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Root disease management in organic agriculture

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Abstract

Conventional farming practices with time have led to decline in soil structure, fertility and microbial diversity and simultaneously given rise to many soil and root borne diseases. Root diseases are more damaging when soil conditions are poor as a result of inadequate drainage, poor soil structure, low organic matter and low soil fertility. In organic farming systems, famers practice many cultural measures like cultivar choice, promotion of soil health by organic amendments, low tillage and natural habitat diversification. Pathogen suppression under organic farming depend upon quality of residues, stage of their decomposition, microbial activity, microbial population dynamics, nutrient concentrations and other associated chemical and physical factors. Organic amendments coupled with no pesticide use enhance both microbial diversity and biochemical activities in soil which decrease disease inoculam through competition and antibiosis mechanisms and increases defense mechanism by antioxidant production. In organic systems plant roots get better colonized by mycorrhizal fungi which protect them from root invading pathogens. Organic farmers also use biological control agents and natural toxic compounds of plant extracts; however, these are methods of last resort.

Key words: Root disease, Organic farming, Cultural control, Management.

Introduction

There is considerable interest in substituting biologically-based inputs for chemicals to manage plant diseases because of concerns over environmental or human health. One such approach is to apply organic amendments to soils to suppress soil-borne diseases (Boehm and Hoitink, 1992). Organic matter is known to improve soil aeration, structure, drainage, moisture holding capacity, nutrient availability, and microbial diversity (Davey, 1996). Organic soil amendments also led to pH stabilization and faster water infiltration rate due to enhanced soil aggregation (Stamatiadis *et al*., 1999). The living components in soils require carbon as an energy source, but there has been a “chemical drip” for the past 50 years with little organic energy input to the system. These production changes have been detrimental to soil health and water quality, leading to an increase in plant diseases and other pest problems (Hoitink and Boehm, 1999).

Soils in organic production systems lost less nitrogen into nearby water systems than did conventional production systems (Liebhardt *et al*., 1989). The amount of soil nitrogen in fields under conventional production systems has been negatively correlated with soil microbial components, whereas soil nitrogen in fields under organic production was positively correlated with soil microbial components (Gunapala and Scow, 1998). Natural pathogen control is not only conserved but is also promoted in organic farming conditions. Most soilborne plant pathogens causing root and foot rots in older plants are usually less prevalent in organic than in conventional farms (Van Bruggen and Termorshuizen 2003). Table (1) lists some examples of field comparisons between organic and conventional agriculture in different crops and location. The mechanisms involved in disease suppression are varied and complex and may differ depending upon the pathogen involved.

Organic amendments added to the soil can induce disease suppression by stimulating antagonist microorganisms (Cook, 1990). The addition of readily available C to the soil, such as a green manure, compost, or plant litter stimulates microbial activity and could cause intense competition for resources which reduces fungal activity (Campbell, 1989). Suppression of disease is also due to parasitism by a biological control agent that feeds directly on the pathogen resulting in a destruction of pathogens (Chernin and Chet, 2002). Disease suppression depends on the specific material used as amendment and its chemical and biological composition (Van Bruggen and Semenov, 2000). Endophytes can also act as biocontrol agents and reduce the diseases by production of antibiotic agents (Lambert *et al*., 1987), siderophore production (Kloepper *et al*., 1980), nutrient competition (Kloepper *et al*., 1980), niche exclusion (Cook and Baker, 1983), and induction of systemic acquired host resistance (Chen *et al*., 1995).

Arbuscular mycorrhizal fungi (AM fungi) are an important part of the soil microbial community, forming a symbiotic relationship with many crop species. The host plant can benefit in a number of ways, including reductions in damage by soil pathogens (Pozo *et al*., 2002), improved water relations (Augé, 2004) and enhanced uptake of some micronutrients (Kothari *et al*., 1991). Organic systems avoid some of the practices most detrimental to AM fungi, such as use of soluble P fertilizers and as a consequence are likely to exhibit increased levels of mycorrhizal colonization in crops and increased numbers of propagules in the soil (Table 2). However, results published thus far are contradictory, some suggesting a benefit from organic farming (Entz *et al*., 2004; Galvan *et al*., 2009; Oehl *et al*., 2003, 2004) .

