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Review Article

SOIL BORNE DISEASES OF MAJOR PULSES AND THEIR BIOLOGICAL MANAGEMENT

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ABSTRACT

The major legume pulses grown world wide, chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik.), faba bean (*Vicia faba* L.), grass pea (*Lathyrus sativus* L.) and field pea (*Pisum sativum* L.) are grown in cool season legume crops, while pigeonpea (*Cajanus cajan* (L.) Millsp.), blackgram (*Vigna mungo* (L.) Hepper), mungbean (*V. radiata* (L.) Wilczek), horsegram (*Macrotyloma uniflorum* (Lam.) Verdc.), cowpea (*V. unguiculata* (L.) Walp) and soybean (*Glycine max* (L.) Merr) are known as warm season legume crops. Biotic hazards such as insects, diseases, nematodes and weeds substantially reduce the yield of these legumes. Among these, soil borne fungi and nematodes are the largest and most important group of organisms affecting all parts of the plant at all stages of growth of legume crops. According to estimates made in India nearly 10-15% of food legumes production is lost due to diseases alone. Among several plant pathogenic fungi, diseases caused by species of *Fusarium*, *Macrophomina*, *Pythium*, *Rhizoctonia* and *Sclerotium* are of great importance to tropical, sub tropical and temperate legume pulses. Perusal of the literature on diseases of legumes and their management reveals new records of diseases, loss estimations, biology of causal agents, identification of host plant resistance and fungicide use. Integrated disease management mainly adopted with biological agents modules for management of important soil borne diseases, which involves the individual component of disease management such as plant resistance, agronomic practices, judicious use of fungicides, biopesticides for pathogen control and risk forecasting that operate on different aspects of the disease etiology, such that they complement each other.

Introduction

Food legumes are of prime importance in human diet and animal feed contributing the major source of vegetable protein. They are an economic source of not only protein, but of carbohydrate, minerals and B-complex vitamins particularly in vegetarian diet (Salunkhe *et al.*, 1985). Pulses occupied an area of about 68.31 million hectare contributing 57.32 metric tons of production to the world food basket. India shared 35.2 per cent of area and 27.65 per cent of global pulses production. India is producing 14.76 million tons of pulses from an area of 23.63 million hectares, which is one of the largest pulses producing countries in the world. However, about 2-3 million tons of pulses are imported annually to meet the domestic consumption requirement. Thus, there is need to increase production and productivity of pulses in the country by more intensive interventions. Chickpea or garbanzo beans are grown in tropical, sub-tropical and temperate regions. Bengal grams are protein rich and one of the earliest cultivated vegetables around; in fact, the Middle East contains Bengal gram remains that are around 7,500 years old. Kabuli type is grown in temperate regions, while the desi type chickpea is grown in the semi-arid tropics. The chickpea is valued for its nutritive seeds with high protein content, 25.3-28.9%, after dehulling. Mungbean (*Vigna radiata*) and Urdbean (*Vigna mungo*) are important pulse crops in our country after chickpea and pigeonpea. Both are important short duration grain legume crops with wide adaptability, low input requirement and have the ability to improve soil fertility by fixing atmospheric nitrogen. Mungbean is grown on about 3.70 million hectares with an annual production 1.57 million tons. Similarly, urdbean is grown on about 3.24 million hectares with annual production of 1.52 million tons. Both the crops are thought to be of Indian origin as evidenced by an occurrence at archaeological sites in the Indian subcontinent. Lentil is an important crop in many parts of the world, cultivated under various production systems. Peas and beans as fresh and dry pulses have been in cultivation for as long as man has been able to cultivate the land. Peas and beans are legumes. Cowpea is the most important legume vegetable grown in India and to a limited extent in Nepal and Bangladesh. Lablab is a source of protein for both humans and livestock. The legume improves soil fertility, is suitable as a cover crop and can be rotated with other crops. Forage legumes are important because they improve soil fertility through nitrogen fixation. Significantly soybean crop has often been mentioned in these countries as the 'Cow of the field', or 'Gold from soil'. Legume pulses are suffering from numerous pathogens and caused yield loss majorly soil borne pathogens. To mitigate the hazardous impact of soil borne pathogens in pulses several practices were adopted. The use of chemical fungicides resulted in environmental pollution and adverse effect on the biotic community. Hence, it is imperative to develop a unique, effective, sustainable disease management programs which are environment friendly and also increases the yield and quality of consumable crops (Parthasarathy *et al*., 2015).

Major Soil Borne Diseases of Pulses

1. Chickpea (Bengalgram): *Cicer arietinum* L.

Chickpea is a member of the Papilionoid subfamily of legumes. It is the third most important grain legume crop in the world, grown in at least 33 countries in South Asia, West Asia, North Africa, East Africa, Southern Europe, North and South America, and Australia. In India, it is cultivating over an area of 8.56 million ha with an annual production of 7.35 million tonnes and productivity of 858 kg ha^{-1} respectively. Chickpea suffers from numerous pathogens and caused yield loss majorly soil borne pathogens (Nene and Reddy, 1987).

