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# Eco-friendly management strategies for soil borne plant pathogens

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## Abstract

Soil borne diseases and pests cause huge yield losses in conventional production system and are very difficult to manage. Chemical soil fumigants like methyl bromide, metham sodium gave satisfactory control but are dangerous to the ecosystem. Other methods of managing soil borne pathogens like soil solarisation, crop rotations, organic amendments and mulches etc. have some potential. This review is an effort to through some light on the different eco-friendly strategies for the management of soil borne plant pathogens.

**Keywords:** Green Manures, Organic Amendments, Organic Farming, Mulches.

## Introduction

Soil borne pests and diseases are known to cause huge losses to crop production and are very difficult to manage. Because of the microscopic size soil borne plant pathogens are, hidden and unevenly distributed in the soil, and even very low populations are often highly damaging. Generally, soilborne diseases are severe and often a limiting factor in conventional production systems, but are rare in undisturbed natural ecosystems (Cook and Baker, 1983). Alike other plant diseases, management of soil borne diseases also based on the basic principles of plant disease management i.e. Avoidance, Exclusion, Eradication, Protection and Therapy. For effective management of soil-borne pathogens an understanding of the target pathogen's behaviour in the soil and different biological, biochemical and physicochemical characteristics of soil (soil temperature, soil moisture, pH, soil organic matter and soil texture etc.), is essentially required. No full proof method for management of soil borne plant pathogens is available and if available its implementation is problematic. Moreover, the development of fungicide resistance in pathogens, and the breakdown or circumvention of host resistance by pathogen populations (McDonald and Linde, 2002) are some of the reasons underlying efforts to develop new disease control measures. Over the last few decades, soil fumigation with chemical fumigants has been the most effective and widely used method for soil-borne pest control (Gan *et al.* 1999). Many traditional chemical soil fumigants like methyl bromide, chloropicrin etc. are very effective in controlling the soil diseases but damaging to the environment, toxic to humans, and harmful to soil micro-flora. The ban and phase-out of methyl bromide highlights the need of development of eco-friendly and effective strategies for soilborne disease management. Diversified options and alternatives are required to fulfil the need of soilborne pest and disease management strategies. Among the different strategies used for management of soilborne plant pathogens eco-friendly options like use of biocontrol agents, green mauring, organic amendments, soil solarization and biofumigation have shown some potential.

**Chemical soil-fumigants and their disadvantages-** Methyl bromide (MB) is a colourless, non-flammable, low boiling point chemical with high vapour pressure (1,600 mm Hg at 20°C) and reasonable water solubility (13.4 g/L) (Yates *et al.* 1996). The first use of methyl bromide as a soil fumigant occurred in France in the 1930s**.** Since its discovery and implementation, methyl bromide has been consistently effective for control of nematodes, fungi, insects and weeds and has been used on more than 100 crops worldwide (Yates *et al.* 1996). This traditional soil fumigant was found detrimental to the environment, toxic to animals and humans, and negatively affecting the beneficial soil organisms (Baker *et al.* 1996). Methyl bromide was classified as a chemical that contributes to the depletion of the earth's Ozone layer under the Montreal Protocol (Majewski *et al.* 1995, Stapleton *et al.* 2000). Abundance of MB in the atmosphere as soil fumigation agent was just one source of factors causing ozone layer depletion. Other sources include, emissions from leaded gasoline (Thomas *et al.* 1997) and biomass burning (Blake *et al.* 1996), as well as natural sources such as oceans (Moore *et al.* 1996), salt marshes (Rhew *et al.* 2000), rice paddies (Redeker *et al.* 2000) and litter decomposition etc. Because of its usefulness as soil fumigant, the loss of methyl bromide has potentially large economic consequences, therefore, EPA has made it a priority to find and register replacements. To this end some progress has been made with the discovery of a number of chemical soil fumigants. The chemical, 1, 3-dichloropropene was registered in 2001 for preplant soil fumigation in strawberries and tomatoes (Ntow and Ajwa, 2009). Other chemicals such as chloropicrin, 1, 3-dichloropropene, propargyl bromide, metham sodium, methyl iodide and sodium azide were evaluated as alternatives to methyl bromide (Ajwa *et al.* 2003), but were not considered for registration in the USA. The phase-out of methyl bromide brings the disadvantages of chemical fumigants into particularly sharp focus and highlights a need for development of diversified options and alternatives for management of soilborne pest and diseases, which could fit into a prophylactic management schedule. For some situations, following alternatives are already available for commercial application.