Manures and Composts

Manures contain volatile fatty acids (VFA) such as acetic, propionic, butyric, isobutyric, and valeric acid (Tenuta *et al*., 2002) that suppress root diseases. About 65% of the manures tested had sufficient concentrations of VFAs to be considered as potentially pathogen suppressing. It was also evident that the predominant species present increase in response to manure application.

Most notably, populations of the fungus *Trichoderma* had increased in several of the treated soils, which may indicate that manure reduces disease severity through the stimulation of microflora with biocontrol properties. Disease suppressive conditions have been obtained in soils following addition of certain composts in greenhouse production systems (Hoitink and Boehm, 1999). Composts have also been found effective as biocontrol agents under field conditions (Keener *et al*., 2000). Of 17 organic composts made from household waste, nine were found to be mildly suppressive and the rest had no effect in reducing *Pythium* damping-off (Erhart *et al*., 1999). Only bark compost was strongly suppressive but its activity could not be related to total biological activity or phenol content of extracts. Dissanayake and Hoy (1999) showed that stubble decline of sugarcane caused by *Pythium arrhenomanes* Drechs. was reduced following applications of composts prepared from cotton gin trash, cottonwood mixed with pine bark or mixed hardwood, municipal biosolids, and sugar mill filter press cake. These materials also stimulated plant growth. Since steam treatment of the amendments before their application eliminated disease suppressive activity, plant growth stimulation was attributed to biological rather than nutritional causes. Green manures also generate by-products of anaerobic fermentation. Studies have shown that *R. solani* suppression is influenced by the type of compost incorporated (Stone *et al*., 2004). While the majority of composts are reported to suppress diseases caused by *Pythium* and *Phytophthora* spp., only a few provide consistently high levels of suppression against *R. solani* (Stone *et al*., 2004). Joshi *et al*., 2009 observed higher disease suppression of *R. solani* by the poultry manure (PM) and plant based compost (LC and UC) treatments as compared to FYM, VC and SMC as shown in Table (3).

Bareeja *et al*. (2010) observed that soil amendments significantly reduced plant mortality from charcoal rot as compared with the unamended control in both years of the field experiment (Table 4). A significant increase in microbial activity in the composted soil, compared with the unamended soil, reflected the greater microbial population and biomass. Microbial activity and charcoal rot incidence were inversely

Table (1): Comparisons of disease levels of some important crops under organic versus conventional management

Crop	Management practices in organic crops	Consequence as compared to conventional	References
Almond	A mixed cover crop, no fertilizers and pesticides	Increased microbial communities	Teviotdale and Hendrics, 1994
Cereals	Organic practices(no fertilizers and pesticides)	Reduce incidence and severity of root rots	Van Brugen, 2003
Potato	Absence of fungicides or only copper fungicides	Reduced *verticilium dahlia*	Lazarovits, 2001
Tomato	Biological insecticides, and living mulch cover crops and composted manure	Lower severity of corky root rot, pythium and phytopthora root rot	Clark *et al*., 1998
Grapes	Cover crops	Reduced severity of fungal root rots	Clark *et al*., 1998

Table (2): AMF spores and root colonization of onion plants grown on conventional and organic soils in England in glasshouse experiment.

Site	AMF Spores(per g-1 Soil)		Root length colonized(%)	
	Conventional	Organic	Conventional	Organic
Cirencester	3.87	27.15	20.1	57.3
Coxwell	8.89	11.02	43.1	83.8
Dugglyby	11.76	12.14	12.0	64.9
Terrington	3.30	10.06	3.8	51.9
Wellesbourne	1.81	1.55	34.4	38.9
Ryton	0.53	1.39	25.5	43.3
Kirton	10.46	14.62	20.02	53.0
SD	4.03	7.79	14.2	14.3

Table (3): Effect of different composts and compost extracts on root rot disease of French bean (Joshi *et al*., 2009)