1.1. Fusarium wilt: *Fusarium oxysporum* Schlechtend.: *Fr*. f. sp. *ciceris* (Padwick)

This disease caused by *Fusarium oxysporum* Schlechtend.: *Fr*. f. sp. *ciceris* (Padwick) Matuo and K. Sato. It was first reported in India by Butler in 1918 but its etiology was not correctly determined until 1940 by Padwick. Symptoms of the disease can develop at any stage of plant growth and affected plants may be grouped in patches or appear spread across a field (Haware *et al*., 1990). Highly susceptible cultivars can show symptoms within 25 days after sowing (designated ‘early wilt’). Symptoms developed severe at 25 and 30˚C, symptoms including flaccidity of individual leaves followed by a light green discoloration, dehydration and disintegrate of the entire plant. Symptoms are usually more conspicuous at the onset of flowering, 6-8 weeks after sowing, and can also appears up on podding stage, and it’s called late wilt. Late wilted plants exhibit drooping of the rachis, petioles and leaflets, followed by chlorosis and necrosis of foliage. Falling is observed in the upper part of the plant, but within few days it occurs on the entire plant. Roots of affected seedlings and plants show no external root discoloration if they are uprooted before being severely affected or dried. Histological distortions occur in the vascular tissues of affected roots and stems as a result of cavity formation between phloem and xylem, xylem and medulla, and phloem and cortical parenchyma, as well as anomalous cellular proliferation in the vascular cambium.

1.2. Collar rot: *Sclerotium rolfsii* Saccardo

Collar rot is one of the most devastating soil borne diseases, infecting usually the collar region and often traversing towards the root system during severe infection (Punja, 1985). The pathogen usually attacks the collar region, causing necrosis due to its extracellular secretions. These are manifested by constricted dry rot at the collar region, which causes the entire plant to wilt. Interestingly, the infection does not usually extend further up the stems and foliage of the plants. *S. rolfsii* has a wide host range with prolific growth and ability to produce persistent sclerotia to inflict the large economic losses associated with the pathogen (Mordue, 1974). Sclerotia serve as the principal over-wintering structure and primary inoculum for disease persistence near the soil surface. Sclerotia may exist free in soil or in association with plant debris (Aycock, 1966).

1.3. Wet root rot: *Rhizoctonia solani* Kuhn.

Symptoms of disease showed gradual yellowing and the petiole leaflets droop without collapse of seedlings. The stems and roots near the lesions show rotting frequently with pinkish mycelial growth. Sclerotia were usually seen. The field symptoms are almost the same as those of collar rot, i.e., drying plants scattered throughout the field. Like collar rot, this disease is most often seen at the seedling stage (up to 6 weeks after sowing) in soils with relatively high moisture content (McCoy and Kraft, 1984). However, in irrigated chickpea, the disease may occur at later stages in the crop growth. Affected seedlings gradually turn yellow and petioles and leaflets droop. Seedlings do not usually collapse. A distinct dark brown lesion appears above the collar region on the main stem and can extend to lower branches in older plants. The stem and root below the lesion shows rotting, frequently with pinkish mycelial growth. Sclerotia are not usually seen. The pathogen can infect at a wide range of soil temperatures, but cool (11-18°C), wet soil conditions are optimum.

1.4. Dry root rot: *Rhizoctonia bataticola* Kuhn

Dry root rot (*Rhizoctonia bataticola*) is important and widespread soil borne diseases in India. The disease generally appears around flowering and podding time in the form of scattered dried plants. The seedlings can also get infected. The susceptibility of the plant to the disease increases with age. Drooping of petioles and leaflets is confined to those at the very top of the plant. Sometimes when the rest of the plant is dry, the topmost leaves are chlorotic. The leaves and stems of affected plants are usually straw colored, but in some cases the lower leaves and stems are brown. The lower portion of the tap root usually remains in the soil when plants are uprooted. The tap root is dark, shows signs of rotting, and is devoid of most of its lateral and finer roots. Dark, minute sclerotial bodies can be seen on the roots exposed or inside the wood. The pathogen is a facultative sporophyte and is both seed borne and soil borne. Maximum ambient temperatures above 30°C, minimum above 20°C, and moisture stress (dry conditions) at the reproductive stages favor disease development.

2. Pigeonpea (Redgram): *Cajanus cajan* (L.) Millsp.

Pigeonpea is one of the major grain legume (pulse) crops of tropics and sub tropics. It finds an important place in the farming systems adopted by small and marginal farmers in a large number of developing countries as it restores the soil fertility by fixing atmospheric nitrogen.

2.1. Fusarium wilt: *Fusarium udum* Butler

It is the most destructive disease of pigeon pea throughout India. The plant mortality up to 50 per cent has been observed with severe infection of wilt. The main symptoms are wilting of seedlings and adult plants. The wilting starts gradually showing yellowing and drying of leaves following by wilting of whole infected plant. The affected plants can easily be recognized in patches in the field. Wilt appears on the young seedlings but mainly observed during flowering and podding stage. Disease symptoms resemble plants suffering from drought even with availability of plenty of soil moisture. Brown or dark purple coloured bands are found on the surface of stem which start from base to several feet above ground level. Drying of plants may be partial or complete. The branches arising from discoloured parts show the wilting symptoms first. The wilting may be partial as the branches on one side will show wilting while on the other side, they remain healthy (Somasekhara *et al.,* 1996). The wilt pathogen *Fusarium udum* is soil borne in nature. The pathogen survives in soil as a saprophyte on dead host roots and other plant part for a long time. Under favourable conditions, the spores germinate with a germ tube which penetrates the fine rootlets. The fungus may move to larger roots if they got injury. The affected roots become black and shrivelled. The disease is favoured at a temperature of 17-25°C. The main infection is through soil only and secondary infection by conidia on the above ground parts is rare. The infected plants develop spores, which fell down on the soil and functions as inoculum for the next crop.

