## IMPACT: SOIL BIOLOGICAL QUALITY

### Reference 3

### Background and objective

Agricultural practices significantly affect soil biodiversity and functions, altering biogeochemical cycles and potentially compromising food production. Increased employment of sustainable agricultural practices is of growing policy concern and requires a better understanding and quantification of how agriculture affects soil functioning. Quantify the effect of agricultural practices on soil nematodes, known to be key biological indicators of soil health. This meta-analysis summarized the effects of tillage, pesticides use, fertilization, manipulation of above-ground plant including cover crop, rotation and agricultural system shift (the conversion from the conventional to conservation or organic agriculture systems). Here we report only the results regarding the conversion of conventional systems to organic.

### Search strategy and selection criteria

The authors conducted a literature search, last updated in October 2019, using the Web of Science (Thomson Reuters) search engine. Studies investigating the effect of agricultural practices on soil nematodes. Studies should include nematode data and evaluate the effects of at least one of the four main agricultural practices (manipulation of plant diversity, pesticide use, tillage, fertilization) or those of different types of agricultural systems ("system") on the nematode community. Here we report only data regarding organic farming systems as compared to conventional systems. (1) Data should be available in the articles either in table or in graphical forms. In the case of graphics, the programme GetData Graph Digitizer (version 2.26 http://getdata-graph-digitizer.com/), was used to extract data from figures. (2) Nematode data should be a measurement of the abundance of nematode trophic groups, that is bacterial feeding (BF), fungal feeding (FF), omnivores and predators (OP) and plant feeding nematodes (PF), and/or nematode diversity and/or nematode indices. Diversity indices were taxonomic richness (S) and Shannon diversity (H'). Nematode indices were the maturity index (MI), plant-parasitic index (PPI), structure index (SI), enrichment index (EI), and nematode channel ratio (NCR). Studies had to report at least one of the abovementioned nematode parameters to be included in this synthesis. (3) Studies needed to evaluate the effect of the conversion of conventional agriculture to organic agriculture. Conventional systems use pesticide, mineral fertilizers and tillage. Organic agriculture does not use synthetic pesticide and mineral fertilizers. Tillage is used for weed management. (4) The samples should be collected from the topsoil layer (soil depth between 0 and 30 cm maximum). (5) Studies needed to report means ($\overline{X}$), standard deviations (SD) or standard errors (SE) and sample size (n, number of true replications) of nematode variables in control and treatment groups. When SD, SE or sample size were missing, articles were discarded as these data are required to compute the effect size. A total of 103 articles, i.e. 30% of articles, met these inclusion criteria and were used in the meta-analysis, corresponding to a total of 1338 unique observations (control + treatment, Fig. 2).

### Data and analysis

The authors used a multilevel meta-analysis model (mixed model) run with the "rma.mv" function from the Metafor package (Viechtbauer, 2010). The model was fed calculated effect sizes and sampling variances (as described above) and fitted via restricted maximum-likelihood estimation. As we obtained multiple effect size values per study (e.g., several sampling dates), we used a mixed model with "study identification" (study ID) as a random factor to take into account the dependencies among estimates from the same study. To estimate the overall effect of agricultural practices on nematode variables under investigation, we first ran a random-effects model without any moderator variables. The responses of the nematode community parameters were statistically significant if the 95% confidence intervals of the agricultural effects did not overlap zero.

| Number of papers | Population | Intervention | Comparator | Outcome | Quality score |
|---|---|---|---|---|---|
| 12 | Not specified | Organic systems | Conventional | Metric: Soil nematodes: 1) Total density; 2) Abundance of bacterial feeders; 3) Abundance of fungal feeders; 4) Abundance of omnivore-predators; 5) Abundance of plant feeders; 6) Taxonomy richness; 7) Shannon diversity index; 8) Maturity index; 9) Plant parasite index; 10) Nematode channel ratio; 11) Enrichment index; 12) Structure index; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control | 93.75 |

### Results

- Converting conventional to organic agriculture was found to have a profound effect on soil nematodes. Organic agricultural systems improved nematode abundance, irrespective of trophic groups.
- Organic agricultural systems induced higher absolute abundance in total nematodes (+33%) and bacterial feeders (+52.8%), but with no effect on nematode diversity and richness.
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### Factors influencing effect sizes

- Fertilisation : The supply of mineral fertilizers did not significantly affect the absolute abundance of soil nematodes not the absolute abundance of the trophic groups but it marginally reduced taxonomic richness, diversity and food web stability (S: 7.2%, H': 3.7% and MI: 7.7%, respectively. the application of organic fertilizers strongly enhanced the total abundance of nematodes (+69.8%), originating from the increase abundance of all trophic group, although not significant for plant-feeding nematodes. The amount of organic fertilizer significantly changed the effect of organic fertilization on nematode parameters,

such as omnivore-predator abundance. Organic fertilization also promoted taxonomic diversity (+8.7%), but induced a significant decrease in the maturity index (−6.5%). Similar patterns were observed when inorganic and organic fertilizers were applied together.

- Diversification strategies : A key result from our statistical analysis was a significant reduction in the absolute abundance of plant feeders (PF, −47.2%) without impacting the total abundance or the abundance of other trophic groups, when a rotation of more than 2 years was applied. This negative effect of rotation on the abundance of plant feeders increased with the duration of the experiment. Rotation also promoted taxonomic richness (+19.3%), the maturity index (+20.3%), enrichment index (+47.0%) and abundance of omnivore-predators (+55.8%, although not significant), while slightly reducing the plant parasitic index (−5.2%). he negative effect of rotation on the abundance of plant-feeding nematodes was more pronounced in soils with higher soil carbon content. We also found positive effects of cover crop on the total nematode abundance (+45.3%), bacterial-feeders (BF, +101.0%) and PF (+79.6%) abundances. In contrast, no effect of plant association on nematode parameters was found, except a slight decrease in community maturity (−10.3%), but this effect appeared transitory and decreased with the experiment duration. Additionally, the introduction of legumes (Fabaceae) to the cropping system was not found to be a significant moderator.

- Pesticides use : No significant global effects of herbicides on the different soil nematode community parameters (except a slight decreasing effect on EI - 5%. In contrast, biocides or nematicides had similar deleterious effects on soil nematodes. Biocides significantly reduced the absolute abundance of nematodes, especially fungal feeders (−52.6%), as well as nematode richness and diversity (S: 7.5%, H': 6.5%), but slightly increased the plant parasite index (+0.7%). The use of nematicides also affected nematodes at the community level by decreasing the total abundance of nematodes (−32.1%), plant feeders (−70.2%), taxonomic richness (−16.6%) and the food web structure (−22.6%, but Rosenberger's number = 14, indicating possible publication bias for these effect sizes).

- Tillage : Tillage affected soil nematodes to a lesser extent than 2 other type of practices: managing plant diversity and fertilization. Notably, the absolute abundance of omnivore-predators was significantly reduced by conventional tillage (−14.4%), especially when the initial nematode abundance was high. The maturity and structure of the nematode community were reduced by tillage (−15.1% and −26.2%, respectively) while BF and fungal-feeder nematodes (FF) were not significantly impacted by tillage. The effects of conventional and conservation tillage on soil nematode were similar except for the abundance of omnivore-predators and SI.

## Conclusion

Organic agricultural systems improved nematode abundance, irrespective of trophic groups.