Treatments	Root rot colonization			
	2005	% Reduction	2006	% Reduction
FYM	43.7	16.8	21.1	20.4
PM	34.4	34.3	13.3	49.8
VC	49.0	6.7	21.6	18.5
LC	28.7	45.3	13.8	47.9
UC	35.0	33.3	17.5	34.0
SMC	42.7	18.7	19.3	27.2
Chemical	28.2	46.3	12.0	54.7
Control	52.5		26.5	

FYM: Farm yard manure, VC: Vermicompost: PM: Poultry manure, LC: Lantana compost, UC; Urtica compost, SMC; Spent mushroom compost correlated only at 20 DAP, which indicated that *M. phaseolina* infected the seedlings either at this stage or just before, but that it was not expressed until late in the season. A Study had reported that microbial activity and microbial biomass are the main predictors of disease suppressiveness, where an inverse correlation exists (Boehm and Hoitink, 1992).

Van Bruggen (1995) indicated that in soils from organically managed farms, lower incidence of corky root rot disease was correlated to unspecified biological soil characteristics, whereas reduced root infection by *Phytophthora parasitica* (Dastur) When soils from organically managed farms were sterilized by irradiation, corky root rot incidence increased suggesting that it was a biological rather than a chemical or physical process that was involved in disease suppression. Davis *et al*. (1996, 2001) showed that the incidence of *Verticillium* wilt decreased after 2 years of green manuring although inoculum levels of the pathogens stayed the same, or in some cases increased 2–4-fold. The diversity of the fungal flora on the roots was increased over soils that were continuously planted to the same crop. Van Bruggen (1995) found that cellulolytic and hemicellulolytic actinomycetes were present in much higher numbers in organically amended soils than those using chemical fertilizers. Knudsen *et al*. (1999) tested the effect of organic versus conventional management on incidence of brown foot rot of cereals caused by *F. culmorum*. The organic treatments provided a disease suppressive environment, but disease suppression was not as high when the inoculum was placed directly on the seed. Disease supressiveness of some composts is given in Table (5).

High nitrogen amendments

High nitrogen amendments such asbone meal, soymeal, and poultry manure significantly reduce the incidence of *Verticillium* wilt, common scab of potato, and plant parasitic nematode populations (Conn and Lazarovits, 1999). Considerable evidence has accumulated to support the view that ammonia liberation following application of high-N amendments is responsible for killing pathogens (Stirling, 1991). This may explain why amendments with a low C:N ratio (<10) are most often found to suppress plant disease. Tenuta (2001) confirmed that ammonia was responsible for killing *V. dahlia* in soil. Soils that readily accumulate ammonia may require lower rates of amendments to kill pathogens. Since the equilibrium point of ammonia declines with increasing temperature, applications combining soymeal or poultry manure with soil heating using solarization have been more effective at controlling disease than either treatment alone (Gamliel *et al*., 2000). Even pathogens considered to be heat tolerant were controlled by this treatment. Tenuta and Lazarovits (2002) found that microsclerotia of *Verticillium* also died at low amendment rates (<1% of soil mass), but only after 2 weeks. Ammonia was not present in sufficient levels to account for this kill and by the time fungal death had occurred, the soil pH had declined to below 7 and ammonia could not be involved. However, the nitrification products, nitrite and nitrate, were detected (Tenuta and Lazarovits, 2002). Under acidic conditions nitrite forms nitrous acid (HNO_2) which can kill microorganisms, including pathogens (Michel and Mew, 1998). When nitrification is inhibited by addition of dicyandiamide, no nitrous acid is formed and microsclerotia survive (Tenuta and Lazarovits, 2002). The accumulation of nitrous acid is regulated by more complex factors including the rate of ammonia and nitrite formation and abiotic reactions that removed them. Nitrous acid occurred only in mineral soils receiving <0.5% meat and bone meal where the soil pH in water was less than 6.0 and the rate of nitrification was rapid. In all instances addition of high nitrogen organic amendments reduced the populations of plant pathogens, but the populations of soil bacteria and fungi increased by two to three log units. Table (6) shows the positive correlation of some root disease with the total nitrogen, thereby supporting the use of manures and composts which release the nitrogen slowly instead of synthetic fertilizers which release the nitrogen at fast rate.

