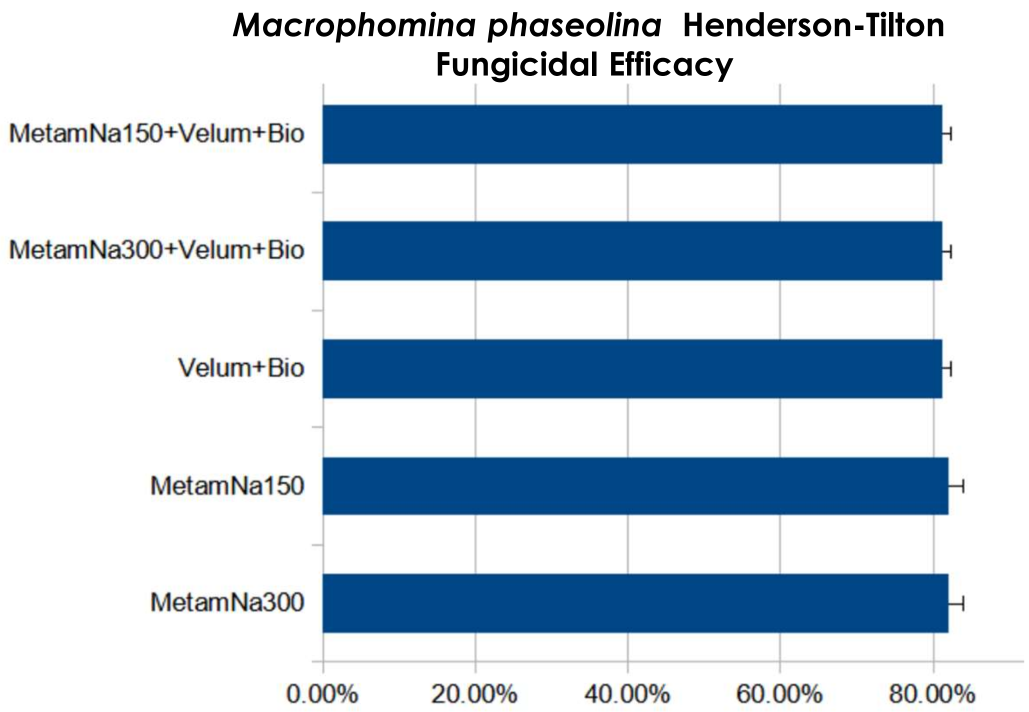
Soil diseases control



***Macrophomina phaseolina* (Charcoal Rot)**

- Population density (sclerotia per g of soil) slightly decreased between sampling time P0 (0.7 ± 0.2) and Pf (0.44 ± 0.17)
- All treatments reduced the population density by ~80%, with no significant differences between them

