Mycopath (2011) 9(2): 87-93

Research Article

Relationship between soil physicochemical characteristics and soil-borne diseases

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Abstract

Soil-borne pathogens cause about 90% of major plant diseases. Pathogen population densities and infection frequencies vary widely with soil physicochemical characteristics which in turn have complex broad ranges differ with time and space. It is a difficult task to change a soil property in favour of particular crop disease suppression and if achieved that alteration influences the health of other crops sown in the same field in next season. A number of articles elaborate the effects of different soil characteristics on a particular disease or diseases of a particular crop. A little or no effort is done to sum up the impact of a particular soil character on a number of diseases of different crops. In this article important soil characteristics are discussed with relation to suppression of diseases of different crop plants. The soil physiochemical characteristic can play vital role in microbial growth, sporulation and diversity and ultimately disease incidence.

Key words: Disease suppression, soil-borne diseases, soil characteristics.

Introduction

Soil is a diverse medium and habitat for large number of complex microbial populations. Some microbes are beneficial and some are harmful for plants, as causal agent of different diseases. Every type of soil has a unique set of inherent as well as acquired physicochemical characteristics. The influence of these characteristics on soil borne diseases is discussed under the following headings.

Soil physical condition

Although the effect of soil physical characteristics on growth and distribution of soil-born plant pathogens is not well documented, however, some sweeping statements are available. In compacted and poor structured soils, Alabouvette *et al*. (1996) reported an increase in incident of diseases caused by *Phytophthora* spp. and *Verticillium* spp., whereas reduction in diseases due to *Rhizoctonia soloni*. Furthermore, soil compaction boost up root rot of white bean (Tu and Tan, 1991), common root rot (Fritz *et al*., 1995) and *Aphanomyces* root rot of pea (Allmaras *et al*., 2003), crown rot of barley, root rot of soybean (Sturz and Carter, 1995), wilt and root rots of chickpea (Bhatti and Kraft, 1992), black root rot in strawberry (Wing *et al*., 1995) and cereal root rot (Sturz *et al*., 1997). Increase in fungal infection due to compaction might be owing to the restricted root growth and development of lateral root branches which in turn release more root exudates per unit soil volume (Russell, 1975). As a contradiction, uncompacting enhanced *Microdochium nivale* induced foot rot (Colbach *et al*., 1996) and sharp eyespot of wheat (Colbach *et al*., 1997).

Soil compaction not only affects the disease incident due to soil-borne pathogens but also the spread of fungus within the soil. Otten *et al*. (2001) observed slighter and slower growing fungal pathozones with increase in soil compaction from 1.3 to 1.5 g cm^{-3} bulk density. Larger soil pores and cracks show more variation in fungal colonization as these act as either channels or obstructions for fungal growth (Otten *et al*., 2004). *Rhizoctonia soloni* is reported to grow predominantly through air filled pore volume and variation in fungal growth distribution was more in the soil then on the surfaces (Otten and Gilligan, 1998; Otten *et al*., 1999).

Soil pH

In humid regions, due to the leaching down of bases, soil pH remains acidic (less than 7). Whereas in arid and semiarid environments, bases (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and CO_3^{2-} and HCO_3^{1-} dominate which produce OH^- and the soil pH exits in alkaline range. Soil pH is the most important soil property which directly effects nutrient solubility and availability to crop plants and indirectly the disease incident. Availability of copper, iron, zinc, manganese and boron decreases whereas that of molybdenum increases with increasing soil pH above 7. Calcium, magnesium, sodium and potassium exist in large quantities in alkaline soils but are not very soluble in neutral and alkaline medium. Optimum concentrations of P are available at a very narrow range of soil pH i.e. 6.5-7.5. Formation of iron and aluminum phosphates in acidic and calcium phosphates in alkaline soils reduces the availability of phosphorus to crop plants. Soil mineral nitrogen (NH^{4+} and NO^{3-}) is less affected and is available at a wide range of soil pH (Khattak, 2001).

Soil pH has a great impact on incidence and severity of a number of plant diseases and its influence might be through changing nutrient status of soil for plants. For example, working with 35 soils, Lacey and Wilson (2001) found that more acidic pH and a lesser incidence of potato scab (Streptomyces scabies). Blaker and MacDonald (1983)showed that the majority of the phytophthora root rot diseases are inhibited by lowpH. and pathogen fail to grow much below 5 (Lambert and Loria, 1989).With soil acidification, suppression of some other diseases like takeall of wheat (Trolldenier, 1981), Phytophthora root rot (Schmitthenner and Canaday, 1983), Take-all patch of turf (Duda, 2008), summer patch of turf (Hill *et al.,* 2003) and sudden death syndrome of soybean (Sanogo and Yang, 2001) is also reported. Johnson and Carrow (1992) reported suppression in centipede decline of centipede turf grass by the reduction of fertilizer application to 100–44–83 kg NPK ha^{-1} and increase in soil pH to 6.2. Other diseases which are favored by acidic soil pH are clubroot of brassicas (Karling 1968) and corky rot of potato (Drinkwater *et al*., 1995).

