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Biofumigation for Management of Soil-Borne Plant Pathogens and Nematodes

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Managing soil-borne pests and diseases is critical for resource poor producers. All cultivated crops are vulnerable to a range of pathogenic organisms that reduce yield by killing the plant or damage the product and make it unmarketable. Control of soil borne pathogen is complicated because even very low populations are often highly damaging, the organisms are hidden and unevenly distributed in the soil, and are often microscopic in size. Farmers therefore often resort to prophylactic application of pesticides prior to planting as insurance against the crop damage and yield loss. Residual pesticides can no longer be used for control of soil borne pathogens as methyl bromide has been phased and the demand for blemish-free produce is increasing. This is one of the reasons why Biofumigation is being investigated to control soil borne diseases with the aim to develop bio-pesticides, which could be effective against various root pathogens without deteriorating soil environment. It is the agronomic practice of using volatile chemicals (allelochemicals), released from decomposing Brassica tissues, to suppress soil-borne pests and pathogens. The most common volatiles produced during the breakdown of Brassicas are isothiocyanates (ITCs). They are related to the active ingredient in the commercial fumigant metham sodium and dazomet and are highly toxic to pests and pathogens and are released following tissue damage, when myrosinase enzymes, at neutral pH, hydrolyse (in presence of water). The biocidal activity of various isothiocyanates (ITCs) released by Brassica tissues is well-known and the potential of Brassicas to suppress a range of soil-borne pathogens viz., Fusarium, Rhizoctonia, Gaeumannomyces and nematode is supported by considerable empirical field evidence. Biofumigation is an ecologically safe and economically sound option for soil-borne pest and disease management to small holders in India.

Introduction

Biofumigation is the agronomical practices of using volatile chemicals (allelochemicals), released from decomposing *Brassica* spp. to suppress soil-borne pathogens and nematodes. The most common volatiles produced during the breakdown of *Brassica* are the isothiocyanates (ITCs). ITCs are related to the active ingredient in the commercial fumigant, metham sodium and dazomet, which are highly toxic to pathogens and pests. They are released following tissue damage, when myrosinase enzymes, at neutral pH, hydrolyse glucosinolates (GSLs). GSLs are sulphur-containing chemicals (thioglucosides) those are produced as secondary metabolites by *Brassica* spp. and a researcher believed their evolutionary role in providing resistance against pathogens and pests (Kumar, 2005).

The term ‘Biofumigation’ was first coined by Kirkegaard *et al*. (1993) who specifically described using GSL hydrolysis products produced by *Brassica* plants, notably ITCs, to control soil borne pathogens and pests.

Current Status of Biofumigation Research

The various *Brassica* spp. can produce suppressive effects on soil borne diseases and pests. The effects are related to the ITCs that form from precursor GSLs when the plant is disrupted and incorporated into soil. There are mainly six types of GSLs in *Brassica* spp. The toxicity of an ITC sometimes differs among organisms, suggesting that specific plants could be utilized more successfully than others for biofumigant effects by matching them to particular diseases or pests. Aromatic ITCs produced from GSLs often found in roots are very toxic (50 or more times greater than metham sodium) but as they are of low volatility, contact with organisms may be reduced. Aliphatic ITCs are more common in shoots and less toxic, their greater volatility may allow easier contact with pathogens (Kumar, 2005).

There is a good association between root GSLs and its effects on diseases and pests. In addition, roots may release ITCs during growth as well as decomposition. Consequently, the biofumigation potential of roots may be disproportionately high compared to shoot and large amounts of root biomass, which may be more effective biofumigants in soil.

Current Research Findings of Biofumigation (Kumar, 2005)

- ITC is the main active ingredient for the suppressive effect.
- ITC concentration is more in roots than shoots.
- Bacteria are less susceptible than fungi.
- No residual effect as ITC is highly volatile.
- Identity and concentration of ITC varies with the variety of mustard and with the soil condition (more sulphur = more GSLs = more ITCs).

Brassica / *Brassica* Products Available for Biofumigation Effect (Kumar, 2005)

The following *Brassica* plant parts and derivatives have Biofumigation properties:

- Brassica plant as a cover crop or intercrop can be slashed and ploughed under at flowering stage to achieve maximum benefit.
- Brassica meal as a cake or powder which can be incorporated in to the soil and may be used as mulch.
- Volatile oil of Mustard (VOOM), which is a mixture of different edible oils of canola and can be used as pre-planting application as an alternative to methyl bromide.

Crop Selection for Biofumigation

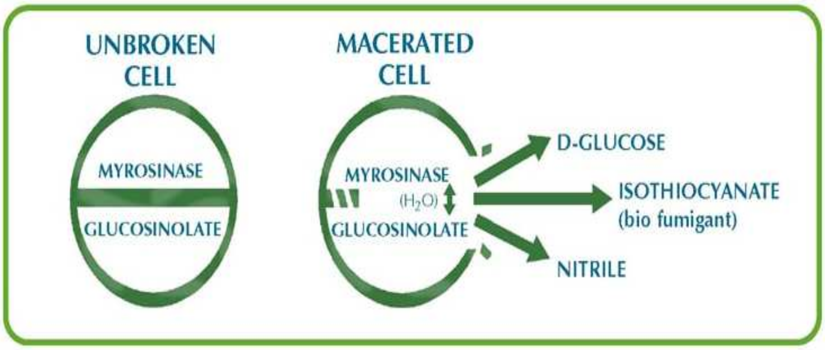
- For maximum biomass production crop selected.
- For temperate regions, cold tolerant crops should be selected for winter plantings to obtain good biomass production.
- Time to maturity (flowering) varies among cultivars and on the season.
- Some *Brassica* biofumigant crops can be highly susceptible to club root and should not be used where this disease is a problem.

