PLANT AND SOIL NEMATODES

SOIL FUMIGATION: DOES IT HAVE A FUTURE AS A NEMATODE CONTROL TACTIC?

Plant-parasitic nematodes affect the yield and quality of most of the food and fibre crops grown in Australia. A range of non-chemical measures have been developed to control these pests but many growers, particularly those in the vegetable industry, rely on nematicides. This fact sheet covers the soil fumigants while information on non-volatile nematicides can be found in Fact sheet PSN 007.

Soil fumigants

During the period from 1970 to 2000, soil fumigation was the primary nematode control strategy in vegetable crops and some perennial horticultural crops. 1,2-dibromo-3-chloropropane (DBCP) and ethylene dibromide (EDB) were commonly used but were deregistered in the 1980s and 90s because they contaminated groundwater and were carcinogenic. A broad-spectrum fumigant (methyl bromide) was also used against nematodes, but was phased from use in 2005 because it depleted the ozone layer.

In January 2023, only five fumigants were available for use in Australia: 1, 3 dichloropropene (1,3 D), ethanedinitrile (EDN), chloropicrin, metham sodium, and dazomet. 1,3D primarily acts against nematodes; EDN is also effective against plant-parasitic nematodes but is usually used when weeds or other soilborne pathogens are the primary problem; and chloropicrin is normally applied when soilborne fungi are being targeted. Metham sodium and dazomet both release methyl isothiocyanate (MIT), a chemical that is active against nematodes, fungi, and germinating weed seeds.

When the above chemicals are applied to soil, they convert to a volatile gas that diffuses through the soil's pore spaces and comes into contact with the pest. Dazomet is a granular product but the other chemicals are normally applied using specialised machinery that injects the chemical into the soil to the required depth. Although metham sodium is usually considered to be a fumigant, its breakdown product (MIT) does not move readily thorough soil in the gaseous phase. Consequently, it is often applied via trickle irrigation. Beds are pre-formed with plastic mulch and trickle tape and the soil is then wetted to allow weed seeds to germinate. Metham sodium is then injected into the mainline for long enough to ensure that the chemical is dispensed throughout the root zone.

Comparative studies in many countries have shown that from a nematode control perspective, fumigants consistently outperform non-volatile nematicides. However, the condition of the soil has major effects on fumigant efficacy, so it is important to understand the requirements for successful fumigation.

- At the time of application, soil must be moist to a depth of at least 30 cm. It must be free of clods and have no compacted layers. Residues from the previous crop should be removed or allowed to decompose, with any remaining residues thoroughly incorporated so that little or no crop residue is on the soil surface.
- Ideally, 1, 3 D should be applied at soil temperatures of 10-20°C, and should not be used at temperatures greater than 27°C. For metham sodium, soil temperatures can range from 10 to 32°C.
- Application rates for the above fumigants increase with the clay content of the soil. For 1, 3 D, 85-112 L/ha are applied to light-textured soils and up to 235 L/ha on heavier soils. Rates for metham sodium range from 250 L/ha for light soils to 700 L/ha for heavy soils. The appropriate label should be consulted for specific details.
- After application, the soil must be sealed immediately to prevent fumigant loss and ensure that an effective concentration of the chemical is maintained for several days.
    - For 1, 3 D, sealing is accomplished by uniformly mixing the soil to 8-10 cm to effectively eliminate chisel or plough spaces that may allow the fumigant to escape. To maximise sealing, the soil surface should be compacted with a roller.
    - When metham sodium is applied by soil injection, one or two light irrigations are also recommended to improve the seal.

- Once the soil is treated, it must be left undisturbed for at least 7 days and remain unplanted for at least 14 days (1, 3 D) or 21 days (metham sodium). Longer intervals are required if the soil is cold or wet, or where the soil has a heavy texture or high levels of organic matter. For metham sodium, an indicator crop such as lettuce or radish can be sown to indicate whether it is safe to plant.

Detailed information on application procedures for EDN is not available, as being a relatively new fumigant, only a limited amount of research has been undertaken and there relatively few reports in the peer-reviewed literature of its performance in the field. Nevertheless, a recent study showed that EDN controlled pathogenic fungi, plant-parasitic nematodes, and several weed species under controlled laboratory conditions (Thalavaiasundaram et al. 2023).

Dazomet has not been considered in this fact sheet because the purchasable product (Basamid™) is too expensive to use in most horticultural situations.

Off-target effects of soil fumigants

Growers considering a soil fumigation program need to understand that they are applying a chemical that not only kills pests and pathogens but also a huge range of beneficial organisms, including the natural enemies of the pests being controlled. Thus, a biological vacuum is being created and if the pest is reintroduced it will multiply quickly due to lack of competition. To avoid reinfestation of nematodes, soil or machinery that could harbour them should not be moved onto treated land, and infested planting material should never be used.

One thing that is clear from many years of research is that fumigation is detrimental to soil health. Soil contains a huge range of bacteria, fungi, protozoa, free-living nematodes, microarthropods and other microscopic organisms that regulate populations of plant-parasitic nematodes and other pests and pathogens, and also provide many important ecosystem services (e.g. improved soil structure and cycling of the nutrients required by plants). These organisms play a vital role in maintaining the health of a soil but they will be decimated when fumigants are applied.

A recent example from Florida provides an example of how soil fumigants are destroying the beneficial organisms that help keep plant-parasitic nematodes under control. In a double-cropping vegetable system, root-knot nematode damage to the second crop was consistently higher when chloropicrin was applied to the first crop. The effect was observed in seven out of ten field trials and was thought to be due to the detrimental effects of chloropicrin on the naturally occurring bacteria, fungi, and other organisms that partially suppress populations of the nematode (Desaeger and Bui, 2022).

Safety considerations

Fumigants are gases that may move off-site and produce adverse side effects that can persist for several days. Thus, it is important that safety measures are implemented so that handlers, re-entry workers and bystanders are protected when fumigants are applied. Growers using these chemicals should familiarise themselves with the requirements for soil preparation and sealing, and must implement the safety measures required by regulatory authorities.

The future

There are four reasons why the soil fumigants currently used in Australia may not be available in future.

- As mentioned previously, several soil fumigants have been phased out or removed from the market in the last 40 years due to unacceptable non-target toxicity or detrimental effects on the environment. It is likely that the remaining fumigants will eventually suffer the same fate.
- Many countries are introducing regulations that list a series of steps that must be taken to ensure safe and effective soil fumigation. Such regulations make fumigation more expensive and may prevent it being used in some circumstances.

- The European Union has decided to phase out the use of metham sodium because of its toxicity to humans and the environment, and the paucity of data on these potential impacts
- When metham sodium is applied repeatedly, its efficacy is markedly reduced because there is an increase in soil microorganisms that are capable of rapidly degrading the chemical. This process is known as enhanced biodegradation and has been reported in Australia (Matthiessen et al. (2004).

Given the above, growers currently using soil fumigants for nematode control need to look forward and develop integrated management programs that provide more sustainable methods of controlling these important pests.

Literature cited and further reading

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Note: The registration status of a pesticide may change, so anyone planning to use a fumigant or nematicide should check the Australian Pesticides and Veterinary Medicines Authority (APVMA) website and find out whether it is currently registered.

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