Nematodes live or at least complete some part of life cycle in the soil. Out of several soil characteristics soil pH is an important factor which affects colonization and densities of nematode population. Different nematode species vary in response to changes in soil pH. *Pratylenchus allenii* nematode (Burns, 1971) and *Helicotylenchus pseudorobustus* nematode (Norton, 1971) colonization of soybean roots was decreased while that of *Hoplolaimus galeatus*, *Xiphinema americanum* and *Tylenchorhynchus nudus* was increased (Norton, 1971) with decreasing soil pH. Population densities of some other nematode species like *Heterodera. avenae* (Duggan, 1963) and *Heterodera glycines* (Francl, 1993; Anand *et al*., 1995) were found positively correlated with soil pH. In a field study, Rogovska *et al*. (2009) reported a decrease in soybean yield with the increase of soil pH, alkalinity stress index and *Heterodera glycines* population densities.

Organic matter

Diseases caused by soil borne pathogens like Phytophthora spp. and Pythium spp. are suppressed in soils, already high in organic matter or by the addition of composts (Hoitink *et al*., 1996; Boehm *et al*., 1997; Benjenana *et al* 2009). Disease suppression with organic amendments might be due to diverse microflora which is associated with partially decomposed organic matter and producing a biological control of diseases caused by Pythium (Hoitink and Boehm, 1999). However, depending upon the type of composted material, duration of disease suppression varied from few weeks to two years (Hoitink, 1980; Hoitink *et al*., 1991). Stone *et al*. (2004) reported that decline in carbohydrate content; microbial activity and biological control agents are some of the factors which results in time based decrease of organic matter mediated dumping off disease suppression.

Compost prepared from waste onion peelings was found to be more effective in reducing viability of sclerotia of *Sclerotium cepivorum* than compost prepared from *Brassica* or carrot wastes (Coventry *et al.*, 2005). In another study hardwood bark compost was found more suppressive to root rot diseases caused by *Phytophthora* than pine bark compost (Spencer and Benson, 1982). Vermi composted cattle manure reduced the severity of Phytophthora root rot of tomato (Szczech *et al*., 1993) and oat straw-chicken manure mixed sand suppressed the same in *Banksia* (Dixon *et al*., 1990).

Primary macronutrients

Availability of primary (N, P, K) and secondary (Ca, Mg, S) macronutrients is not only a limiting factor for growth and development of plants but also affects disease incident and severity. As a general rule increase in nitrogen supply to the crop plants increases the disease incidence (Graham, 1983) particularly if phosphorus and potassium are deficient (Mengel and Kirkby, 1978). Nitrogen enhances the vegetative growth of the plant and creates a carbon sink at growing tips, which in turn extract carbon from the major metabolic processes involved in plant defence against pathogen (Horsfall and Cowling, 1980). Nitrate and ammonium forms of nitrogen are metabolized differently in plant body and plants grow on different nitrogen nutrition vary in response to pathogen attack. Concerning the N content of soil, more associations have been found. A positive association was found between the N content of soil and the suppressiveness towards ectoparasitic nematodes (Rimé *et al.*, 2003), Pseudomonas syringae on bean and cucumber (Rotenberg *et al*., 2005), Gaeumanomyces graminis var tritici (Ggt) and R. solani on wheat (Pankhurst *et al*., 2002), and Fusarium spp. on asparagus (Hamel *et al*., 2005). Whereas, diseases due to *Pythium* and *Ophiobolus* species enhanced with NO_3-N and reduced with NH_4-N (Huber and Watson, 1974). Incidence of corky root of tomato, caused by *Pyrenocaeta lycopersici*, was increased with increasing rate of soil nitrate content and nitrogen in the plant tissue (Drinkwater *et al*., 1995). Thompson *et al*. (1995) reported a suppression of summer patch of Kentucky bluegrass (*Poa pratensis*) by the application of ammonium nitrogen as opposed to nitrate nitrogen.

Owing to the physiological involvement in a number of metabolic processes of plant, phosphorus and potassium play their role in maintaining crop health. As instance, incidence of Potato scab of growing potatoes was increased without any phosphate fertilizer (Davis *et al*. 1976a). Graham (1983) reported a decrease in incidence of powdery mildew and *Pythium* root rot with optimum phosphorus supply. Potassium fertilizers minimized the severity of late blight of potato caused by *Phytophthora infestans* (Goss, 1968). Severity of root rots particularly those caused by *Fusarium* spp., *Pythium* spp., and *Phytophthora* spp. was reduced with potassium application (Graham, 1983).

