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Are there alternatives to chemical soil fumigation?

The use of chemical soil fumigation is being questioned in Europe. In various places, research is being carried out into alternative ways to disinfect the soil and into other ways to ensure the better growth of trees planted in soil previously occupied by related species.

Every fruit grower knows that fruit trees planted in soil where fruit trees have been planted before, will grow less vigorously than trees planted in soil that has never had fruit trees in it. Because fruit growers nowadays tend to grub up their orchards more quickly and replant them, and because trees are planted in exactly the same place due to the presence of, for instance, the hail net construction, it is more often the case that trees grow poorly. There are various causes for soil exhaustion or Specific Apple Replant Disease (SARD) and the situation is not yet completely clear. What is certain is that there are multiple causes. In addition to nematodes (in particular *Pratylenchus penetrans*), soil fungi and bacteria (such as *Phytophthora, Pythium, Penicillium, Pseudomonas* and actinomycetes) play a role in soil exhaustion. These saprophytic organisms can damage or inhibit the growth of the young plant roots.

On the plots where chemical soil fumigation was used, the trees grew most vigorously. *EFM*

Wide diversity of preparations

There are theoretically various options to 'control' the hazardous fungi. Heating the soil (steaming) to a temperature in excess of 90°C kills most fungi and bacteria. However, in an orchard this is hardly a feasible option and (too) expensive.
Another way of killing hazardous fungi, but also nematodes, in the soil is by using biofumigation. Cruciferae crops such as mustard or rapeseed contain glucosinolates which, after being shredded, release isothiocyanate, a soil disinfectant.
A third possibility is to use antagonist micro-organisms, for example *Bacillus subtilis, Pseudomonas fluorescens, Trichoderma spp and Streptomyces spp*. These fungi establish themselves in the soil and prevent the hazardous micro-organisms from doing their job. The problem is that these substances do not work when the soil is already exhausted. The preparations must be used preventively.
Mycorrhiza fungi have a somewhat more indirect action on soil exhaustion. These fungi promote the growth of plant roots and by doing so should ensure that the trees are less bothered by soil exhaustion.
Both antagonists and mycorrhiza can be bought in various preparations. The problem is that there are hardly any trials that clearly prove that these preparations are effective. Fortunately, trials are being done in several locations to establish the effectiveness of a large number of them.

Nematodes and soil exhaustion

The idea that fungi play a role in soil exhaustion is not very old. However, it has been known for a long time that nematodes are a possible cause. Nematodes are in particular found in lighter soils and they are responsible for trees growing poorly. They are rather easy to control using chemical soil fumigation. However, the use of chemical soil fumigation is being questioned in many countries. Alternatives are being sought in various places, however, it seems that it is not easy to match its effectiveness.

Extensive trial started

On the request of and financed by the Dutch ministry of Agriculture, Nature and Food Quality, the 'Praktijkonderzoek Plant & Omgeving' (PPO) research institute carried out research into alternative ways of reducing soil exhaustion on sandy soils. Various methods were compared to standard chemical soil fumigation (see Trial involving seven treatments).
Soil samples showed that traditional chemical soil fumigation killed by far the most nematodes in the soil (see Figure 1). Sowing Tagetes also resulted in effective nematode control. This was also the case for the trial where first Tagetes was sown, then the plants were worked into the soil and then the soil was covered by plastic. The other treatments (black fallow, organic soil disinfection using *Avena strigosa* (Lopsided Oat or

Trees growing too weakly in the untreated block (black fallow).

Sowing Tagetes considerably reduced the number of nematodes in the soil.

Trial involving seven treatments

In 2007, PPO trialled seven different treatments on a 1-hectare plot of sandy soil. The objective was to identify ways of reducing soil exhaustion. The trial is made up of five repetitive trial blocks (plots of 9 by 20 metres) on a site where five-year old apple trees (Topaz) had been grubbed up in the spring of 2007. The trees were grubbed because they were no longer growing due to a serious nematode infection. In the spring of 2009, apple trees (Elstar and Red Boskoop) were planted to be able to determine the effects of soil disinfection on growth and the number of fruit.

