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Disease management approaches-strategies and concepts

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Abstract
Plant diseases are considered an important biotic constraint which leads to significant crop losses worldwide. Over the past few decades application of pesticides was the dominant form of disease control in developed and increasingly in developing countries. However, many problems have been associated with such an approach such as the frequent emergence of fungicide resistance in pathogens and the harmful effects of fungicides to human health and the environment. The concept of Integrated Disease Management (IDM) where diseases are managed by integrating biological, cultural, physical and chemical control strategies in a holistic way rather than using a single component strategy proved to be more effective and sustainable. 'Integrated Disease Management' involves the selection and application of a harmonious range of control strategies that minimise losses and maximise returns. IDM calls for minimal use of pesticides. Success requires appropriate policies in place that cover a wide range of themes such as plant protection, private sector investment, trade and export, food safety, land use, education and awareness, and agriculture extension. Wide adoption of IDM practices is a pre-requisite for achieving impact at the country level. Experience over the last few decades clearly showed that adoption and support for using participatory approaches help farmers improve their overall field management, including disease management, reducing costs and improving production efficiency.

Keywords: Pesticides, IDM, resistance, production efficiency

Introduction
A plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. When a virulent pathogen is dispersed onto a susceptible host and the environmental conditions are suitable then a plant disease develops and symptoms become evident. Disease control strategies must therefore focus on the host, the pathogen and/or the environment. Management of pathogen involves the practices directed to exclude, reduce or eradicate inoculums. Management of the host involves the practices directed to improve plant vigor and induce resistance through nutrition, introduction of genetic resistance through breeding and providing need based protection by chemical means. Management of environment involves the practices that modify the environment which is not favorable to pathogen or disease development and does not predispose host to attack. Each of the disease control strategies by itself is not able to provide adequate control. However, when several such strategies are used in combination then acceptable control is achieved. Effective disease management must be integrated with management of the whole farm. The absence of symptoms does not indicate an absence of disease. Basic strategies should be implemented regardless of whether or not a significant disease problem is evident. These basic strategies should focus on the host, the pathogen and the environment. Integrated disease management has been reported to be quite effective for control of soil-borne plant pathogens (Upadhyay and Rai, 1989) [49], including *Fusarium* wilt (Srivastava and Saksena, 1968; Locke *et al*., 1985) [54, 23]. Kaur and Mukhopadhyay (1992) [19] found that integration of seed treatment of chickpea with vitavax - 200 and Ziram with soil application of *T. harzianum* resulted in reduction of chickpea wilt complex up to 63.3%.

Use of resistant varieties together with soil drench on 0.3 per cent Bavistin (Carbendazim) 45 days after planting and three times at 10 days intervals thereafter was suggested to control *Fusarium* wilt of gladiolus. (Kaur *et al*., 1989) [20]. Naik and Sen (1991) [26] recommended crop rotation with garlic, onion and radish, mixed cropping with bhendi and onion, avoiding cultivation of symptomless carriers like cowpea and tomato, use of resistant cultivars Smokylee and Colhoun Gray and biocontrol agent *A. niger* in integrated disease management of *Fusarium* wilt of watermelon. Seed coating with different bioagents (*Bacillus subtilis*, *Gliocladium virens*, *Trichoderma harzianum*, *Trichoderma viride*) and carboxin (vitavax) significantly controlled the wilt of chickpea by 30.0-45.8 per cent over control (Rajib *et al*., 1996) [31].

Principles of IDM

Information on etiology, symptoms, pathogenesis and epidemiology of plant diseases are intellectually interesting and scientifically justified but most important of all they are useful as they help in formulation of methods developed for successful management of disease and thereby increasing the quantity and improving the quality of plant and plant products. Practices of disease management vary considerably from one disease to another depending upon the type of pathogen, the host and the biotic and abiotic factors involved. Contrary to management of human and animal diseases where every individual is attended, the plants are generally treated as populations and measures used as preventive rather than curative.

Principles for plant diseases control were first classified by Whetzel (1929) into exclusion, eradication, protection and immunization. Further advances in plant pathology leading to development of newer methods. Two more principles - avoidance and therapy were created (NAS, 1968)

Avoidance

It involves avoiding disease by planting at time when, or in areas where inoculums is absent or ineffective due to environmental conditions. The major aim is to enable the host to avoid contact with the pathogen or to ensure that the susceptible stage of the plant does not coincide with favourable conditions for the pathogen. The main practices under avoidance are choice of geographical area, selection of the field, choice of sowing/ planting time, selection of seed and planting material, short duration / disease escaping varieties and modification of agronomic/cultural practices. The potato cultivation at high altitude is relatively free from viruses; as prevailing environmental conditions do not permit the build up of vector populations. Similarly, early planting of potato or wheat, in indo Gangetic plains may escape late blight or stem rust damage respectively.

Exclusion

It means preventing the inoculums from entering or establishing in a field or area where it does not exist. Seed certification, crop inspection, eradication of inoculums and / or insect vectors, and quarantine measures are some of the means of preventing the spread for pathogens. For some diseases, seed borne pathogens are primary means of pathogen dissemination. Growers should purchase seed that has been tested and certified to be below a certain threshold infestation level or that has been treated to reduce pathogen infestation levels. Transplants used should be as free as possible from pathogen contamination and diseases.