**Soil solarization -** The literal meaning of term solarisation refers to a chemical change in glass, caused by sunlight or another ultraviolet radiation, which causes a photochemical reaction resulting in a decrease in ultraviolet transmission in addition to a noticeable colour change (Koller, 1965). Now soil solarisation is widely used to describe a treatment in which moist soil mulched for 4-5 weeks before planting with transparent polyethylene film during the hot summer months, to effectively disinfest certain phytopathogenic fungi and weeds (Katan *et al.* 1976, Katan, 1981). Soil solarization, either alone or in combination with organic amendments (Gamliel and Stapleton, 1993, Katan, 1981), and soil flooding in some cases, are (Strandberg, 1987) effective alternatives for control of soilborne plant pathogens in specific areas or under specific conditions. Soil borne diseases viz. Verticillium and Fusarium wilts of several crops have been successfully controlled by solarization, as well as diseases caused by *Bipolaris sorokiniana, Didymella lycopersicil; Phytophthora cinnamomi, Plasmodiophora brassicae, Pyrenochaeta lycopersici, Pyrenochaeta terrestris, Pythium myrothecium, Pythium ultimum, Rhizoctonia solani, Sclerotium oryzae, Sclerotium rolfsii,* and *Thielaviopsis basicola.* Pathogenic fungi including *Pythium irregulare*, *Sclerotium cepivorum*, and *Sclerotinia minor* were reduced in artificially inoculated soils (Stapleton and Devay, 1986).

**Biological Control -** Biological control is the reduction of inoculum density or disease producing activities of a pathogen or parasite in its active or dormant state, by one or more organisms, accomplished naturally or through manipulation of the environment, host, or antagonists, or by mass introduction of one or more antagonists (Baker and Cook, 1974). Biological control represents the introduction of antagonistic microorganisms into the aerial parts of the plant, in the soil or in the rhizosphere or rhizoplane, to control soil-borne pathogens. Biological control agents (BCAs) have been dominated by bacteria (90%) and fungi (10%). Avirulent strains of *Ralstonia solanacearum*, *Pseudomonas* spp., *Bacillus* spp. and *Streptomyces* spp. etc. are some common BCAs (Yuliar *et al.* 2015). The important genera of fungi used as biocontrol agents against plant pathogens are *Trichoderma*, *Gliocladium, Aspergillus, Penicillium, Neurospora, Chaetomium*, *Dactylella, Arthrobotrys*, *Catenaria*, *Paecilomyces*, *Glomus,* etc. To manage soil borne plant pathogens a biocontrol agent needs to either be applied around the plant root or seeds as seed treatment (Brown, 1974; Cook and Baker, 1983; Harman, 1991; Whipps, 1997) or to be directly incorporated in the soil. It is very difficult to achieve disease suppression for very long by introduction of a single biocontrol agent to soils. The introduced BCA will take time to be established in the soil and may not be competitive with existing microorganisms. Main mechanisms involved in biological control are mycoparasitism, antibiosis, competition and inactivation of pathogenic enzymes, induced resistance and growth promotion etc. Suppressive soils may provide long term protection against soil borne plant pathogens (Liu and Baker, 1980), along with altering the microclimate near plant roots by using organic amendments beneficial for plants but harmful for the pathogens (Cook and Baker,1983). Despite of numerous reports on mycoparasitism and suppressive soils, biocontrol of soil borne fungi is not a practical reality and commercially feasible (Singh and Sachan, 2013). Therefore, to apply biocontrol agent in the soil, incorporation of FYM enriched with biocontrol agents has been recommended. Various reports on the failure of biocontrol agents under field condition are attributed mainly to its lacking to establish and occupy the new ecological niches to displace the pathogen.