Methodology of Biofumigation

The fresh mass of *Brassica* spp. incorporated in the soil, which can be done directly if the biomass is collected from grown crops or with mass taken from other resources and brought into the plot /field. If the mass is transported to the field, the soil should be well prepared before the incorporation. Irrigate the field, if possible by sprinkling, until the soil is saturated, although watering can be done by flooding or drip irrigation. Cover the soil surface tightly with the transparent plastic film for at least two weeks to retain the gases produced from the biodegradation of the organic matter. The film is removed after 3-4 weeks and the soil slightly removed in order to permit the gases to escape from the soil. Planting of the interested crop can be followed after 24 hours (Reddy, 2011).

Mode of Action

The principle is based on the use of plants with high levels of glucosinolates, naturally occurring plant sulphur compounds providing the plants protection. When the plants are incorporated into the soil, glucosinolates are broken down by the plant enzyme myrosinase, producing active phytochemicals, isothiocyanates. Common sources of ITCs are methyl, 2- propenyl, 3-butenyl, 4-pentenyl, benzyl, 2-phenylethyl (Karvina and Mndumbu, 2012). The glucosinolate-myrosinase system is the most accepted theory involved in defense against plant pathogens and herbivores (Botti *et al*., 1995). Allyl isothiocyanates and methyl isothiocyanates volatiles were completely inhibitory to zoospores of *Aphanomyces euteiches* (Lewis and Papavizas, 1971). Six *Brassica* species were assayed for inhibition of *Fusarium sambucinum*, only B. *nigra* and B. *juncea* suppress radial growth of F. *sambucinum* (Mayton *et al*., 1996).



Management

Soil-borne plant pathogens

Brassica cover crops may reduce or suppress some pathogens including *Verticillium* wilt in potato, *Rhizoctonia* (root rot) in bean, *Pythium* (root rot) in lettuce, *Fusarium* (root rot) in pea and carrot. Biofumigation is the use of volatile plant chemical ITCs for control of soil-borne pathogens and pests. These products have been shown to suppress the pathogens *Botrytis cinerea*, *Rhizoctonia solani*, *Fusarium oxysporum* and *Cladosporium fulvum* (Urbasch, 1984). The volatiles from several *Brassica* spp. suppressed the growth of the tomato pathogens *viz*., *Pythium ultimum*, *Rhizoctonia solani* and *Sclerotium rolfsii* and the biocidal activity of *Brassica* spp. against fungal pathogens, nematodes, weeds and insects is frequently attributed to ITCs from *Brassica* spp. Mustard residue provided maximum control of collar rot under pot culture and nursery conditions and cabbage residue for white root rot under pot culture and nursery condition (Sharma and Negi, 2013). The effect of adding the mustard plant parts significantly reduced the disease incidence of *S. rolfsii*, initially the disease incidence was minimum (37.33%) at 0 day application of *S. rolfsii* immediately after incorporation of mustard plant parts (Goud *et al*., 2013). Incorporation of chrysanthemum found an effective application of biofumigants against *Verticillium dahliae* Kleb. in greenhouses (Masheva *et al*., 2012). Biofumigation with cabbage in soil on *F. oxysporum* population, high variability in the biofumigation effect was observed, both 3 and 5kg cabbage residue biofumigant doses revealed highest pathogen mortality during April with low concentration of pathogen (Iriarte *et al*., 2011). The most serious soil borne bacterial wilt (*Ralstonia solanacearum*) in vegetable crops *viz*., eggplant, tomato and potatoes was effectively reduced by using Indian mustard residue (Kumar, 2005).

Nematodes

Biofumigation has a similar efficacy as methyl bromide in root-knot nematode (*Meloidogyne incognita*) control in pepper. Incorporating *Brassica* spp. gave good control of most serious pest of the potato crop with 60-85% reduction seen in cyst nematodes (*Globodera rostochiensis*). Cabbage, cauliflower, Chinese cabbage and radish are well known for their biofumigation properties against nematodes population but radish leaf residues was found most effective (Anita, 2012). The field application of cauliflower and cabbage residue were effectively controlled the root-knot nematode (*Meloidogyne incognita*) in both the season and increased the yield of cucumber (Abed *et al*., 2011).

Conclusion

Biofumigation is an alternative control method, which works on the principle of exploiting the natural biocide compounds from glucosinolate containing plants (*Brassica*) to suppress soil-borne fungal pathogens (*Pythium* spp., *Rhizoctonia solani*, *Sclerotium rolfsii*, *Fusarium oxysporum*, *Verticillium dahliae* Kleb, *Gaeumannomyces graminis var. tritici*), bacterial pathogens (*Ralstonia solanacearum*) and nematodes (*Meloidogyne incognita*, *Globodera rostochiensis*), and also act as a soil heater to enhance biological activities. Isothiocyanates are produced during glucosinolate hydrolysis, which occurs when *Brassica* plant tissues are broken down, allowing both glucosinolates and a myrosinase to encounter each other and hydrolysis to occur. In turn, this releases one of several products, including Isothiocyanates. After phasing out of Methyl Bromide (MB), biofumigation is fast becoming the most sustainable option for management of soil borne pathogens, nematodes and to some extent bacterial diseases originating from the soil.

Future thrust

- Appropriate species of *Brassica* having high amount of GSLs in their tissue should be identified.
- Bio-products of the mustard oil industry such as mustard meal and powder should be evaluated for the management of soil borne pathogens.
- Need to develop varieties containing higher glucosinolates for the management of soil borne pathogens.
- It is necessary to carry out long-term research to learn the susceptibility of soil microbes in relation to the biofumigation.

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