Cover crops

Cover crops are typically grown during the off-season with an annual cash crop. Cover crops have usually been turned under prior to planting the cash crop. When they are incorporated into the soil they become a green manure. Cover crops may or may not have any harvestable yield value.

Table (4): Effect of compost-amendments on severity of dry root rot of cowpea (Bareeja *et al*., 2010)

Compost amendments'	Dry root rot mortality	
	2001	2002
Calotropis procera	07.5 (15.85)	05.0 (12.72)
Prosopis juliflora	07.9 (16.28)	03.8 (11.04)
Azadirachta indica	04.6 (12.36)	08.2 (16.29)
Acacia nilotica	05.9 (14.02)	05.2 (12.83)
Farm yard manure	08.5 (16.98)	06.5 (14.78)
Unamended soil	11.9 (20.14)	11.1 (18.97)
C.D.	2.43	3.11

The figures in parenthesis are angular transformed values

Table (5): Disease suppressiveness(%) of some composts in 5 pathosystems (Termorshuizen *et al*., 2006)

Compost	*Verticilium dahliae* (egg plant)	*R. Solani* Cauliflower	*P. nicotianae* Tomato	*R. solani* Pine	*F. oxysporium* Flax
Horse manure	87.6	50.6	n.d.	-7.1	71.9
Tree bark, slurries and green wastes	34.8	32.1	37.9	8.4	65.2
Urban biowastes of wine grapes	46.6	2.4	32.4	92.6	56.1
Woody wastes and poultry manure	59.1	-10.1	85.7	27.2	65.9
Spent mushroom compost	37.7	35.3	92.1	1.8	63.8
Wood chips, horse manure	49.9	12.4	n.d	15.4	58.2
Muncipal sewage, sludge, yard waste	34.5	87.3	6.3	83.5	2.1
Yard waste (wood materials, grass clippings)	-21.1	57.8	84.8	0.9	64.2

Table 6. Correlation between incidence of various foot and root rots and total nitrogen applied as fertilizer or manure (Van Brruggen and Termoshuizen, 2003)

Foot/root disease	Pathogen	Correlation coefficient
Fusarium rot	*Fusarium culmorum*	0.85
Fusarium snow mould	*Gerlachia nivalis*	0.87
Fusarium scab	*Fuarium graminium*	0.97
Eye spot	*Pseudocercoporella herpotrichoides*	0.79
Sharp eye spot	*Rhizoctonia cerealis*	0.72

However, they have been demonstrated to reduce erosion (Creamer *et al*., 1997), improve the physical characteristics of the soil (Reid and Goss, 1981), and reduce plant diseases (Sumner *et al*., 1981). Green manures have also been shown to increase soil organic matter (Allison, 1973), increase microbial activity (Harris *et al*., 1994), and suppress plant diseases (Viaene , 1996). Results of a greenhouse test have shown that green manures of the cover crops included differed significantly in their suppression of root rot severity and damage to bean growth. In addition, differential effects of green manures of various cover crops on the severity of root rot and bean yield have also been observed under field conditions.