**Organic amendments -** Historically, organic amendments such as animal manure, green manure, composts and peats have been used for increasing productivity of the soil even before the development of chemical fertilizers. They are known to improve plant health and increases crop yield by reducing pathogen populations (Lazarovits *et al.* 2000) both in conventional and organic agriculture system (Cavigelli and Thien, 2003), and decrease the incidence of disease caused by soilborne pathogens (Litterick *et al.* 2004). There are many examples of incorporating organic matter such as dry or green oat, barley, maize, tree bark and chicken manure for the control of *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, and *Thielaviopsis* spp. etc. (Cook and Baker, 1983). Several reports worldwide suggested the use of organic amendments effectively control soilborne diseases caused by *Fusarium* spp. (Szczech, 1999), *Phytophthora* spp. (Szczech and Smolinska, 2001), *Pythium* spp. (McKellar and Nelson, 2003; Veeken *et al.* 2005), *Rhizoctonia solani* (Diab *et al.* 2003), *Sclerotinia* spp. (Boulter *et al.* 2002), *Sclerotium* spp. (Coventry *et al.* 2005), *Thielaviopsis basicola* (Papavizas, 1968) and *Verticillium dahliae* (Lazarovits *et al.* 1999) etc. A number of mechanisms have been proposed to explain the benefits of organic amendments such as stimulation of natural enemies of plant pathogens (Hoitink and Boehm, 1999), fungistasis effect (Lockwood, 1990), release of fungitoxic or nematicidal compounds during organic matter decomposition (Tenuta and Lazarovits, 2002a; Ferraz and de Freitas, 2004), improved plant tolerance (Melakeberhan, 2006) , alteration in soil structure and ecology (Muller and Gooch, 1982 ) or induction of systemic resistance in the host plants (Pharand *et al.* 2002). In general, residues from previous crops are convenient to use as organic amendments. Low nematode population levels have been reported by using crops such as sunn hemp or marigold because they are poor or non-hosts of various nematodes (Hooks *et al.* 2010; McSorley, 2011).

However, despite the potential value of organic soil amendment, there are several concerns about its efficacy, inconsistency in reducing diseases and potential side-effects that limit practical applications. There are some reports indicating that the effectiveness of organic amendment is variable and, in some cases, could enhance disease severity (Tilston *et al.* 2002). Organic amendment were reported to provide substrate for saprophytic growth , thereby increase inoculum of pathogenic fungi and Oomycetes (Manici *et al.* 2000), or negatively affect the crop by releasing phytotoxic compounds (Bonanomi *et al.* 2006) that could damage plant roots and predispose them to pathogenic attack (Ye *et al.* 2004). These inconsistent disease control results obtained with OM amendments, suggests they could cause both suppressive (disease reduction) and conducive (disease increase) effects. In addition, despite extensive research, the effect of different OM amendments on management of soilborne plant pathogens is not always significant (Termorshuizen *et al.* 2006).

**Green Manuring -** Green manuring is a traditional technology has been used to enhance soil fertility since ancient times (Bailey and Lazarovits, 2003). Green manures are soil fertility building crops, grown for the benefit of the soil, for eg. Legumes or clovers (*Trifolium* spp.), medics (*Medicago* spp.), trefoils (*Lotus* spp.), sanfoin (*Onobrychis viciifolia*), Lupins, *Fenugreek* (*Trigonella foenum-graecum*), *Field beans* (*Vicia faba*), Peas (*Pisum satvium)*, Cow pea (*Vigna unguiculata* or *Vigna sinensis*)*;*Cereals, Rye (*Secale cereale*), Oats (*Avena sativa*) or barley (*Hordeum vulgare*), Grasses, *Perennial ryegrass* (*Lolium perenne*), Timothy (*Phleum pratense*), *Fescues* (*Festuca* spp.), *Brassicas*, Buckwheat (*Fagopyrum esculentum*) etc. Green manures add organic matter to the soil, improves its physical and biological properties and therefore, assist with pest, disease and weed management. The process of growing of plant material, usually legumes for the purpose of incorporating it into the soil is called as green manuring. Green manure of *Brassica* can also act as trap crops (Thorup-Kirstensen *et al.* 2003) and widely known for its potential to manage different soil borne plant pathogens. The well documented case of their use for trap crop is for the control of sugarbeet nematode (*Heterodera schactii*) in North Europe (Muller, 1999). In this case the *Brassica* are invaded by nematodes, which then develop within the root, but their sexual differentiation disrupts, resulting in very few numbers of females in subsequent generations, thus causing decline in nematode population. Yulianti in 2007 found that the addition of *brassicas* green manure to soil at 5% concentration suppressed the saprophytic growth of *Ralstonia solani* for about 82–87% comparing to control. In another experiment, Larkin and Griffin, 2007 found that powdery scab of potato, was reduced by green manuring of Indian mustard, rapeseed and canola by 15–40%. Moreover canola and rapeseed reduced black scurf by 70–80% and in *in vitro* assays, volatiles released from chopped leaf material inhibited growth of a variety of soilborne pathogens of potato, including *Rhizoctonia solani, Phytophthora erythroseptica, Pythium ultimum, Sclerotinia sclerotiorum,* and *Fusarium sambucinam,* with Indian mustard resulting in nearly complete inhibition (80–100%).