Eradication

The process of reducing, inactivating, eliminating or destroying inoculums at the source, either from a region or from an individual plant in which it is already established is termed as eradication. Eradication involves eliminating the pathogen from infested areas; the magnitude of the operation involved may vary considerably. One of the most extensive eradication operations carried out so far was to get rid of the citrus canker (*Xanthomonas axonopodis*) in the USA during 1927- 35. As many as 4 million citrus trees were cut and burnt at a cost of about 2.5 million dollars to eradicate the pathogen. The practices invariably employed to achieve eradication of inoculums include eradication of alternate and / or collateral hosts, crop rotations, field sanitations, heat or chemical treatments of plant materials or soil, biological control etc.

Protection

The protection of infection courts against the inoculums of many fast spreading infectious pathogen, brought by wind from neigh boring fields or any other distant place of survival. It can be achieved by creating toxic barrier between the plant surface and the inoculums. Methods employed to achieve such results are chemical sprays, dusts, modification of environment, and modification of host nutrition.

Host resistance

It utilizes in – built mechanism to resist various activities of pathogen. The infection or subsequent damage by pathogen can be rendered ineffective through genetic manipulation or by chemotherapy. The host resistance can also be induced by use of certain biotic and abiotic factors. Plant breeding techniques include selection, mutation and hybridization have helped in developing crop varieties resistant to specific pathogen or group of pathogens. Use of biotechnological tools such as tissue culture, genetic engineering and protoplast fusion are being used to develop resistant cultivars of various economically important crops.

Therapy

It is the treatment of infected host plant, which is attempted in case of economically important horticulture plants. As a principle of plant disease control, it provides an opportunity to cure or rejuvenate the diseased host plant by use of physical or chemical agents. Therapy is a curative procedure and is applied to individuals after infection has taken place.

Components of Integrated Disease Management

IDM is currently defined as: “a sustainable approach to managing diseases by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks”. Accordingly, the major components of disease management summarized here are: cultural control, biological control and chemical control. Even though these components will be dealt with individually, it should be mentioned that often the different components are complementary to each other with strong interaction among and between them and the environment and that it is essential to break away from relying on a single-technology and to adopt a more ecological approach built around a fundamental understanding of population biology at the local farm level and to rely on the integration of control components which are readily available to the resource-poor farmers (Thomas, 1999) [42].

Cultural control

This refer to the manipulation of crop environment in order to make it less favorable for the pathogen, through the adoption of measures such as adjusting planting time, plant spacing, season, irrigation, green manuring, crop rotation and crop combination either alone or in combination with other techniques. Cultural control methods not only serve in promoting the healthy growth of the crop, but are also effective in directly reducing inoculum potential (pruning, roguing, crop rotation, ploughing, etc.) and in enhancing the biological activities of antagonists in the soil (solarization, crop rotation, mulching, etc.).

The practice of crop rotation (Brust and King, 1994) [4], intercropping (Trenbath, 1993) [45] and multiple cropping (Thurston, 1992) [43] have long been regarded as successful means of reducing diseases and pathogen populations. Natarajan *et al*. (1985) [27] reported 24 per cent wilt in pigeonpea intercropped with sorghum, compared to 85 per cent wilt in the sole crop. Perrin (1977) [30] reported higher and more dependable returns in intercropping, compared to mono cropping in capital scarce, labour intensive, high pest and disease prone agriculture systems. A variation in disease intensity with the intercrop was reported by Kloos *et al.* (1987) in their studies on potato wilt, caused by *Pseudomonas solanacearum.* Soil amendments have been reported to be effective for biocontrol of diseases. Amendments in the form of plant debris, green manure, farmyard manure, compost, oilcakes, fertilizers are known to improve crop productivity by improving nutrient status and soil tilth. Further, these materials can either increase or decrease plant pathogen levels and there by disease intensity (Sivaprakasam, 1990) [39]. Katznelson (1946) [17] had suggested that addition of organic matter to soil may exert an indirect rhizosphere effect by influencing the rate of plant growth. Soil amendments that suppressed root pathogens increased soil microflora but decreased rhizosphere flora (Katznelson, 1965) [18]. Antagonism (competition, antibiosis including lysis and exploitation) has also been considered as one of the main causes of suppression of plant pathogens in soil (Park, 1960) [28].

Application of nitrogen through neem coated urea was also reported to reduce the incidence of rice sheath rot (Alagarsamy *et al*., 1987) [1]. The effect of different forms of nitrogenous fertilizers on *Fusarium* wilt incidence in pigeonpea was reported by (Raghuchander *et al*., 1993).

The addition of nitrogenous fertilizers to potato crops infected with *Verticillium*, also appeared to have a good effect, a high fertilizer level delaying symptom expression and reducing disease severity (Whilhelm, 1951) [55]. Among the plant nutrients, potassium has significant role in governing resistance to plant diseases. Several workers reported control of cotton wilt through potassium fertilization (Tisdale and Dick, 1939; and McNew, 1953) [44, 25].