Impact of soil health management practices on soilborne pathogens

All cultural practices are known to directly or indirectly affect populations of soilborne pathogens and the severity of their resultant root diseases. Soil biology is a major component and contributes significantly to soil quality and productivity. The major activities of soil microbes include the decomposition of organic materials, mineralization of nutrients, nitrogen fixation, suppression of crop pathogens and protection of roots. Tillage practices that reduce soil compaction, increase drainage, and increase soil temperature reduce the severity and damage of root rot pathogens to many vegetables. Loosening the soil by breaking hard pans and subsoiling after seedbed preparation were found to reduce *Fusarium* root rot damage and increase yield of beans (Burke *et al*., 1972). The beneficial effect of loosening the soil on bean yield was attributed mainly to the greater penetration and greater formation of roots, especially at deeper soil depths where the densities of root rot pathogens is rather low. Deep plowing and turning under of infected crop residue have been shown to reduce a number of bean diseases such as *Rhizoctonia* root rot (Lewis *et al*., 1983) and to increase colonization of bean roots by beneficial mycorrhizal fungi (Mulligan *et al*., 1985). Results from reduced tillage experiment showed that beans grown in the rototilled and chisel-plowed plots had significantly higher root rot severity than those grown on the normally-plowed(moldboard) plots established in a heavily infested field with root rot pathogens (Abawi and Crosier, 1992). Continuous cropping with a susceptible host, or susceptible alternate hosts, can result in the build-up of soil populations of specific plant pathogens, resulting in a decline in crop yield and quality (Honeycutt *et al*., 1996). Rotating crops with plants less susceptible to specific pathogens causes a decline in populations of the pathogen due to natural mortality and the antagonistic activities of co-existent root zone microorganisms. Choice of crop in a rotation may garner microbial benefits beyond those normally associated with pathogen host range and saprophytic pathogen survival. For example, analysis of microbial populations in plant tissues and soils when clover preceded potato in a rotation revealed that 25 bacterial species were common to both clover and potatoes and represented 73% of culturable bacteria recovered from clover roots and potato tubers (Sturz*et al*., 1998). Of the bacteria tested, 74% showed in vitro antibiosis to *Rhizoctonia solani* Kuhn, 1858 (Sturz *et al*., 1998). More bacteria inhibitory to *R. solani* were found within plant tissues than in the root zone, emphasizing that adaptation of bacteria to host plants can result in the expression of a mutually beneficial relationship (Sturz *et al*., 1998). Plants under monoculture have been shown to support and respond to populations of rhizosphere microorganisms antagonistic to their pathogens. Rhizosphere inhabiting bacteria can be crop specific (Glandorf *et al*., 1993). Reduced tillage practices, or conservation tillage systems as they are also known, include no-till and minimum tillage regimens (Bailey *et al*., 2001; Sturz *et al*., 1998).

Intercropping cumin, anise, onion and garlic decreased damping-off and root rot diseases of lentil significantly. Anise caused the greater effect than other tested crops under greenhouse and field conditions, while intercropping onion recorded the lowest effect. On the other hand, garlic intercropping produced the highest lentil seed yield (Table 7).

Armanious, 2000 reported that cotton, onion or cucumber intercropping suppressed cotton root rot and wilt diseases. Garlic intercropped with Brussicasp could also alleviate white rot of garlic (Zewde *et al*., 2007). Also, watermelon intercropped with aerobically growing rice controlled Fusarium wilt disease in watermelon (Ren *et al*., 2008).

Table (7): Damping-off and root rot severity on lentil plants caused by *Rhizoctonia solani* as influenced by the preceding crops and intercrops (Abdel-Monaim *et al*., 2011)

Preceded crop	% Damping off	% Root rot
Okra	30.0	14.1
Sesamum	52.5	19.71
Sorghum	40.0	14.7
Maize	45.0	17.9
Millet	30.0	16.3
Cowpea	30.0	10.0
Groundnut	75.0	21.9
Gaur	27.5	12.3
Soybean	75.0	23.9
Intercrops	% Damping off	% Root rot
Cumin	24.3	11.5
Anise	12.4	8.6
Onion	21.0	12.9
Garlic	15.9	10.0
Control	30.5	17.8

The preferred characteristics of a cover crop for suppressing damage by root pathogens are that it is a non-host or poor host to the target pathogen(s) and that it would also suppress the existing soil population of the pathogen(s) when incorporated as a green manure. Crop rotation is one of the recommended agricultural managements for increasing crop production as well as diseases control, especially those caused by soil-borne fungi. The highest decrease of damping-off and root rot as well as production of the highest seed yield was recorded when lentil was cultivated after cowpea and gaur. On contrary, cultivation of soybean, sesame and groundnut before lentil increased damping-off and root rot severity and decreased seed yield.

