Biofumigation: Suppression and Management of Soil borne pathogens

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Abstract :

Soil fumigation with broad-spectrum biocides is a non-selective means of killing soil-borne pathogens in forest seedling nurseries. Beneficial microorganisms (antagonists, competitors, pathogen parasites and mycorrhizal fungi) are also killed by most fumigants. Organisms are killed by direct contact with fumigants. Dormant structures of microorganisms are usually more resistant to fumigant action. Specific fumigants are more effective against certain microorganisms. In this review the effects of bio fumation aon plant pathogens are discussed.

Key words: bio fumigation & pathogens

Introduction :

The term 'Biofumigation' was originally coined by J.A. Kirkegaard to describe the process of growing, incorporating certain brassicaceous varieties into the soil, leading to the release of isothiocyanate compounds (ITCs) by the hydrolysis of glucosinolate (GSL) compounds present in the plant tissues **(Kirkegaard et al., 1993).** It effects on a wide range of soil borne pests and diseases. Biofumigation is the inhibition of soil borne pests and diseases through the use of plants that produce suppressing chemicals is called secondary metabolites. In most cases these biofumigant plants are macerated and incorporated into the soil so they can release their suppressing chemicals.

Some Biofumigant crops:

Plants such as mustard, broccoli, cauliflower, rapeseed, having some organic compounds called glucosinolate. When the plants tissues are ruptured, biologically active chemicals are produced. One of the most important compounds released is isothiocyanate (ITC). The pungency mustard plants are caused by ITCs released when the tissues are mashed. ITCs are considered beneficial to human health but at low concentrations. Some commonly used biofumigant crops include: Mustard, Cabbage and Broccoli.

Importance of Biofumigant crops:

Soil borne pathogens are becoming more difficult to control due to production of resistance against pathogens and restricted use of certain chemicals. The cost of chemicals is also becoming a trouble. Mustard is a well understood biofumigant. Mustard and most other plants from the Brassica family produce chemicals called "glucosinolate". When glucosinolate come in contact with water and a family of enzyme myrosinase, contained in plant cells, they are transformed in another group of compounds called "isothiocyanate". **(Matthiessen and Kirkegaard, 2006)**. These inhibitory compounds like isothiocyanates gives mustard its biofumigation power. Isothiocyanates are also responsible for giving plants from the Brassicaceae family their bitter/hot/spicy taste. The isothiocyanate that is produced by mustard is called "Allyl isothiocyanate" (AITC). AITC is a compound that is very similar to the compound that is contained in the commercial fumigant Vapam®.

Isothiocyanates (ITC) and nitriles have been determined to control bacteria, (**Delaquis and Mazza, 1995**) fungi, **(Sarwar et al., 1998)** insects, **(Noble et al., 1999)** and nematodes **(Mojtahedi et al., 1993)** in laboratory experiments. **(Sarwar et al., 1998).** Allyl isothiocyanate

(AITC) is the prevalent ITC produced by Indian mustard (*B. juncea*). There are about 18 different types of GSLs compounds commonly found in brassicaceous plants which vary in their structure depending on the type of organic side chain (aromatic, aliphatic or indolyl) on the molecule. The profile, concentration and distribution of these GSLs vary within and between Brassicaceous species and in different plant tissues, and consequently the concentration and type of biocidal hydrolysis products evolved also varies **(Kirkegaard and Sarwar, 1998).**

Mode of action of Brassicaceous crops:

Many Brassicaceous species produce significant levels of glucosinolates (GSLs), which are present in plant cells separately from the enzyme myrosinase and are in themselves not fungitoxic **(Manici et al., 1997)**. However, when plant cells are bursted the glucosinolates (GSLs) and myrosinase come into contact and are hydrolysed in the presence of water to release various products, including isothiocyanates (ITCs) **(Vig et al., 2009)**. ITCs have a wide range of biocidal aspects and are acutely toxic to a variety of pests and soil borne pathogens **(Chew, 1987).** Glucosinolates (GSLs) having β-thioglucoside N-hydroxysulfates, with a side group (R) and a sulphur-linked β-d-glucopyranose moiety **(Fahey et al., 2001)** and are allocated as aliphatic, aromatic or indole GSLs according to the type of side chain **(Fenwick et al., 1983).** The R group is maintained in the ITCs and influences its biological activity.

There are some various GSLs and ITCs compounds present in brassicaceous crops:

Brassicaceous Crops	GSLs	ITCs

Black mustard *(Brassica nigra)*	Sinigrin	2-propenyl-ITC (allyl-ITC)
White mustard *(Sinapsis alba)*	Sinalbin	4-hydroxybenzyl-ITC
Brown mustard *(Brassica juncea)*	Sinigrin	2-propenyl-ITC (allyl-ITC)
Rocket *(Eruca sativa)*	Glucoerucin	4-methylthiobutyl-ITC
Radish *(Raphanus sativus)*	Glucoraphenin	4-methylsulfinyl-3-butenyl--ITC

Although Isothiocyanates (ITCs) have generally considered as the most bioactive of the hydrolysis products, other compounds such as non-glucosinolate sulphur containing compounds, fatty acids, nitriles and ionic thiocyanates may also affects pests and plant diseases. **(Matthiessen & Kirkegaard, 2006)**

