Biofumigation in Crop Protection

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Introduction

Biofumigation is incorporating the soil amendment (fresh plant material, manures) into the soil, which in turn produces organic compounds during the development of succeeding crop species thus helping to defend against pests and pathogens. Biofumigation is one of the important tools and cost-effective methods in crop disease control. This method is simple, alternative to chemicals which control pests, soil borne pathogens including *Fusarium* spp and *Phytopthora* spp and nematodes. This biofumigated soil also has increased activity of beneficial bacteria and fungi supporting the plant growth and defense against stress conditions. Biofumigation materials improve soil organic matter, nitrogen, phosphorous and potassium content; improve soil temperature and physiological performance of the crop. Basically, biofumigation is a non-chemical soil disinfection method.

Biofumigation In Eco-Agriculture

In agricultural crop protection, chemical control is currently dominant, but most of the regulatory guidance is moving towards eco-agriculture and conservation agriculture. In the case of pest and disease management, it requires sustainable management and conservation of biodiversity. The main principle of agro-ecological crop protection (ACP) as stated by Deguine et al. (2017) is to prevent and reduce the risk of pest infestations or outbreaks. Habitat management which is an important factor under ACP involves planting permanent ground cover, flower strips, and plants to attract natural enemies. Creating unfavorable habitat for the pest and pathogens, favorable habitat for the natural enemies and biocontrol agents is possible by introducing biodiversity in the agro-ecosystem than monocropping. Crops belonging to Brassica family (cabbage, cauliflower, mustard etc), Moringaceae, Capparidaceae are majorly used as biofumigant crops. These crops contain secondary metabolites like glucosinolates. During the decomposition of crop residues, the metabolite breaks down into thiocyanates, isothiocyanates and others. The predominant breakdown product isothiocyanates have biocidal activity on harmful fungi, bacteria, nematodes and weeds.

Biofumigation, in addition to pest and disease management improves soil physical, chemical and biological properties by altering the soil texture enhancing water infiltration and water holding capacity. The community structures of the beneficial microorganisms are known to increase. The acids from the decomposition of green manures help in release of minerals for the succeeding crop. Biofumigation prevents wind erosion and surface run-off. More importantly it increases nitrogen content of the soil. Since biofumigation provides vegetative cover, weeds, population of nematodes and soil-borne pathogens are kept under control.

Components of Biofumigation

***Crop rotation**:* Sequential cultivation of crops belonging to different botanical family in the same land is known as crop rotation. Crop rotation with biofumigation crops helps to improve soil health and effectively manage pest and diseases. The non-host plants leave the pests and pathogens under starvation. However, choice of the crops should be made in such a way to avoid outbreak of new pests and pathogens. According to Flint and Roberts (1988), crop rotation is used to manage the pest population and its mobility due to non-availability of host and thus limitation in the infestation source.

Incorporation of biofumigants: Mustard family crops are incorporated after cultivation for the purpose of converting glucosinolates to isothiocyanates. To achieve higher amount of release of this breakdown metabolite, water is supplied to ensure complete hydrolysis. Covering the soil with plastic mulch is followed since some of the isothiocyanates are volatile in nature. Yield of crops was found to be increased due to incorporation of mustard family plants in the soil.

Cover and green manure cropping: Green manure crops are basically planted between the main crops. They generally act as natural soil cover enriching nitrogen, improving microbial activity, protecting the land from erosion, controlling weeds, controlling pests and pathogens by acting as non-host plants. Everts (2002) reported that the cover crops can reduce population of infectious bacterial and fungal pathogens by breaking their life cycle. Sorghum is known to reduce soil inoculum of bacterial blight to the succeeding crop. Cover crops also act as host for natural enemies (predators and parasitoids). The natural enemies migrate from harvested winter crop to the spring planted crops. Growing of clover and cereal rye is known to reduce infestation of cabbage fly. Larkin and Griffin (2007) reported that the mustard plants can suppress common scab pathogen (*Streptomyces scabies*) in potato. Population of the wilt pathogen *Verticillium dahiliae* (infective propagules) was found to be reduced to great extent when mustard, canola, and radish were grown.

Trap crops: Trap crops are used as one of the pest management measures to deviate pests and protect the main crop from infestation. When these plants are chopped and incorporated in the soil, they release metabolites to kill soil-borne pathogens. Jaffee et al. (1998) suggested that specific Brassica species can be used as trap crops for nematode management.

Biofumigation Crops

Brassica species: White mustard (*Sinapis alba*), yellow mustard (*Brassica hirta*), Indian mustard (*Brassica juncea*), black mustard (*Brassica* nigra) are used as biofumigation crops for the management of weeds and wilt causing pathogens. Mustards contain high levels of glucosinolates. Radish is known to control cyst nematodes in the soil. Rapeseed species such as *Brassica napus* and *Brassica rapa* are used for management of nematodes as well. Turnip, in addition to nematode and pest control, facilitates water infiltration by forming numerous micro-channels in the soil. Brassica rapa gives effective control of bacterial wilt caused by *Ralstonia solanacearum* in tomato. Mustard can control *Fusarium* wilt in beans and

Phytopthora fruit rots in other crops. Soil-borne pathogen, *Rhizoctonia solani* which has a broader host range gets significantly reduced by the decomposing *Brassica juncea* plant tissues. The volatile chemicals from biofumigation crops control *Fusarium oxysporum, Rhizoctonia solani, Botrytis cinerea, Cladosporium fulvam, Pythium ultimum* and *Sclerotium rolfsi*. Incorporation of green cover crops suppresses *Verticillium* in potato, *Pythium*, *Fusarium* and *Rhizoctonia* in beans, *Pythium* in lettuce, *Aphanomyces* rot in onion, *Pythium*, *Rhizoctonia* and *Fusarium* root rot in peas and *Fusarium* in carrot. Biofumigation using Brassica species crops can eliminate weeds to the range of 20-90%. Incorporating meadow foam (*Limnanthus alba*) seed meal in the field limits the weed growth upto 90%. Allyl isothiocyanates can inhibit the growth of weeds like redroot pigweed.

Non-Brassica species: Decomposition of crop residues of barley, wheat, oats show inhibitory effects on soil-borne plant pathogens and nematodes. Strong nematicidal activity is observed in Sudan grass and sorghum. Onion releases volatile sulphur compounds such as thiosulfinates which are converted into disulfides during decomposition. Dimethyl disulphide (DMDS), dipropyl disulphide (DPDS), diallyl disulphide (DADS) have potential of inhibiting various fungal pathogens including *Colletrotrichum*, *Fusarium* etc. DMDS has toxic effect on termites. Metabolites released from garlic residues in moist soils inhibit weeds such as black nightshade, common purslane and banyard grass.

Conclusions

Removal and destruction of crop residues is part of the integrated pest and disease management in agricultural crops. This is recommended if the standing crop is affected by pest, disease or nematode outbreak. However, if the standing crop has not experienced such infestations, incorporation of residues in the soil can serve as effective pest and disease management strategy for future crops. The understanding of the contribution of metabolites and fermented products of the crop residues to the soil needs further exploration. Complete profiling of metabolites of every crop residue in the soil through metabolomics can help to strengthen the basic information in this subject. Although the release of metabolites from crop residues is slower, it can provide a long-term beneficial effect. Crop rotations with Brassica species crops are necessary in a cropping pattern to control pest and diseases since these crops are best suited for biofumigation, thanks to their biochemical composition. More research and optimization of crop residue management are critical for the success of agro-ecological crop protection in a non-chemical way.

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