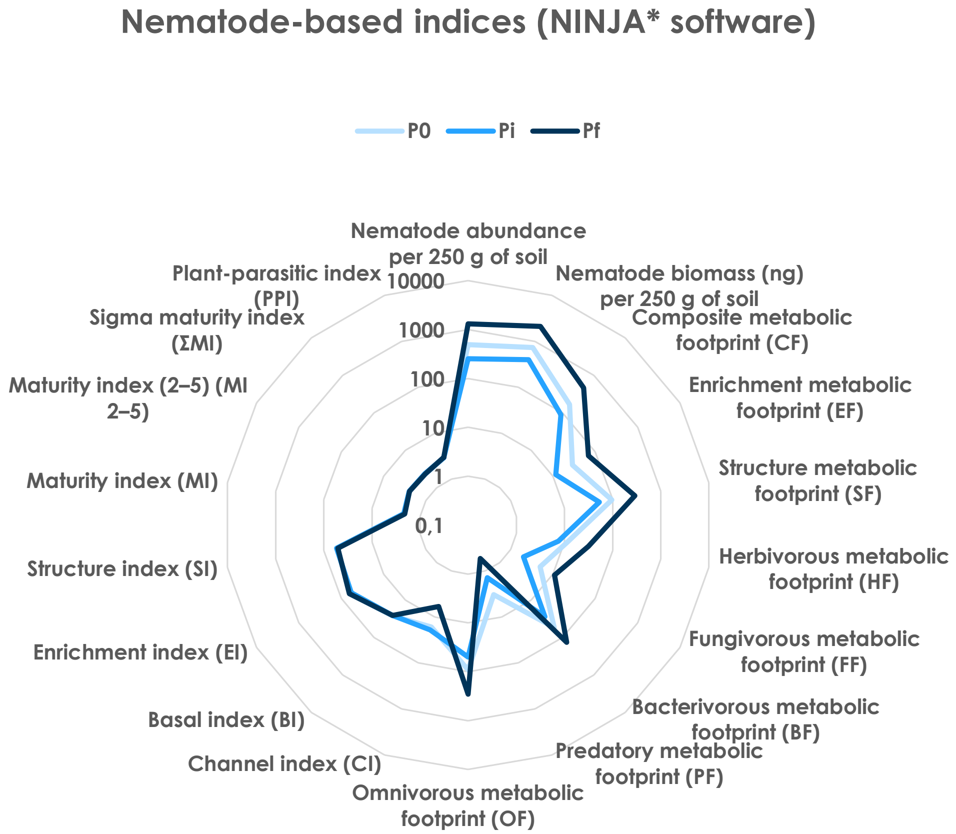
***Fusarium spp.* (Wilt, Root Rot)**

- The effectiveness of the treatments in controlling *Fusarium* populations was lower, between 67% (V + Bio) and 76% (MeNa 300)

Overall, the addition of microorganisms did not improve the effectiveness of the fumigant treatment.

MeNa 300 provided 76-80% control of main soil diseases. The addition of Bio did not improve the effectiveness

Soil food-web status (nematode indices) - Control



Temporal variations of nematode-based indices during the strawberry crop

- Nematode abundance, biomass, and metabolic footprint decreased from P0 to Pi, then increased significantly by Pf
- No significant differences were found among sampling times (P0, Pi, Pf) for the trophic-network indices (CI, BI, EI, SI) or in the maturity indices (Mi, MI 2-5, ∑MI, PPI)

Effects of treatments on nematode-based indices

- The treatment V + Bio reduced the enrichment (23.19 ± 7.89) and fungivore metabolic footprints (4.56 ± 1.32) and increased the herbivore metabolic footprint (22.00 ± 4.10) compared to the untreated control (EF: 45.18 ± 10.58, FF: 7.60 ± 1.93 and HF: 14.05 ± 3.60, respectively).

MeNa’s effects on bacterivorous and fungivorous nematodes persist for less time than those from V+Bio, implying a briefer disturbance to soil community structure.

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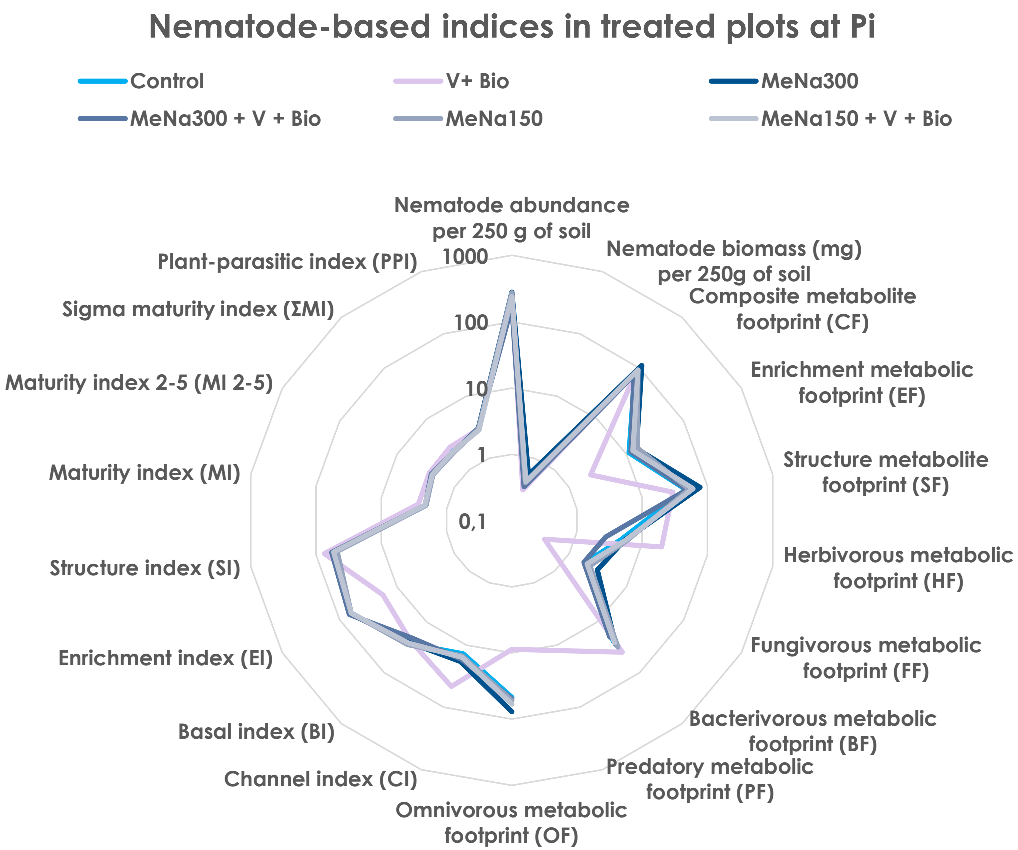
* Nematode Indicator Joint Analysis (NINJA)