Secondary macronutrients and micronutrients

Calcium, magnesium and sulfur are the secondary macronutrients and are not applied to field crops as regularly and attentively as NPK. During the reclamation of calcareous sodic and calcareous saline sodic soils, the applications of gypsum, sulfuric acid and elemental sulfur are the major sources of secondary nutrients. However, in acidic soils calcium is mostly added through calcium nitrate and lime applications. Calcium nitrate, gypsum and lime are sources of calcium with varying solubility in the soil environment. Out of these three amendments, calcium nitrate is the most and lime is the least soluble compound and gypsum with intermediate solubility. Impact of these soil amendments on plant disease severity varied with solubility. Lambert and Manzer (1991) reported that same amount of gypsum and lime reduced the severity of soft rot of potato by 28% and 8%, respectively. The results of the addition of gypsum to control soft rot of daughter potatoes are not consistent. Bain *et al.* (1996) reported a delay in incidence of potato aerial blackleg infection and seed piece soft rot by the application of gypsum at 14-27 metric tons calcium per hectare per year. Application of calcium strengthens the cell as higher Ca concentrations make the cell walls more resistant to enzymatic degradation (McGuire and Kelman 1984). Due to the same reason calcium deficient potatoes are more susceptible to heat stress (Tawfik *et al.,* 1996) and postharvest diseases (Conway *et al.*, 1994). McGuire and Keiman (1986) reported a gradual decrease in soft rot of potato with increasing rate of calcium.

Calcium enhanced common scab of potato by increasing soil pH and this is the fact which always confuses the specific role of calcium in disease severity (Lambert and Manzer, 1991). In some cases application of gypsum increased the soil calcium but did not enhance potato scab (Wiechel *et al.,* 2007). This thing allows the soil application of gypsum and/or hot lime to minimal reasonable rates in scab by potato growing areas.

Effect sulfur application on disease incident might be due to soil acidification or sulfur uptake. Reduction in incidence of potato scab was noted with different doses of elemental sulfur (Davis *et al.,* 1976). Use of ammonium sulfate as a source of nitrogen fertilizer reduced scab up to 86 % however, the effect was more pronounced at lower initial pH 5.0 than at higher one 5.9 (Terman *et al*., 1948). Application of 0.5 MT ha^{-1} of elemental sulfur reduced the soil pH from 6.1 to 5.4 and reduced potato scab by 27 % (Barnes, 1972). The possible mechanism for the reduction of scab with sulfur might be due to the conversion of S to H_2S in reduced environment as toxicity of hydrogen sulfide to *S. scabiei* is already reported by Vlitos and Hooker (1951).

Increase in manganese availability reduced the common scab of potato in some cases (Mortvedt *et al.,* 1961; Mortvedt *et al.,* 1963; McGregor and Wilson, 1966; Davis *et al.,* 1976a) and did not affect the disease severity in others (Keinath and Loria, 1989) and caused phytotoxicity (Barnes, 1972). Manganese sulphate applied @ 163 kg ha^{-1} to a soil having pH 4.9 to 5.5 significantly reduced potato scab without increasing tuber yield. In a soil, already containing sufficient amount of manganese, addition of manganese sulphate did not reduce common scab (Mortvedt *et al.*, 1961).

Role of manganese in disease resistance might be due to its participation as a cofactor of enzymes involved in oxidation and/or reduction metabolism of the plant. Inconsistent behaviour of metal in controlling common scab of potato might be due to the reason that manganese concentration required for proper functioning of plant is a suboptimal for disease resistance (Lambert *et al*., 2005).

Conclusion

Soil-borne plant pathogens, particularly fungus species of genus *Pythium, Fusarium, Rhizoctonia, Aphanomyces, Ophiobolus, Phytophthora and Verticillium* cause serious type of rots and other diseases to various crop plants. These pathogen populations vary in response to soil characteristics and soil management is an effective tool in suppressing a soil borne disease. Management of soil for disease suppression comprises of field physical operations and amendment based change in a soil property. Owing to the big volume of field soil with good buffering capacity, characteristics like soil tilth, pH, organic matter content and most of the nutrient concentrations are difficult to change and to confine the change for a single crop season. Amendment based alteration in a soil property to suppress a particular pathogen may favour the incidence of another disease of the same or next season crop. Thus better understanding of the impact of a soil property on a number of pathogen population densities and disease incident will help to manage soil in favour of all crops in rotation instead a particular disease of a single crop.

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