Prevention of pathogen establishment in organic farming

Colonization of agricultural environment by pathogens is prevented through sanitation, source isolation, and other protective measures. Practices to prevent colonization and establishment of pathogens via sanitation, clean seeds or vegetative propagating materials, crop rotation, adjustment of planting time, removal of certain weeds are more important for organic farming because curative measures are restricted here. Pathogens can be avoided by adapting the crop planting time or rotating crops that harbor different suites of pathogens (temporal isolation). The time between rotations of a particular crop is usually longer in organic than conventional field crop production (5–8 years v 2–3 years). Successive planting of the same crop is not permitted in organic farming but rotation times are minimized in organic greenhouse production as only high value crops with similar cultural practices can be grown such as tomato, sweet pepper and cucumber in rotation. Invasion biology and Meta population theory claim that organisms can be prevented from spreading into patchy islands when the distance between patches is large. Therefore, crop fields can be isolated from source pools by keeping large distances between fields with the same crop. In organic agriculture with longer rotations, the patch sizes (fields with a certain crop) are frequently smaller than in conventional agriculture. Moreover, fields are often separated by strips of natural vegetation on organic farms. Thus, crop plants can be pathogen-free as a consequence of locating fields distant from colonizer pools.

Regulation of established pathogens

Once a pathogen becomes established in the soil various processes act either to enhance its abundance or to suppress its abundance and spread (persistence at low levels). These processes involve either host or product quality or the presence of suppressive agents in the community that regulate population growth of the pathogen in the crop environment. In addition, physical impedance to spread by enhanced distances between hosts or physical barriers contributes pathogen regulation. Indeed, crop resistance to pathogens is a mainstay of organic agriculture. Resistance to pathogen exploitation is brought about by selecting varieties with genetically based resistance traits, managing the phenotype, health and nutrient concentration to reduce its suitability for pathogens, or managing crop and non-crop vegetation to reduce the concentration of food plants for pathogens.

Host plant resistance

Host plant quality is optimized for crop protection by adequate nutrient status and maintenance of health by the balanced nutrition and toxic or repellent properties are sufficient to directly reduce pathogen exploitation and survival. The decision to use a resistant variety is set for the season as its use will be determined by the probability of invasion, the severity of pathogen, any associated loss of yield quality or quantity, marketability, complementarily with other crop protection tactics, and the effectiveness of the resistant cultivar against the target and other possible exploiters. Depending on the target pathogens, plant quality-based resistance can be induced by regulating the type and quantity of nutrients and moisture applied to the crop. For example water shortage accelerates the breakdown and mobilization of proteins and enriches the phloem nutrient quality for aphids, whereas excess moisture may predispose the crop to root-rotting pathogens. Thus, management practices can enhance or reduce host plant resistance by regulating the quality of food source for pathogens (Letourneau, 1997). Likewise, certain physiological conditions increase the incidence and severity of disease, and can be mitigated by management practices. For example, high N concentrations in soil and plant tissues may predispose a crop to diseases like powdery mildew, rust and certain root-rotting pathogens (Daamen *et al*., 1989). However, shortages of some elements may also enhance the susceptibility to certain diseases; for example, K shortages increase the risk of *Verticillium* wilt in cotton, and calcium (Ca) shortages enhance susceptibility to *Pythium* root rot (Engelhard, 1989).

Inherently resistant cultivars have been available for many crops, providing resistance against diseases caused by fungi, bacteria, viruses and nematodes. For example leaf toughness forms a significant impediment to pathogen ingression on many crops (Agrios, 1997). Alkaloids such as nicotine, glucosinolates and cyanogenic glycosides, found in tobacco, cabbage and cassava respectively, are not only toxic to most herbivores but also to many plant pathogens (Agrios, 1997). If a single gene governs resistance to pest exploitation, a cascade of biochemical reactions is usually triggered by a particular elicitor of a pathogen, resulting in strong resistance. In many cases a pathogen population can adapt relatively easily to this kind of resistance through heavy selection pressure, while counter-resistance is not so easily selected against multiple, mild resistance factors. For this reason, organic growers prefer to use plant cultivars with broad resistance based on multiple genes. For the same reason, many organic growers prefer open-pollinated varieties over hybrids. Moreover, mild resistance based on multiple genes can still be effective, when combined with other tactics such as biological control of pathogens or vectors, even when it is insufficient to control a pathogen (Wyss *et al*., 2001).