Soil food-web status (nematode indices) - Pi



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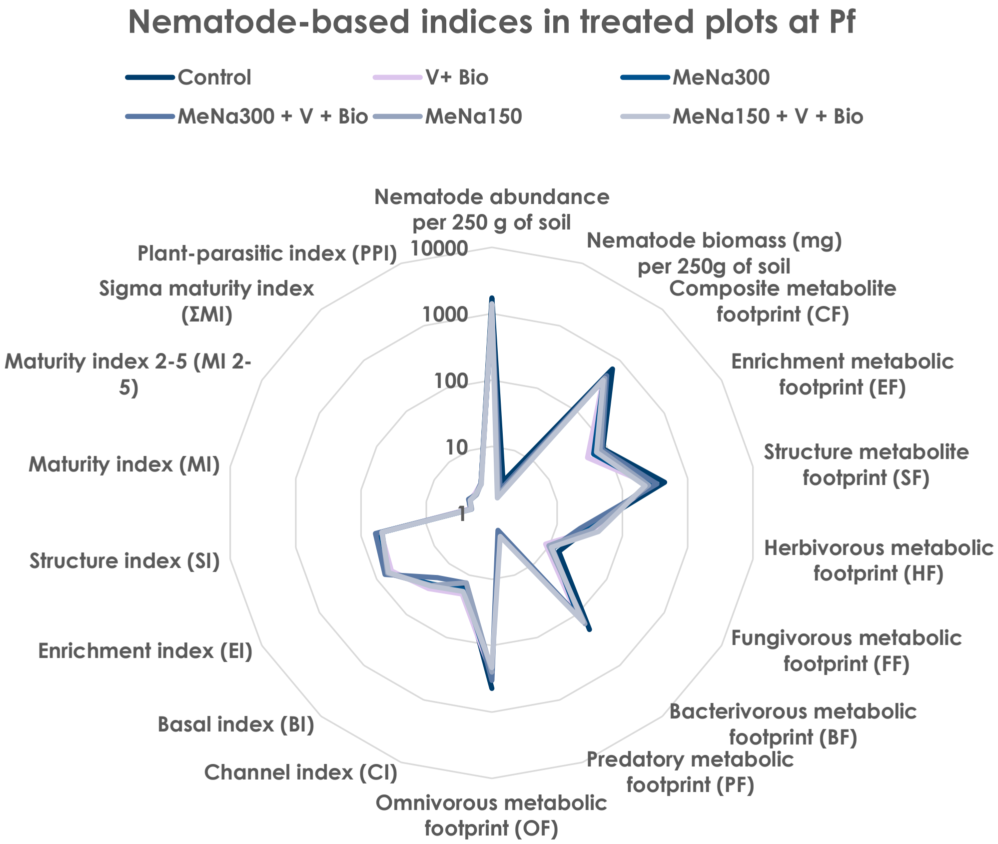
Soil food-web status (nematode indices) - Pf



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Take-home message

Efficacy

- MeNa under TIF provides effective control of soil-borne diseases and plant-parasitic nematodes and delivers early yield gains

Integrated Program

- MeNa at reduced dose of 300 $L \cdot ha^{-1}$ is a good alternative for soil disinfestation in South Spain strawberry cultivation conditions
- The addition of microorganisms did not bring consistent added value on top of MeNa in this 1st year of study

Soil resilience

- MeNa complies with the durable fumigation program designed to minimize persistent non-target impacts

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Conclusions

Limitations

- Single season, single site, initial pathogen pressure

Outlook

- Planned multi-cycle assessment
- Preliminary results from Year-2 confirm performance of MeNa 300 / 150

Overall conclusion

- MeNa 300 is a good alternative for soil disinfestation in South Spain strawberry cultivation conditions
- The post-planting nematicide and microorganisms did not guarantee a sufficient level of control
- The application of microorganisms did not improve the efficacy of the fumigant treatment

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Thank you.

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