In 2007, the following treatments were performed:

1. **Untreated control**. The weeds were continually removed (black fallow).
2. **Chemical soil fumigation** using metam-natrium (Monam, active ingredient *methyl isothiocyanate*). The soil was disinfected in both 2007 and 2008. 750 litres per hectare were used. Costs approximately € 1,700.
3. **Growing African Marigold** (*Tagetes patula*). Between mid May and mid July, 6 kilos of seed were sown per hectare. When nematodes penetrate the Tagetes roots and then the cells, the plant responds by creating an ozone-like substance that kills nematodes. Costs approximately € 500.
4. **Organic soil disinfection**. In this block, per hectare 100 kilos of *Avena strigosa* cv. Pratex were sown. The plants were shredded in October, worked into the soil and then the soil was covered with plastic for fifteen weeks. The organic matter mixed with the soil (50 tonnes per hectare) decomposes. This extracts oxygen from the soil and releases substances that kill nematodes, soil fungi and some root weeds. Costs approximately € 4,250.
5. **African Marigolds plus organic soil disinfection**. Instead of using *Avena strigosa*, in this block, Tagetes were sown, the plants were worked into the soil and the soil covered with plastic. Costs approximately € 4,500.
6. **Biofumigation**. In this block, Sarepta mustard was sown, allowed to grow and then shredded and worked into the soil in the autumn. When the Sarepta mustard decomposes, gases are released (among others isothiocyanate) that kill soil fungi and nematodes. When biofumigation is used, the soil does not need to be covered with plastic. After working the organic matter into the soil, the plot is irrigated to start off the decomposition process. Costs approximately € 500.
7. **Compost**. The soil structure and the soil life improve by adding 50 tonnes of compost per hectare. Costs approximately € 2,000.

In 2008, the entire site was sown with *Avena strigosa*.

The trial site.

Bristle Oat) or biofumigation) were not effective or much less effective.

Growth

The growth of the trees was proportional to the level of nematode control achieved by the treatments. The trees in the soil where chemical soil fumigation was employed clearly grew the strongest in the second leaf. On the entire trial site, irrespective of the treatment given, the trees produced too little in the second leaf due to a disappointing fruit set. As a result, the trees in the chemically fumigated trial blocks probably grew too strongly. Whether this is the case shall become evident in the third or fourth leaf.
The trees in the trial blocks where Tagetes had been sown before the trees were planted grew clearly less strongly than the trees in the chemically fumigated block, however, they grew sufficiently well. Where the Tagetes was also worked into the soil and where the soil was then covered with plastic (organic soil disinfection), growth was stronger than in the block where Tagetes was just sown. In the trial fields where black fallow, organic soil disinfection or biofumigation was used, from the cultivation point of view, the trees probably grew too weakly.

Conclusions

Chemical soil fumigation clearly resulted in the best nematode control and the trees that grew most strongly (in the second leaf). Sowing Tagetes, whether or not worked into the soil that was then covered with plastic (organic disinfection), also resulted in trees that grew well, but somewhat less strongly than the trees in the chemically disinfected soil. The question is what is most desirable from the cultivation point of view. This will be shown in the coming years. Trees planted in a sandy soil that is infected by nematodes regularly continue to grow very weakly even after four or five years. A very good start (therefore with strong growth) can then be an advantage. However, if the nematode population remains small, somewhat weaker growth in the first and second leaf might be better. This is because it is known that when chemical soil fumigation is used, the nematode population can return to a high level once more after approximately two years. The expectation is that this will take about three to four years in a plot where Tagetes has been grown.

In this trial block, Tagetes was sown, the resulting plants were worked into the soil and then the soil was covered with plastic (organic soil disinfection).

Biofumigation using Sarepta mustard promoted instead of reduced the number of nematodes.

Figure 1. Number of Pratylenchus nematodes per 100 ml soil during sampling in March 2008