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Biofumigation to suppress pests, weeds and diseases

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Summary

- **Biofumigation is the suppression of soil-borne pests and pathogens by compounds emitted from brassica green manure crops macerated and incorporated into the soil.**
- **The most commonly grown biofumigant crops are Indian mustard, rocket and oil radish.**
- **Biofumigant crops can also improve soil quality and soil health, leading to yield benefits to following crops.**
- **Specific agronomy requirements are needed to maximise the benefits of biofumigant crops.**

Introduction

Soil-borne pests and pathogens, which include many nematode and fungal species, can be significant issues in crop production. With likely restrictions to, and loss of soil applied pesticides that have traditionally been used to manage soil-borne pests and diseases, attention in recent years been directed towards the development of new approaches that have broad efficacy and are suitable for use on a wide range of crops. One of these approaches is biofumigation, which relates to the suppression of soil-borne pests and pathogens by volatile compounds emitted from organic plant material. Biofumigation typically involves growing brassica green manure crops which are macerated and incorporated into the soil, and as the plant material breaks down it produces the volatiles that have biological activity against pests, pathogens and weeds.

There is strong evidence that biofumigation can reduce potato cyst nematode (PCN) populations by up to 70%, and limited evidence for suppression of free-living nematodes and spraing, powdery scab, black dot, Pythium, Rhizoctonia, Verticillium, Fusarium, Sclerotinia, and weeds.

In addition, biofumigant crops can improve soil fertility and structure; add nutrients and organic matter to the soil; improve soil aeration; increase water infiltration and holding capacity; reduce soil erosion from wind and water; increase soil biodiversity by stimulating the growth of beneficial microbes and other soil organisms; and lead to measurable yield increases in following crops.

There are a range of different biofumigant crop species available, with the most commonly grown being Indian mustard (*Brassica juncea*), rocket (*Eruca sativa)* and oil radish (*Raphanus sativus)*, although most of the research to date has focused on Indian mustard.

Choice of biofumigant crop

Indian mustard (Fig.1) is a summer crop, and as the biofumigant potential relies on achieving as much biomass as possible, growing it over the winter is not feasible, especially in Scotland. One of the potential drawbacks on using Indian mustard as a biofumigant crop is that it needs to be planted by mid-July to flower in good time, which does not allow much leeway within a typical Scottish crop rotation. The growing period is 8–14 weeks, with maceration and incorporation as they

Fig.1 Indian mustard © Matthew Back

The European Agricultural Fund for Rural Development
Europe investing in rural areas

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reach early to mid-flowering. This summer–autumn window enables a biofumigant crop access to long day lengths and high ultraviolet (UV) radiation, which is important for the production of the precursors to the toxic volatiles released on soil incorporation and for the production of maximum biofumigant biomass. This window also allows incorporation of biofumigant material into warm soils (>10°C), which helps toxic gases move through soil.

Fig. 2 Rocket © Matthew Back

If drilling is late, rocket (Fig. 2) rather than Indian mustard, or a combination of both biofumigants is recommended. Rocket matures more quickly than Indian mustard, although the penalty is lower biomass. Irrigation may be needed for crop establishment in this window. When mixing two different biofumigant crops, consider seed size as the seeds of rocket and Indian mustard can separate out in the drill.

In terms of efficacy against PCN, reductions in PCN populations is usually between 40–70%. This is however subject to best practice and favourable environmental conditions, which are outlined later in this Technical Note.

Autumn-established biofumigants for overwintering have lower potential than summer biofumigant crops. The restriction is due to shortening days with lower UV exposure and limitations on fertiliser applications. Low soil temperatures and wet soils also limit efficacy. However, the winter window is suitable for oil radish (Fig. 3) to grow.

Fig. 3 Oil radish © Matthew Back

Oil radish is difficult to macerate but is very cold-hardy. If established by early to mid-September, oil radish can be grown over winter, during which it releases bioactive compounds from its roots. These crops are usually incorporated in March–April, which provides a long window for low doses of root-released volatiles to interact with soil pests and pathogens. Maximum efficacy for this window in terms of reducing PCN populations has been found to be between 10–30%, although there is limited data on this.

Spring-established biofumigants are probably not feasible for Scottish growers unless they harvest a crop early in the year such as overwintered carrots. There is no recorded PCN efficacy data for biofumigants grown in this window, although crops are expected to be effective, as biofumigants grown in this window will have access to lengthening days with high UV. Crops could exceed 50 t/ha fresh weight, if water and nitrogen are in good supply.

Agronomy requirements

Recent research carried out by SRUC in collaboration with Harper-Adams University and Barworth Agriculture has identified the best practice for growing biofumigant crops and these are summarised below.

- It is wise to plan ahead when considering sowing biofumigant crops. Determining the sowing window (summer, autumn/winter or spring), and the purpose of the biofumigant crop: what pest or pathogen is to be targeted, is advised. It is recommended that soil samples be taken prior to sowing the biofumigant crop to determine the population of the pest or pathogen being targeted. For example, the population of PCN eggs/g of soil, the free-living nematode population, the number of powdery scab spore balls/g of soil. Post-biofumigation, the efficacy of the control can be assessed by taking further soil samples for the targeted pest or pathogen.
- Pick the best biofumigant crop for the time of sowing and the targeted pest or pathogen. Indian mustard, rocket or oil radish each have their favoured time of sowing as outlined above.
- Be aware that some biofumigant crops will provide a breeding ground for clubroot and exacerbate the issue, affecting future brassica vegetable crops and oilseed rape in the rotation. Request information from seed suppliers on varietal resistance to clubroot. Some oil radish varieties are resistant, but most mustards and rocket are not.
- Sourcing the seed is important in order to get the best out of your biofumigant crop. As with arable crops, not all varieties of the biofumigant crops have the same biofumigant potential.
- For Indian mustard, varieties proven to have good biofumigant potential include Caliente Mustard Superhot 199 (sometimes called ISCI 99) and Caliente Mustard Rojo (both from Tozer Seeds), Scala and Vitasso (both from Boston Seeds), and Pacific Gold/Spudguard (from Chemspec East Anglia).