2.2. Phytophthora Blight: *Phytophthora drechsleri* Tucker f. sp. *cajani*

Blight causes rapid wilting of plants, desiccation and upward rolling of leaflets followed by withering of petioles and small stems. Infected plants have brown water soaked circular or irregular lesions on leaves which become necrotic afterward. Affected plants also show brown to dark brown slightly sunken marked lesions on their stem near soil surface and on the above ground part of the stem. The lesions enlarge in size and girdle the stems which break at this point. In advanced stages, the stem is commonly swollen into cankerous structures near the lesions. The seedlings die suddenly due to infection. In severe cases, the whole foliage becomes blighted. White-pink fungal growth appears on the blighted area under congenial weather conditions (Kannaiyan *et al.*, 1980). The seedlings are highly prone to this infection and dry plants are common during rainy season. The disease is serious when continuous rains occur or there is water logging in the field. Such conditions can create epidemic of the disease, however plants are not affected after 60 days of growth. The pathogen survives in soil and on infected plant debris. Cloudy weather and drizzling rain with temperature of 25°C favour infection. Low lying areas where water stagnates and close spacing encourage blight build up. Warm and humid weather after infection result in rapid development of disease.

2.3. Collar Rot: *Sclerotium rolfsii* Saccardo

A seedling disease that usually appears within a month of sowing, when patches of dead seedlings at the primary leaf stage are seen, scattered over the field. The seedlings may turn slightly chlorotic before they die (Singh *et al.,* 1987). The confirmatory symptom is rotting in the collar region that is covered with white mycelial growth; this differentiates collar rot from other seedling diseases caused by *Fusarium, Rhizoctonia*, or *Pythium*. Seedlings affected by collar rot can be uprooted easily, but the lower part of their roots usually remain in soil. Sometimes white or brown sclerotial bodies of the fungus can be found attached to the collar region of a dead seedling or in the soil around it.

2.4. Dry Root Rot: *Rhizoctonia bataticola* (Taub.) Butler; *Macrophomina phaseolina* (Tassi) Goidanich.

Infected plants suddenly and prematurely dry up. When such plants are uprooted their roots are rotten and shredded. The finer roots are mainly affected and have dark, blackened streaks underneath their bark with evident dark sclerotial bodies (Lokesha and Benagi, 2007). Such roots are brittle and break when touched. Under hot, humid conditions root rotting extends to the base of the stem. Early symptoms on stems and branches are spindle-shaped lesions with light gray centers and brown margins with scattered pycnidial bodies. The lesions coalesce and cause the branches or whole plants to dry up and die.

3a. Urdbean (Blackgram): *Vigna mungo* (L.) Hepper

Archaeological studies have shown that it was cultivated in the country as far back as 2200 B.C. Based on seed color and other characteristics urdbean have been grouped under two main types viz. var. mungo with large black seed and early maturity and var. viridis with small greenish seed and late maturity. It is an important pulse crop and serves as a major source of dietary protein for the majority of people. High values of lysine make urdbean an excellent complement to rice in terms of balanced human nutrition.

3b. Mungbean (Greengram):

Vigna radiata is under cultivation since prehistoric time in India. It is also known as green gram and serve are a major source of dietary protein for the vast majority of people. India is the largest producer of mungbean and account 54% of the world production and covers 65% of the world acreage.

3.1. Charcoal rot/ Dry root rot/Stem canker: *Macrophomina phaseolina*

The pathogens cause seed decay, root rot, damping-off, seedling blight, stem canker and leaf blight in green gram and also in black gram. The disease occurs commonly at podding stage. In the initial stages, the fungus causes seed rot, seedling blight and root rot symptoms. The affected leaves turn yellow in colour and brown irregular lesions appear on leaves. On coalescence of such lesions, big blotches are formed and the affected leaves start drying prematurely. Roots and basal portion of the stem become black in colour and the bark peels off easily. The affected plants dry up gradually. When the tap root of the affected plant is split open, reddening of internal tissues is visible.

3.2. Wet root rot: *Rhizoctonia solani*

Reddish to dark brown root lesions can develop on epicotyls and hypocotyls. Brown discoloration occurring near the soil line on the epicotyls could girdle the stem. Seeds may rot, or when growing, develop rot or pre and post-emergent damping-off. Lesions developing on roots that eventually progress enough to pinch them off can be observed. Stems lesions can develop at or below the soil line. The lesions may expand above the soil line to the lower branches in older plants. Leaves can turn yellow upwards from the base of the plants. Circular patches of stunted plants may be observed in the field. A plant that can be easily pulled out from the soil is indicative of rot.

3.3. *Pythium* Seed, Seedling and Root Rot: *Pythium* sp.

Root tissue may die and become discolored, leading to less branching and fewer feeder roots. Low emergence and seed rot could occur. Discoloration of the crown and hypocotyl's tissue may be observed as rotting progresses. Stunting of plants is common and some plants can die before flowering, leading to reduced yield.

4. Lentil: *Lens culinaris* Medik

Lentil crops are affected by a number of diseases caused by bacteria, fungi, viruses and nematodes. Some diseases are common in most lentil-growing regions worldwide, whereas others are limited to certain production areas. Hence, proper management of these diseases is necessary to ensure sustainable productivity and profitability of lentil.

