Opinion

Biological soil disinfestation and biofumigation: alternatives for chemical fumigation in organic farming

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The issue of soil borne plant pathogens and nematodes is becoming more serious in the farming systems which involve narrow crop rotations. Various strategies are being employed to manage them under field conditions. Fumigation of soil using some chemicals is one among them. However, due to environmental hazards associated with fumigation through chemicals, it has become very essential to find some alternatives for the control of soil borne pathogens especially under organic farming. Chemicals such as metam sodium, 1,3-dichloropropene(1,3-D), carbon disulphide, propylene oxide, methyl iodide and propargyl bromide are employed for fumigation of soil in conventional agriculture. However, they are not permitted in organic farming. Methyl bromide, very effective biofumigant has been phased out after the enforcement of Montreal Protocol with the establishment of methyl bromide as a ozone depleting compound in 1993[1] in most countries. Effective nonchemical methods of control like soil solarization or flooding can reduce inoculum levels of soil borne pathogens, but solarization is restricted to warmer areas where solar radiation is sufficiently intense to create lethal soil temperatures and flooding is not feasible in most locations. Biological soil disinfestation (BSD) and biofumigation are the important ecofriendly methods and effective alternatives for chemical fumigants for the management of soil-borne pathogens without causing harm to the environment in hilly areas where under temperate climate soil solarisation is not effective.

Biological soil disinfestation (BSD) (Figure 1) is a sustainable method of disinfesting the soil[2] and will be very effective against wide variety of soil borne pathogens, nematodes and also even some weed seeds. It has also been referred to as anaerobic soil disinfestation, soil reductive sterilization, reductive soil disinfestation, and anaerobically-mediated biological soil disinfestation. It has broad spectrum activity against many soil borne fungi, various plant pathogenic nematodes and is also similar to methyl bromide in efficacy.[3] The concept of BSD is very simple and combines the incorporation of fresh organic amendments (40tonnes per ha) in soil at the depth of 30-40 cm and covering the soil with airtight clear or black plastic after irrigating the field to create an anaerobic environment in the soil that results in elimination of soil borne pathogens. The tarp is removed after 6 to 8 weeks and the soil is allowed to stabilize for a few days before planting. Easily decomposable organic materials such as wheat bran, molasses, rice straw, rice bran *etc*. have been effective and can also be used for biological soil disinfestation. During BSD treatment; anaerobiosis is created by increasing the microbial respiration. The easily available carbon from the readily decomposable organic soil amendments used in BSD provides substrate (food source) for rapid growth and respiration of soil microbes. As a result, available soil oxygen is reduced as the soil is irrigated to fill the pore space and plastic with low oxygen permeability character used limits gaseous exchange between the soil and the ambient atmospheres above the plastic mulch. This creates anaerobic conditions that persist until the carbon source is utilized or soil moisture content drops (typically one to two weeks). Besides anaerobiocity, the suppression of soil-borne fungal pathogens might be attributed to other factors like high temperature, organic acids (acetic, propionate and butyric acids) generated, and metal ions released into soil water[4] and also biocontrol of plant pathogens by anaerobic microbes. Anaerobic bacteria such as *Clostrdium*, *Enterobacter*, *Acintobactor* and others increase in number in the oxygen deprived soil during biological soil disinfestations.[5]

Figure 1 Biological soil disinfestation.

Bio fumigation is another eco-friendly method and is similar to that of BSD, but uses crops belonging to Brassicaceae as rotation crops or green manure crops. The term biofumigation represents suppression of soil borne pests by compounds released by various Brassica plant species.[6] All brassicaceous plants contain glucosinolates which are hydrolysed by the enzyme myrosinase (thioglucoside glucohydrolase, EC 3.2.3.1) as a result of tissue damage to release among other volatile products, isothiocyanates which appear to have either fungistatic or fungicidal properties. The activity of isothiocyanates results from irreversible interactions with proteins.[7] Plants should be chopped well and incorporated into the soil no later than full bloom for best glucosinolate production. Besides Brassicas, plants belonging to Caricaceae, Moringaceae, Salvadoraceae and Tropaeolaceae families also have biofumigant properties.[8] Sorghum

also has biofumigation effect which produce cyanogenic glucoside compound called dhurrin and releases cyanides upon break down[9] that have been found to be effective against nematodes and fungi like *Verticillium*. Apart from disease suppression, these methods also improve soil physical structure and porosity by adding organic matter to the soil. Germinating weed seeds, nematodes, bacteria, fungi, viruses and insects can be suppressed by using this method.[7] The content and concentration of glucosinolates vary among the cultivars and stage of the development. Different biofumigation crops will have different biofumigation potential and produce different levels of pathogen control. Lack of disease suppression in biofumigation is often attributed to differences in glucosinolate concentrations of incorporated Brassicaceous materials. Lack of nematode suppression at lower *Brassica juncea* biomass application levels may be explained by the difficulty in achieving uniform distribution of the amendment in the soil and the high volatility of allyl ITC.[10] When *Brassica* spp. with high glucosinolate content is used as amendments, sufficient biomass must be applied to allow uniform distribution through the soil profile for subsequent volatilization. This requirement may be even more critical in cooler climates. Therefore, to achieve the most effective biofumigation results it appears that it is necessary to gain an understanding of glucosinolate hydrolysis products formed by different Brassica cultivars, and their interactions with different soil borne pathogens. By gaining greater understanding of the specific processes occurring during biofumigation, it is hoped that it can be used in a targeted manner to control specific pathogens, and aim to provide more effective and efficient soil borne pathogens nematode control.

There has been a high demand for organic food. Accordingly, organic agriculture is gaining importance worldwide due to increased concern of food safety and deleterious effect of pesticides on human health and environment. Therefore, biological soil disinfestations and biofumigation hold plenty of promise in organic farming as a crop protection tool for the management of plant pathogens and nematodes, besides, proper utilization of biomass and waste materials from weed and Braassica plant species. However, there is a need to screen and evaluate the local Brassicas for biofumigation potential. The incorporation process should be standardized to maximise the exposure of the organisms to the toxic compounds at the most vulnerable stage.[11,12] Similarly different weed species should be studied and evaluated for utilization in biofumigation and biological soil disinfestation. The use of biofumigation and biological disinfestation for pest and disease control should be disseminated to the farmers for proper implementation especially where solarisation and other chemical fumigation is not feasible.

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Conflict of interest

The author declares no conflict of interest.

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