Community resistance – vegetation, pathogens and biological control

A mixed cropping or mixed varietal scheme reduces the concentration of suitable food plants for pathogens that are specialized on a subset of the plants or varieties grown in the mixture (Mundt, 2002). Spread of plant pathogens is inhibited by resistant components in the mixture forming obstacles and traps. Intercropping is an integral part of many low-input, traditional cropping systems in the tropics, but is only occasionally used for products destined for the organic market, especially in temperate regions. Organic practices that promote the richness of plant-supported microbes and herbivores in the community can cause such a 'dilution effect' of the pestiferous taxa, thus reducing crop injury levels and yield loss. Organic crop production relies on the suppression of pathogens and pests through the introduction, conservation or enhancement, or augmentation of predators (or parasitoids).

Natural biological controls of pathogens are enhanced in organic systems that foster and maintain biodiversity through limited use of disruptive curatives coupled with vegetation management (Barbosa, 1998). Plants growing within and near the crop field offer resources for natural enemies such as alternate hosts, pollen or nectar, as well as microhabitats that are not available in weed-free monocultures (Letourneau and Altieri, 1999) or extensive cropping operations with little non-crop vegetation. Microbial communities in organically managed soils are often highly diverse compared to simpler systems managed with low vegetation. Consequently, plant pathogens are frequently suppressed in organic farming systems by enhanced microbial complexity and activity, brought about by regular soil amendment with recalcitrant organic materials like mature composts and manure (Van Bruggen and Termorshuizen, 2003, Litterick *et al*., 2004).

Curative control

There are limited options for curative control allowed under organic agriculture, which vary from country to country. Table (2) provides a representative list of botanically derived pesticides, microbial agents and other naturally available materials typically approved under organic standards. These materials vary in their toxicity levels and non-target effects. In many countries, copper fungicides are allowed for persistent problems such as the control of late blight on potatoes and downy mildew on grapes. Similarly, sulfur fungicides are used to control powdery mildew on various crops and scab (*Venturia inaequalis*) on apples and pears. The number of sulfur sprays may even exceed that of synthetic fungicides in conventional apple production, but the environmental impact may still be lower (Spruijt-Verkerke *et al*., 2004).

The environmental impact of copper can be significant, considering the broad impact spectrum and the tendency to accumulate in soil. Some synthetically produced curatives, such as pyrethroids, are allowed for certain uses as an exception to the rule. However, the organic regulations are adjusted constantly, and curative applications are becoming more restricted. For example, copper fungicides are already banned in many countries. Compost extracts are used more frequently, and are commercially formulated. They can be very effective in disease control, depending on the starting material, the composting and fermentation procedures, and the final microbial activity. Curative biological control can be accomplished by inundative release of selected biocontrol agents. Although many specific biological control agents against plant pathogens have been identified, relatively few species have been registered for field use, primarily fungi and bacteria for pathogen control.

Conclusion

Organic soils had a higher biological diversity and activity in the soil and are more stable systems with a larger soil health. The main reasons for the higher biodiversity in the organic soil is due to Improved soil health which results due to lower plow depth and especially the use of the organic amendments and the absence of artificial fertilizer, which results in lower nitrate levels and a higher biodiversity. Root disease severity is generally decreased after few years of conversion in organic farming through competition, parasitism, antibiosis, SAR and increased mycorrhizal colonization. Sometimes initial increase is observed due to inexperience of the farmer. Therefore, it is important to develop indicators for ecosystem health and understand the factors that lead to disease suppression. Even more than conventional farmers, organic farmers need to reach various objectives with a coherent set of cultural practices that will satisfy the requirement of sustained profitability.

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