4.1. Fusarium Wilt: *Fusarium oxysporum* Schlecht. : Fr. f. sp. *lentis*

Fusarium wilt of lentil is an important soil-borne disease, and causes significant yield loss under dry and warm conditions. The disease occurs in most lentil production regions, and has been reported to occur in at least 26 countries. Fusarium wilt of lentil can be observed at the seedling and reproductive stages. It usually occurs during the reproductive stages from flowering to pod filling, causing yellowing, leaf curling and stunted growth. Infected plants show reduced root development, sometimes with yellowish-brown discoloration of vascular tissue and poorly developed nodules

4.2. Sclerotinia Stem Rot: *Sclerotinia sclerotiorum* (Lib.) de Bary

Sclerotinia stem rot has a worldwide distribution and occurs on more than 400 plant species in 75 families (Boland and Hall, 1994). Economic losses can occur in lush lentil canopies under wet conditions (Akem *et al.*, 2006). Infected plants exhibit bleached lesions on stems, leaves, pedicels and pods, which are sometimes covered by a characteristic cottony white mycelium occasionally harbouring dark sclerotia. Stem infection can cause wilting of plants. The disease is promoted by high plant density, excessive vegetative growth and high precipitation in the last third of the lentil-growing season (Akem *et al*., 2006). Infection on lentil is initiated through ascospores released from carpogenically germinating sclerotia, as well as through myceliogenically germinated sclerotia that have overwintered on or near the soil surface.

5. Peas (*Pisum sativum* L.) **and Beans** (*Phaseolus vulgaris* L.)

Peas and beans seeds, stems and roots may be infected by an array of soil-borne pathogenic fungi from planting to harvest. Symptoms such as wilt, root rot, foot rot, damping-off, seedling blight and seed decay are common to all and, as a result, it is difficult to differentiate among them. Both *Pythium* and *Rhizoctonia* have wide host ranges. *Aphanomyces euteiches* affects a wide range of Leguminosae. *Fusarium oxysporum* f. sp. *pisi* and *F. solani* f. sp. *pisi* are pathogenic only to pea (Biddle and Cattlin, 2007).

5.1. Seedling Rot: *Pythium* spp. *Pythium ultimum*

The seed is susceptible to infection by various soil-borne fungi including *Pythium* spp. *Pythium ultimum* is often associated with such infection. The cotyledons begin to decay shortly after the emergence of the radical. If germination occurs, then the young rootlets become infected and the seedling often fails to emerge from the soil. The first sign of a problem is a poor seedling establishment, resulting in a low plant population (Biddle and Cattlin, 2007). By digging along the rows, the remains of the seed coat may be found together with a wet rotted cotyledon. Seedlings may have decayed hypocotyls and rootlets.

5.2. Root Rot: *Thanatephorus cucumeris* syn. *Rhizoctonia solani*

Rhizoctonia causes a stem rot of young seedlings, and is noticed after emergence when soil conditions may have been consolidated on the surface by heavy rain or excessive irrigation. The stem base is shriveled with deeply sunken lesions which may completely girdle the stem. The lesion edges may be slightly red in colour and small black sclerotia may develop on the surface. Infected plants wilt and die.

5.3. Root Rot: *Aphanomyces euteiches*

Peas can develop symptoms from any time after the first two or three leaf nodes have been produced but, more often; it is at flowering time that the plants show the most obvious effects. Plants are stunted in patches that can be small to extend over the field. These areas often coincide with wetter areas of soil or where drainage has been impeded by cultivation compaction (Biddle and Cattlin, 2007). Plants are severely stunted, the root system is decayed, there is an absence of viable nitrogen-fixing nodules, and the plants die from the base upwards. Often, the epidermis of the roots strips away during an examination to leave the vascular strands exposed.

5.4. Fusarium Wilt: *Fusarium oxysporum* f. sp. *pisi* Races 1, 2, and 5

Diseases caused by *Fusarium oxysporum* often result in a vascular wilting of the plant during the time of flowering and pod setting. Fusarium wilt is characterized by a stunting of the plant, together with a colour change affecting the whole foliage which, at first, turns a greyish yellow before shrivelling and resulting in the death of the plant (Biddle and Cattlin, 2007). The leaves roll inwards and when the stem tissue is scraped back to reveal the vascular tissue, the colour is yellow to slightly orange-red which is more pronounced at the nodes. Plants are usually affected in patches in the field.

5.5. Foot Rot (Peas): *Fusarium solani* f. sp. *pisi* and *Phoma medicaginis* var. *pinodella*

The first signs of infection appear from early flowering onwards. Areas, either defined or scattered across the field, begin to develop a pale colouration which later changes to a more distinctive yellowish color. Plants within these areas are often stunted, the leaves are small and the lower leaves begin to shrivel upwards to the growing point. Pods are very small, few in number and often the plant dies before the pods reach their potential. The base of the plant can be brown or black at soil level, where the stem may also develop a strangled appearance. The root system is poorly developed with an absence of nitrogen-fixing root nodules. Roots are often brown and, if the vascular tissue is exposed at the stem base down to the taproot, there is a brick-red colour, especially where *Fusarium solani* is the main pathogen.

5.6. **Foot Rot (Beans):** *Fusarium solani, Phoma medicaginis* var. *pinodella*, and *F. culmorum*

Beans with blackened stem bases can be found at any time during the late spring or early summer, and are particularly noticeable at the beginning of flowering. Affected plants are stunted and pale in colour, and the root systems are poorly developed with few, if any, viable nitrogen-fixing nodules. Affected plants occur in patches and are often associated with compacted or waterlogged soil. The internal tissues of the vascular system may be brown or red-brown in colour where *Fusarium solani* is the primary pathogen. *Phoma medicaginis* infection causes a breakdown of the epidermis of the stem base at soil level. The stems may shrivel and the plants develop a strangled appearance. *Fusarium culmorum* infection is characterized by a basal stem rot, which forms a deep lesion just above soil level. The lesion is black and often contains pink spore masses of the fungus.