Brassicaceous crops for control of soilborne diseases:

There are many articles on inhibition of soilborne pathogens through the use of brassicaceous plants, some of which have been summarised by **Matthiessen & Kirkegaard (2006) and Motisi et al., (2010)** caused inhibitory effects on many pathogens including *Pythium*, *Rhizoctonia*, *Fusarium*, *Phytophthora*, *Sclerotinia* and *Verticillium* and also the species of endoparasitic and semi-endoparasitic nematodes such as *Pratylenchus ,Tylenchus, Globodera and Meloidogne,*. There is a concern that biofumigation for suppressing soilborne pests and pathogens does not constitute a large area of work and there has been a lack of a consistent experimental approach. It is clear that in-vitro studies that these pathogens vary in their sensitivity to different ITCs **(e.g. Brown and Morra, 1997; Smith and Kirkegaard, 2002)**

Use of brassicaceous crops:

These crops can be used in a number of different ways for control of soil borne diseases:

Brassicaceous crops as Intercropping

In this case, the aerial parts of mustard plants are harvested and hence activity against plants diseases on GSLs, ITCs or other compounds released maceration of plant parts. Several studies stated that both GSLs and ITCs in the rhizosphere which have been implicated in the inhibition of pests and soil borne plant diseases **(van Dam et al., 2009)** Moreover, GSLs and ITCs may also inhibit soilborne pathogens and some beneficial fungi such as *Trichoderma* show high tolerances to Isothiocyanates (ITCs) **(Galetti et al., 2008; Gimsing and Kirkegaard, 2009, Smith and Kirkegaard, 2002).**

Incorporation of brassicaceous plants into soil

This is the most significant use of brassicaceous plants where a crop is grown specifically for incorporation with the aim of converting GSLs to ITCs. To achieve high levels of Isothiocyanates release, completely maceration of plant parts followed by rapid incorporation into soil is required and addition of water to ensure complete hydrolysis **(Matthiessen & Kirkegaard, 2006; Kirkegaard, 2009).** As some ITCs are quite volatile, sealing/smearing the soil with a roller or covering the soil with plastic sheets may be useful. **(Kirkegaard and Matthiessen, 2004).**

Maximising ITC-mediated disease suppression

According to the Matthiessen & Kirkegaard (2006) and Kirkegaard (2009), there are many ways in which biofumigation can be optimised. In brief these are:

1.Create a relationship between GSL, ITC levels and suppression of pathogens: There are different effective brassicaceous crops need to be used for inhibition of the target pathogen. This can be done through in vitro consideration focussing on the effect on resting structures such as sclerotia, microsclerotia, and chlamydospores or ideally in soil-based assays under controlled conditions to establish the best biofumigant for a particular soilborne pathogens. **(Downie et al., 2012).**

2.Selection of convenient brassica species or varieties: The brassicaceous plants species or varieties may also need to be selected based on growth rate, winter hardiness, and glucosinolates production at different times of year depending on when it is intended to be incorporated. Seed meals and processed biofumigants may be more useful for the control of more resistant resting structures such as microsclerotia of *Verticillium dahliae.* **(Neubauer et al., 2014).**

3.Optimization of agronomy: The Agronomic factors such as seed rate, sowing time, application of fertiliser and optimum incorporation time to be considered in order to maximise biomass of biofumigant crop and Glucosinolates level. For instance, Glucosinolates (GSLs) concentration in plant parts has been examined to be modified by sulphur and nitrogen supply mediated by fertilization. **(Li et al., 2007).**

4. Incorporation of high amounts of brassicaceous plants biomass: According to the data of J.A Kirkegaard that up to 5% w/w crop biomass is required to maximise inhibition of plant diseases and typically 50 tons per hectare is required to achieve an efficient result. (Tozer Seeds, pers. comm.).

5. Increase the efficiency of ITCs: cell disruption is key to efficient conversion of GSLs to ITCs and Implements and equipment's for pulverising and macerating of plant is superior to chopping. Immediate incorporation is then required with addition of water to maximise GSL hydrolysis and smearing the soil with polythene sheets will maximise ITC retention.

6. Allow 10-15 days before planting following main crops: because of Isothiocyanates (ITCs) and other products of Glucosinolates (GSL) hydrolysis may be harmful for plants.

Conclusion:

When the mustard crop managed properly, it offers to inhibit the soil borne pests and pathogens. The brasssicaceous crops like mustard, rapeseed used as a biofumigant crops and also effective for organic producers. It is important to strictly follow the outlined cultural practices if you want to have any chance of success using mustard as a biofumigant. Proper chopping of plant material and soil incorporation is of utmost importance. Although mustard is a remarkable biofumigant, it has similar benefits that is expected from any other cover crop such as; prevention of soil erosion, recycling of soil nutrients, improved soil structure and maintaining soil organic matter. Mustard can also act as a deterrent to many insects (wireworm) and pests therefore it may prevent many problems from occurring in your field. Interestingly, there are other crops that show possible biofumigation effect such as but not limited to; buckwheat, pearl millet, sorghum-sudan grass, rape seed and oil seed.

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