- For rocket, recommended varieties are Nemat (from Tozer Seeds) and Trio (from Joordens Zaden)
- There are several oil radish varieties available, with most information on biofumigation potential being available for Bento (from Senova) and Doublet (from Nickersons).
- Seed can be sown by direct drilling or by a seeder mounted on a subsoiler, ideally to a depth of 2-3 cm
- Seed rates do vary though and are summarised below, but check with seed supplier.

  Indian mustard

  o Caliente Mustard Superhot 199 – 8-10 kg/ha

  o Caliente Mustard Rojo – 7 kg/ha

  o Scala and Vitasso – 5 kg/ha

  o Spudguard – 10-15 kg/ha

  Rocket

  o Nemat – 6-8 kg/ha

  o Trio – 8-10 kg/ha

  Oil radish

  o Bento – 25-30 kg/ha

  o Doublet – 20-25 kg/ha

- To maximise the biofumigation effect of Indian mustard and rocket, fertiliser inputs are needed, typically 100-150 kg/ha of nitrogen and 25-50 kg/ha of sulphur, and irrigation may be required for establishment or to prevent early senescence of the crop.
- Oil radish inputs are nitrogen at 30-40 kg/ha, and sulphur at 15–20 kg/ha.

Note that Indian mustard will be susceptible to attack by insect pests of brassica crops such as flea beetles and cabbage root fly, and all crops may suffer the ravages of pigeons which can lead to a delay in biomass production and enable weeds to compete with the crop. Herbicides are not usually needed unless weed populations are high and the crop has been slow to establish ground cover.

Maceration and incorporation

The ideal timing for maceration and incorporation of summer biofumigants is when the crop is at early to mid-flowering when the foliage is still succulent. Note that summer crops may need irrigation prior to maceration and incorporation if soils are below 50% of field capacity.

Soil moisture should be between 75% and 100% – moist, but not sodden. Having the right moisture content is so critical that irrigation should be considered if the equipment is available rather than waste the crop by destroying it in the wrong conditions. Soil temperatures should also be above 10°C to maximise volatile gas dispersion through the soil after incorporation.

For overwintered biofumigants such as oil radish, macerate and incorporate at least 2 weeks before planting a spring crop, preferably longer to avoid any phytotoxic effects from the biofumigant crop.

Use a flail or haulm topper for maceration, fitted with blunt hammer or solid V-tines (Fig. 4). Front-mount the maceration implements where possible. Keep the tractor forward speed as slow as practicable to reduce the bite length of the macerator. The aim is to produce a biofumigant pulp for easier incorporation.

Fig. 4 Flail and rotavator combination © Bill Watts

Fig. 5 Front mounted flail and rear mounted spader © Bill Watts

Ideally rear-mount a rotavator or spader for incorporation on the same tractor or on a following tractor to incorporate immediately after maceration. Other incorporation implements can be used. Single pass systems using a front mounted flail and rear mounted spader or similar incorporation implement are best. Where this set-up is not available a multitude of other techniques can be used involving shallow rotavators, terradiscs, ploughs, power-harrows, rolls etc. The trick is to minimise tractor passes and repetitive operations whilst ensuring the pulp material is macerated and mixed into the profile evenly into the top 30 cm of soil and incorporated within 20–30 seconds of maceration. Seal the soil either by smear-roll, heavy flat roll, or by the hood of a rotavator. Sealing the surface stops the gas released from the plants being lost rapidly into the environment, while still allowing it to move freely through the soil profile.

There needs to be a minimum 2 week gap between incorporating a biofumigant and planting a new crop. This is to avoid phytotoxic effects in the new crop from biofumigant organic matter breakdown.

How much will biofumigation cost?

Depending on the biofumigant crop, seed costs are in the region of £5-10/kg, which equates to between £60-100/ha. Estimates vary for other costs such as establishment (£15-30/ha), fertiliser (£50-220/ha, depending on summer or winter sowing), irrigation (£85-155/ha) and machinery (£100-150/ha).

It is estimated that the total cost for a low-input overwintered biofumigant crop can be around £270-300/ha, but bear in mind that this will have lower biofumigation potential (10-30% PCN reduction for example) than a spring/summer biofumigant crop. However, the other benefits to soil and yield increases in following crops will also be possible.

A spring or summer biofumigant crop is likely to cost in the region of £400–500/ha but could extend to £675/ha if additional costs such as irrigation are needed to increase the soil moisture at incorporation.

Further information

The web links below have information on the seed suppliers and further details on the biofumigants mentioned in this Technical Note.

https://www.tozerseeds.com/uk/wp-content/uploads/sites/9/2017/01/Caliente-Mustard-Caliente-Superhot-199.pdf

https://www.tozerseeds.com/uk/wp-content/uploads/sites/9/2018/07/Mustard-Caliente-Rojo.pdf

https://www.tozerseeds.com/wp-content/uploads/2017/01/caliente-mustard-brochure-.pdf

https://www.bostonseeds.com/library/factsheets/Vittasso_pdf_Brochure.pdf

https://www.bostonseeds.com/products/11/Forage-Crops/51/Brown-Mustard/#product2083

https://www.chemspec.co.uk/biofumigation/

https://www.joordens.com/site/assets/files/1400/trio_rocket_lettuce_en.pdf

http://www.senova.uk.com/cover-crops/4593691340

https://www.nickersondirect.co.uk/products/smallholders/doublet/

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