5.7. Stem Rot: *Sclerotinia trifoliorum*

Bean infection is noticed in early spring following invasion of the stems by the fungus. Stems develop a watery soft rot, and then turn black as they decay further before collapsing. Individuals or small groups of plants may be infected in discrete areas over the field. Infected stems become covered with white mycelium, and black round or oval resting bodies (sclerotia) of the fungus develop in or on the surface of the stem (Biddle and Cattlin, 2007).

6. Horsegram: *Macrotyloma uniflorum* (Lam.) Verdc

6.1. Dry root rot: *Macrophomina phaseolina* (Tassi) Goud

The first outward symptom of the disease is yellowing of the leaves. Within three or four days they drop off. The affected plants wilt and die within a week. The bark of the root and basal stem are fibrous and are found associated with black powdery mass of sclerotia of the fungus. The plants bear pods with partially filled seeds. The disease appears in patches and becomes severe during dry periods.

6.2. Aerial blight: *Rhizoctonia solani* Kuhn

Aerial blight is seen on the foliage as irregular water soaked area. Under high atmospheric humidity the spots coalesce rapidly and cover a large part of the leaf lamina. There will be white mycelial growth also on the affected area. Severely affected leaves shed in large number.

7. Lablab: *Lablab purpureus* (L.) Sweet

Lablab is a dual-purpose legume. It is traditionally grown as a pulse crop for human consumption, fodder, green manure, cover crop in south and Southeast Asia and eastern Africa. It is also used as a fodder legume sown for grazing and conservation in broad-acre agricultural systems in tropical environments with a summer rainfall. It is sown as a monoculture or in intercrop systems.

7.1. Wilt: *Fusarium oxysporum* f. sp. *Tracheiphilum* (E.F.Sm.) Snyder and H.N. Hansen *Fusarium oxysporum* f. sp. *tracheiphilum* attacks young and old plants. Symptoms of the disease are visible on leaves, stem and roots. The vascular bundles show brownish-black discoloration. All plant parts are affected and showing different symptoms, initially, leaves turn yellowing, withering, chlorosis and leaf dropping. Shoots are dry and naked, blackened and swollen, wilt. Seeds were discoloration, shrivelling, ashy white and shrunken. Roots were rotten; reduced root system; absence of lateral roots.

8. Cowpea: *Vigna unguiculata* (L.) Walp.

Cowpea an annual legume, is also commonly referred to as southern pea, black eye pea, crowder pea. It is chiefly used as a grain crop, for animal fodder, or as a vegetable.

8.1. Wilt: *Fusurium oxysporum* f. sp. *tracheiphilum*

Leaves of infected plants are limp and yellowed and in young plants a rapid wilt leads to death. Older plants are stunted, leaves turn yellow and then fall and the plant gradually wilts. The vascular tissue is typically necrotic, and it is this symptom, and the presence of characteristic spores, which distinguish the disease from the stem rots.

9. Soybean: *Glycine max* (L.) Merr.

The use of soybean dates back to the beginning of China's agricultural age. Recognizing soybean as the 'golden bean’ or the 'miracle bean’, the western world provided a massive push to its growth during the early part of the century. Soybean has come to be recognized as one of the premier agricultural crops today for various reasons.

9.1. Charcoal Rot: *Macrophomina phaseolina*

Charcoal rot symptoms typically appear as soybeans approach maturity. The earliest symptoms are smaller than normal sized leaves, which become chlorotic, then turn brown, but remain attached to the petiole giving the entire plant a dull greenish-yellow appearance. In many cases, these plants wilt and die (Sinclair, 1982). At early reproductive stages, a light gray to silver discoloration of the sub-epidermal tissue develops on taproot and lower part of the stem. Removal of epidermal tissue reveals numerous small, charcoal-black fruiting bodies (microsclerotia) embedded in the lower stem and taproot (Bissonnette, 2012).

Biological agents widely used against soil borne diseases

Seed and seedling diseases, root rot and wilts are caused by a numerous soilborne fungi, all of which are facultative parasites and saprophytes and can survive in soil for prolong periods even in the absence of a susceptible host. In general, these diseases are serious yield loss where short rotations or monoculture of pulse crops are the rule. Control of these diseases requires an integrated approach of genetic resistance tolerance, cultural practices, appropriate seed treatments with biocontrol agents and fungicides. Most economical and sustainable approach is biological control of this soil borne pathogens. Potential antagonists, especially *Pseudomonas fluorescens* and *Bacillus subtilis* are promising candidates as bio-protectants (Parthasarathy *et al*., 2016). The application of a single antagonist is not likely to be better in all environmental conditions where it is applied (Narayanan *et al*., 2016). Application of *T. viride, T. harzianum, P. fluorescens* and *B. subtilis* along with neem cake and compost enhanced the survivability of bioagents and suppression of soil borne diseases (Narayanan *et al*., 2015; Shanmugapackiam *et al*., 2016).

1. *Trichoderma* spp.