Recently, green manure amendments of rapeseed and Ethiopian mustard were reported to significantly reduced disease incidence of Fusarium basal rot (FBR) of shallot by 21% and 30% and disease severity by 23% and 29%, respectively (Sintayehu *et al*. 2014). The use of mustard (*Brassica* spp. and *Sinapis* spp.) as green manures and seed cakes provide promising alternatives to synthetic chemical fumigants and make it a reasonable choice for development of new technologies like biofumigation.

**Biofumigation -** The use of mustard (*Brassica* spp. and *Sinapis* spp.) green manures and seed cakes provide promising alternatives to synthetic chemical fumigants and the word biofumigation was coined. The term biofumigants is usually applied to those plants, which contain considerable quantities of glucosinolates (GLS), which are organic compounds containing sulphur (Clarke, 2010). *Brassicas* are known to have this compound in their cells; therefore, they are very important as a biofumigant. Other important biofumigants are sorghums, capsicum, marigolds, organic manures and swine manures etc. some fungal agents like Muscodor albus and *Ceratocystis fimbriata* are also known to control post harvest diseases of stone fruits, citrus and grapes etc.
Biofumigation of soil controls a number of weeds, nematodes and a variety of fungal soil-borne diseases but bacteria are less prone to it. Biofumigation is a novel method for controlling a range of post harvest diseases of fruits. For eg. volatiles produced by *Muscodor albus,* a mixture of low molecular weight compounds, are biocidal or biostatic to a broad variety of microorganisms (Strobel *et al.* 2001; Worapong *et al.* 2001), including *Botrytis cinerea, Geotrichum citri-aurantii, G. candidum,Monilinia fructicola*, *Penicillium digitatum,* and *P. expansum* (Mercier and Jiménez, 2004; Mercier and Smilanick, 2005.). Placement of *Muscodor albus* inside grape packages significantly controlled gray mold and may be a feasible approach to manage postharvest decay of table grape (Gabler *et al.* 2006).

## Conclusion

Soil-borne plant diseases like root rots, collar rots, wilts and damping off etc. cause serious yield losses in almost every agricultural, plantation and vegetable crops. The host range of soil-borne plant pathogens viz. *Rhizoctonia solani*, *Fusarium oxysporum*, *Verticillium*, *Sclerotium rolfsii*, *Sclerotium scerotinia*, *Phythium* and *Phytophthora* etc. is very wide. Conversely, the occurrence of soil borne plant diseases is very rare in natural or undisturbed ecosystem but they are very destructive for conventional production system. Traditionally, management of soil borne diseases was often based on the application of chemical soil fumigants like methyl bromide, metham sodium, chloropicrin etc. which was successful in managing the problem. With the realization of ill-effects of these chemical soil fumigants to the environment, humans as well as animals, efforts were started to find out some alternatives to them. Soil borne plant pathogens flourish well in unhealthy soil which is deprived of nutrition and beneficial microflora and fauna. Therefore, the key for their management resides in keeping the soil healthy with the incorporation of green manures, mulches, organic amendments and composts etc. These products not only improve soil fertility but also make it suppressive for soil-borne pathogens. Therefore, they should be used more frequently for the management of plant pathogens in the soil. More research should be done on these technologies and their implementation at the farmer's level should be made.

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