Biological control

Success in using microorganisms against plant pathogens started with the control of crown gall with *Agrobacterium radiobacter*K84 (Kerr,1980) [21], and that of seedling blights caused by *Pythium* and *Rhizoctonia* with *Trichoderma harzianum* (Harmanand Bjorkman, 1998) [14], *Gliocladium virens* (Lumsdenand Walter, 1995) [24] and *Streptomyces griseus* (Cook *et al*.,1996) [9]. However, the use of naturally occurring bio-controlagents (antagonists) of plant pathogens can be traced back to many centuries through the traditional practice of crop rotations that primarily permit the reduction of pathogens' inoculum potential in the soil below injury level.

Biological control remains an attractive possibility for many soil borne plant pathogens. It has been found at least partially successful for many wilt causing fusaria (Baker and Cook, 1974; Cook and Baker, 1983) [8-9]. Introduction of the antagonist along with planting material has been reported to be more economical and effective method of biological control (Cook and Baker, 1983) [8]. Antagonists when applied to seeds were found to colonize the rhizosphere and offer protection against several soil borne pathogens (Chao *et al.*, 1986; Turner and Backrnan, 1991; Harman, 1991) [6, 46, 13].

Significant reduction in wilt disease was also obtained in cotton, melon and wheat crops with seed treatment of *Trichoderma harzianum* (Sivan and Chet, 1986) [37]. Seed treatment with *Trichoderma* also afforded better protection against crown rot of tomatoes, in fields naturally infested with *Fusarium oxysporum* f. sp. *lycopersici* (Sivan *et al.*, 1987) [38].

In early studies, *Bacillus subtillis* was identified as a potential antagonist (IARI, 1950; Vasudeva and Roy, 1950; Vasudeva *et al.*, 1962 and1963) [50-53]. Singh and Singh (1980, 1981 and 1983) also observed antagonism of *Bacillus subtilis* against *Fusarium udum* in soil amended with organic matter. Further, Cook and Baker (1983) [8] reported *Bacillus subtilis* to have good potential for biological control of several plant pathogens. *Aspergillus nidulans* has also been identified as a possible biocontrol agent in slightly acidic to alkaline soil at higher temperatures (Upadhyay, 1987) [48].

Host plant resistance is the main stay of integrated disease management in any crop, as it is a cheap and safe method of disease control (Songa, 1990) [41]. Soilsaprophytes and antagonists such as *T. viride* and *A. niger* were among the mycoflora of the wilt resistant cultivar ICP 8858, while the mycoflora of the susceptible cultivar ICP 85 18 showed a predominance of *F. udum* during all the stages of plant growth (ShaikImam and Nusrath, 1987) [32].

Chemical control

Chemical control is widely used to maintain green leaf area and increase grain yield. Fungicide treatment has been found to be effective when the infection level is visually more than 5% of the leaf area (Cook *et al.* 1999) [11]. The computer-based forecasting system has been developed to gain control of diseases using environmentally-sound and economically-viable fungicide strategies (Jorgensen *et al.* 2000) [15]. The aim is to use the dose, which gives the best margin over fungicide input (Dammer *et al*. 2007; Jorgensen *et al.* 2008) [16]. The economical benefit should be achieved from proper timing of reduced fungicide doses, which give substantial increases in net yield and cost-effectiveness. Another strategy is the proper choice of fungicide; its dose and application time are important in achieving economic efficacy (Leadbeater *et al*. 2000) [22]. Sinha (1975) [36] reported that Bavistin applied as a soil drench at 2000Ppm, 10 days before inoculation of pigeonpea plants with *Fusarium udum* controlled the wilt. Griseohlvin and bulbiformin, two antibiotics were also found very effective against *Fusarium udum* (Vasudeva *et al.*, 1958 and Chakrabarti and Nandi, 1969) [5].

Seed treatment is one aspect of crop management. It is an advanced and economic delivery system to protect the genetic potential of the seed against diseases from the moment of sowing and also partial replacement of the conventional foliar application (Smiley *et al.* 2002; Clark 2008) [40, 7]. Seed treatments with fungicides have antagonistic activity against pathogenic fungi on seed-borne and root rot diseases and are capable of suppressing root rots as well as other plant diseases (Bailey and Lazarovits 2003; Pauliz 2006) [2, 29].

Conclusion

IDM consists of scouting with timely application of a combination of strategies and tactics. These may include site selection and preparation, utilizing resistant cultivars, altering planting practices, modifying the environment by drainage, irrigation, pruning, thinning, shading, etc., and applying pesticides, if necessary. But in addition to these traditional measures, monitoring environmental factors (temperature, moisture, soil pH, nutrients, etc.), disease forecasting, and establishing economic thresholds are important to the management scheme. These measures should be applied in a coordinated integrated and harmonized manner to maximize the benefits of each component. Training and awareness raising of farmers, disease survey teams, agricultural development officers, extension agents and policy makers remains to be an important factor for the successful implementation of IDM strategies.

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