Trichoderma spp. has been investigated as biological control agents for over 70 years. The genus *Trichoderma* comprises a numerous strains that act as efficient biocontrol agents. The most effective species of *Trichoderma* are *T. virens*, *T. viride*, *T. koningii*, *T. polysporum, T. hamatum* and above all *T. harzianum.* These biocontrol agents suppress plant pathogens through a variety of mechanisms especially mycoparasitism, competition, induced resistance, antibiosis etc. Effectiveness of *Trichoderma* strains against a pathogen depends on several factors such as the target fungus, the crop plant and the environmental conditions including soil nutrition. pH, temperature and iron contents. Activation of each mechanism implies the production of specific compounds and metabolites such as plant growth factors, hydrolytic enzymes, siderophores, antibiotics etc. *Trichoderma* species are known to produce over 40 different metabolites that may contribute to their mycoparasitic and antibiotic action. These metabolites can be either overproduced or combined with appropriate biocontrol strains in order to obtain new formulations for use in more efficient control of plant diseases. *Trichoderma* Strains grow rapidly when inoculated in the soil, because they are naturally resistant to many toxic compounds, including herbicides, fungicides and pesticides. Root colonization by *Trichoderma* strains frequently enhances root growth and development, crop productivity, resistance to abiotic stresses and the uptake and use of nutrients. Seed treatment by *T. viride* resulted upto 20% increase in the germination in seeds (Shanmugaiah *et al*., 2009). Crop productivity in fields may increase up to 300% after addition of *T. hamatum* or *T. koningii*. In experiments carried out in green houses, there was also a considerable yield increase when plant seeds were previously treated with spores from *Trichoderma* spp. (Chet *et al*., 1997). *T. harzianum* produced a wide zone of inhibition against *F. udum* and suppressed mycelial growth by 89%. The mode of mycoparasitism was observed to be entirely different between *T. viride* and *R. solani* (Pandey *et al.*, 2005). *T. harzianum* exhibits excellent mycoparasitic activity against *R. solani* hyphae (Altomare *et al*., 1999). *T. harzianum* hyphae coiled around the pathogen. Later on pegging started and knob like haustoria formed inside the hyphae of *R. solani*. The cytoplasmic contents may be taken through the haustoria and only cell wall was clearly visible without cytoplasm.

2. *Pseudomonas fluorescens*

Pseudomonas fluorescens is the most versatile plant growth promoter and possesses great antagonistic potential against plant pathogens. The bacterium has revolutionized the field of biological control of soil borne plant pathogenic fungi. This bacterium produces phenazine, pyrolnintrin, phloroglucinol and siderophores, which may be involved in the suppression of the wilt fungus and other pathogens. Application of bio-inoculants either alone or consortia eventually induced the defense enzymes for restriction of pathogens. Van Peer *et al*. (1991) obtained evidence of induced systemic resistance in the host after inoculation of the fluorescent Pseudomonads strain. Leeman *et al*. (1996) reported satisfactory control of fusarium wilt of radish by treating the seed with *P. fluorescens*. Van Peer *et al*. (1991) reported evidence of induced systemic resistance in the host after inoculation of *P. fluorescens* strain on the root, against *F. oxysporum* f. sp. *dianthi* inoculated on the stem. Bacterization of chickpea seeds with a siderophore producing fluorescent pseudomonas reduced the number of chickpea wilted plants in a wilt sick soil by 52%. Other *in vitro* tests have demonstrated antifungal activity of certain strains of *P. fluorescens* against *F. oxysporum* f. sp. *ciceri* and *F. udum*. M'Piga *et al*. (1997) reported that seed treatment with *P. fluorescens* isolate 63-28 prevented the entry of Fusarium in vascular tissues by strengthening cell wall structures and accumulation of phenolic substances and chitinases. Ramamoorthy *et al*. (2002) reported that seed treatment with talc formulation of *P. fluorescens* isolate Pf1 reduced the incidence of fusarium wilt in tomato caused by *F. oxysporum* f. sp. *lycopersici* in greenhouse as well as field condition. Saikia *et al*. (2003) reported induction of systemic resistance against wilt of chickpea caused by *F. oxysporum* f. sp. *ciceri* and 26-50% reduction in wilt severity after soil application of *P. fluorescens*.

3. *Bacillus subtilis*

Bacillus subtilis also occurs in the soil surrounding the roots and has been reported as an antifungal agent against numerous plant pathogens. The principal mechanism for fungicidal action involves the production of antibiotics (Mckeen *et al.,* 1986). *B. subtilis* strains also produce volatile substances which have been shown to inhibit the growth of a range of organisms, including *Rhizoctonia solani* and *Pythium ultimum* (Fiddaman and Rossal, 1993). Two isolates of *B. subtilis* were found antagonistic to *F. oxysporum* f. sp. *ciceri* (Dhedhi *et al.,* 1990). Wilt of chickpea caused by *F. oxysporum* f. sp. *ciceri* was greatly suppressed by *B. subtilis* isolate GBO3 (Hervas *et al.,* 1998). The same isolate was reported to activate an ISR pathway in Arabidopsis by the production of some volatiles (Compant *et al*., 2005). *B. subtilis* produced a wide zone of inhibition against *F. udum* and completely inhibited spore germination at $8x10^{-7}$ cells/ml (Sumitha and Gaikwad, 1995). Bochow *et al*. (1995) demonstrated that certain root colonizing strains of B. subtilis play a role as biocontrol agents through induced systemic tolerance of treated seedlings against attack by *F. oxysporum*. Seed treatment of pigeonpea with *B. subtilis* and 5 *Trichoderma* spp. effectively controlled pigeonpea wilt and enhanced the yield considerably (Nakkeeran and Renukadevi, 1997).

IDM approaches:

- Long crop rotations for 3-4 year with non host crop like, tobacco, sorghum, pearl millet, cotton is recommended and has been found very effective for wilt and root rot disease management.
- Selection of disease-free fields, soil solarization or summer ploughing and wide row interspacing are good agricultural cultural practices advocated for soil borne disease management.
- Mixed cropping with sorghum, amendment of soil with oil cakes, appliances of trace elements such as boron, zinc and manganese and a heavy dose of green leaf manure crops are remedial measures helps in checking the severity of wilt and blight diseases.
- Cultivation of legumes on ridges with proper drainage system and avoiding the sowing in heavy soil helpful in disease management.
- Soil amendment with *Trichoderma* @ 1.0 kg + 100 kg FYM at the time of field preparation to reduce the incidence of wilt disease. Treat the seeds with hexaconazole + captan @ 2.5g/kg seed or metalaxyl @ 2.0 g per kg of seeds (or) carbendazim or thiram @ 2 g/kg of seed 24 hours before sowing (or) with talc formulation of

Trichoderma viride @ 4 g/kg of seed (or) *Pseudomonas fluorescens* @ 10 g/kg seed for better management of diseases.

- First treat the seeds with biocontrol agents and then with Rhizobium. Fungicides and biocontrol agents are incompatible. There should be an interval of at least 24 hours after fungicidal treatment for giving the bacterial culture treatment.
- Preventive sprays of mancozeb, wettable sulphur or metalaxyl at 15-20 days interval starting from 15 days after germination reduces the incidences of diseases.
- Cultivation of disease tolerant varieties is the most effective method to manage wilt and other diseases.

Conclusion

Recently, the IDM and biocontrol approaches have been initiated by cultural, physical, chemical with compatible efficient antagonistic microorganisms to combat the soil borne diseases in leguminaceae pulses. Also the development of resistant varieties and combined application of IDM module is considered as more practicable. However, developing resistant varieties is a tedious and time consuming procedure. Keeping this in view, present investigations were envisaged with the development of biological based integrated management schedule for soil borne diseases.

References

Akem, C., M. Bellar and B. Bayaa. 2006. Comparative growth and pathogenicity of geographical isolates of *Sclerotinia sclerotiorum* on lentil genotypes. *Plant Pathology Journal,* **5:** 67–71.

Altomare, C., W.A. Norvell, T. Bjorkman and G.E. Harman. 1999. Solubilization of phosphate and micro nutrients by the plant growth promoting fungus *Trichoderma harzianum* Riafi. *Applied Environmental Microbiology*, **65**: 2926-2933.

Aycock, R. 1966. Stem rot and other diseases caused by *Sclerotium rolfsii. NC. Agricultural Experimentation Station Technical Bulletin,* **174**: 202.

Biddle, A.J. and N.D. Cattlin. 2007. *Pests and Diseases of Peas and Beans – A Colour Handbook.* Manson Publishing Ltd, 73, Corringham Road, London NW11 7DL, UK, pp. 43-125.

Bissonnette, S. 2012. Charcoal Rot is a Hot Disease in Soybeans. *Illinois*, **19**: 2. http://bulletin.ipm.illinois.edu.

Boland, G.J. and R. Hall. 1994. Index of plant hosts of *Sclerotinia sclerotiorum*. *Canadian Journal of Plant Pathology,* **16**: 93-108.

Chet, I., J. Inbar and Y. Hadar. 1997. Fungal Antagonists and mycoparasites. In: The Mycota, Environmental and Microbial Relationship, (Eds.) Wicklowand D.T. and B. Sodermstrom. Springer, Verlog, Berlin, Germany, pp: 165-184.

Compant, S., B. Duffy, J. Nowak, C. Climent and E.A. Barka. 2005. Use of plant growth promoting bacteria for biocontrol of plant diseases: principles. Mechanisms of action and furure prospects. *Applied Environmental Microbiology*, **71**: 4951-4959.

Dhedhi, B.M., O. Gupta and V.A. Patel. 1990. Influence of metabolities of microorganisms on the growth of *Fusarium oxysporum* f. sp. *ciceri*. *Indian Journal of Mycology and Plant Pathology*, **20(1):** 66-69.

Fiddaman, P.J. and S. Rossal. 1993. The production of antifungal volatiles by *Bacillus subtilis*. *Journal of Bacteriology*, **74**: 119-126.

Haware, M.P., R.M. Jimenez-Diaz, K.S. Amin, J.C. Phillips and H. Halila. 1990. Integrated management of wilt and root rots of chickpea. Chickpea in the Nineties. In: *Proceedings of the second international workshop on chickpea improvement*, Patancheru, India, November 12-15, pp. 129-137.

Hervas, A., B. Landa, L.E. Datnoff and R.M. Jimenez-Diaz. 1998. Effects of commercial and indigenous microorganisms on Fusarium wilt development in chickpea. *Biological Control,* **13**: 166-176.

Kannaiyan, J., O.K. Ribeiro, D.C. Erwin and Y.L. Nene. 1980. *Phytophtora* blight of pigeonpea in India. *Mycologia,* **72:** 169-181.

Leeman, M, F.M. den Ouden, J.A. van Pelt, C. Cornelissen, A. Matamala-Garros, P.A.H.M. Bakker and B. Schippers. 1996. Suppression of *Fusarium* wilt of radish by co-inoculation of fluorescent *Pseudomonas* spp. and root-colonizing fungi. *European Journal of Plant Pathology*, **102:** 21-31.

Lokesha, N.M. and V.I. Benagi. 2007. Biological Management of Pigeonpea Dry Root Rot Caused by *Macrophomina phaseolina. Karnataka Journal of Agricultural Sciences*, **20** (1): 54–56.

M'Piga, P., R.R. Belanger, T.C. Paulitz and M. Benhamou. 1997. Increased resistance to *Fusarium oxysporum* f. sp. *radicus lycopersici* in tomato plants treated with the endophytic bactinum *Pseudomonas fluorescens* strain 63-28. *Physiology and Molecular Plant Pathology,* **50**: 301-320.

McKeen, C.D., C.C. Reilly and P.L. Pusey. 1986. Production and partial characterization of antifungal substances antagonistic to *Monilinia fructicola* from *Bacillus subtilis*. *Phytopathology,* **76:** 136–139.

Mordue, J.E.M. 1974. *Corticium rolfsii*. Description of pathogenic fungi and bacteria. No. 410. Commonwealth Mycological Institute, Kew, Surrey, England, pp. 212-245.

Nakkeeran, S. and P. Renukadevi. 1997. Seed borne microflora of pigeon pea and their management. *Plant Disease Research*, **12**: 103-107.

Narayanan, P., S**.** Parthasarathy, J. Rajalakshmi, K. Arunkumar and S. Vanitha. 2016. Systemic elicitation of defense related enzymes suppressing *Fusarium* wilt in mulberry (Morus spp.). *African Journal of Microbiological Research,* **10(22):** 813-819.

Narayanan, P., S. Vanitha, J. Rajalakshmi, S. Parthasarathy, K. Arunkumar, K. Nagendran, and G. Karthikeyan. 2015. Efficacy of bio-control agents and fungicides in management of mulberry wilt caused by *Fusarium solani. Journal of Biological Control*, **29(2):** 107-114.

Nene, Y.L and M.V. Reddy. 1987. Chickpea diseases and their control. In: The Chickpea (Eds.) Saxena, M.C. and K.B. Singh, CAB International., Oxon, UK, pp. 233-270.

Pandey, K.K., P.K. Pandey and J.P. Upadhya. 2005. Mycoparasitism of *Trichoderma* spp. on *Fusarium* and *Rhizoctonia*. *Journal of Mycology and Pathology,* **35**:174-176.

Parthasarathy, S., V. Jaiganesh, J. Rajalakshmi, R. Priyanka and A. Venkatesh. 2015. Implication of induced systemic resistance in blackgram (*Vigna mungo* (L.) Hepper) by plant activator compounds. *Advances in Applied Research,* **7(2)**: 1-5.

Parthasarathy, S., G. Thiribhuvanamala, K.S. Subramanian and K. Prabakar. 2016. Bacterial antagonists and hexanal-induced systemic resistance of mango fruits against *Lasiodiplodia theobromae* causing stem-end rot. *Journal of Plant Interactions,* **11**(1): 158-166.

Punja, Z.K. 1985. Biology, ecology and control of *Sclerotium rolfsii*. *Annual Review of Phytopathology,* **23**, 97–127.

Ramamoorthy, V., T. Raguchander and R. Samiyappan. 2002. Induction of defense-related proteins in tomato roots treated with *Pseudomonas fluorescens* Pf1 and *Fusarium oxysporum* f. sp. *lycopersici. Plant and Soil*, **239**: 55–68.

Saikia, R., T. Sing, R. Kumar, J. Srivastava, A.K. Srivastava, K. Singh and D.K. Arora. 2003. Role of salicylic acid in systemic resistance induced by *Pseudomonas fluorescens* against *Fusarium oxysporum* f. sp. *ciceri* in chickpea. *Microbiology Research,* **158**: 203-213.

Salunkhe, D.K., S.S. Kadam and J.K. Chavan. 1985. Post harvest Biotechnology of legumes, CRC Press, Boca Raton, Florida, pp. 35-160.

Shanmugaiah, V., M. Balasubramanian, S. Gomathinayagam, P.T. Mahohrn and A. Rajendran. 2009. Effects of single application of *Trichoderma viride*, *Pseudomonas fluorescens* on growth promotion in cotton plants. *African Journal of Agricultural Research,* **4**: 1220-1225.

Shanmugapackiam, S., S**.** Parthasarathy, M. Daniel Jebaraj and David John Christopher. 2016. Exploitation of compost amended biological agents for the management of vascular wilt (*Fusarium oxysporum* f. sp. *lycopersici*) in tomato. *Advances in Life Sciences*, **5**(7): 808-814.

Sinclair, J.B. 1982. Compendium of Soybean Diseases, *American Phytopathological Society*, Saint Paul, Minnisota, USA, pp. 65-89.

Singh, H.B., D.N. Upadhyay and L.R. Saha. 1987. Collar Rot of Pigeonpea in Nagaland and India. *International Pigeonpea Newsletter,* **6:** 52-53.

Somasekhara, Y.M., T.B. Anilkumar and A.L. Siddaramaiah. 1996. Biocontrol of pigeonpea (*Cajanuscajan* (L.) Millsp.) wilt (*Fusarium udum* Butler). *Mysore Journal of Agricultural Sciences*, **30**: 159-1 63.

Sumitha, R. and S.J. Gaikwad. 1995. Checking *Fusarium* wilt of pigeonpea by biological means. *Journal of Soils and Crops*, **5(2)**: 163-165.

Van Peer, R., G.J. Niemasn and B. Shippers. 1991. Induced resistance and phytoalexin accumulation in biological control of fusarium wilt of carnation by *Pseudomonas* strain WCS 417r. *Phytopathology*, **81**: 728-734.

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