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A Review: Integrated Disease Management Approaches For Macrophomina Phaseolina

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Abstract

Macrophomina phaseolina causes dry root rot, charcoal rot diseases in various crop species. It is cause severe yield loss even upto cent per cent in crop like groundnut. It can survive at high temperature in the soil in the form of resting spores. Use of single approach of disease management, sometimes couldn't work effectively; rather, combined uses of various management practices show better response in different crops and this collective approach termed as integrated disease management (IDM). Also, integrated disease management gives opportunity to less use of hazardous chemicals and insists ecofriendly management of the pathogen. Sowing of resistance varieties of black gram, soybean, chickpea had shown up to 100 disease control or no disease infection. Use of bio-control agents like Trichoderma sp., Pseudomonas sp. as a seed treatment, a soil application or/and foliar spray found to be effective against pathogen and also improved growth of crops. Following of cultural practices i.e., water stress management, crop rotation, inter-cropping proved effective to reduce inoculums load and infection of M. phaseolina. Adding of inorganic salts such as lime, gypsum and compost in the soil may alter the micro-environment unsuitable for the pathogens and help to reduce inoculums. Combinations of phyto extract with chemical fungicides and also individual use favors reduction in rate of disease infection. This review focuses on integrated approaches for management of Macrophomina phaseolina towards sustainable agriculture.

KEYWORDS: Macrophomina phaseolina, integrated disease management, Bioagents, Dry root rot, charcoal rot, stalk rot

Introduction:

In this fast growing world, malnutrition and food scarcity are the major problem which causes is faced by the human race. It is important to decrease this malnsutrition and this food scarcity by producing the food crops in required amount. The food crops should be produced in optimum quantity as well as with the enough more nutritional capabilities. Among the food crops, cereals mainly provide us the carbohydrates; pulses are grown for their protein and other essential aminoacids and so on (Laskowski et al., 2019).

Macrophomina phaseolina (Tassi) Goid (Marquez et al., 2021) causes dry root rot and charcoal rot in various important crops i.e. black gram, gram, sorghum, maize, green gram, soybean, sunflower, mustard, groundnut, etc. (Dhingra and Sinclair, 1978; Ghosh et al., 2018). This fungus is a necrotroph and it will be survive in the soil viable for many years. Under high temperatures (30–35 °C) and low soil moisture (below 60%), this fungus can cause substantial yield losses in crops such as soybean and sorghum, impacting incomes of farmers (Kaur et al., 2012). In the worst case scenario, cent per cent yield losses have been recorded in groundnut cultivars when disease appeared at pre-emergence stage (Sharma and Bhowmik, 1986). So, it is necessary to control the pathogen with the proper management practices. By using one approach of management method, sometimes we couldn't control the effectively. So it is important to control them through various management practices with the help of integrated disease management (Elmerich, C et al., 2022).

Integrated disease management:

Integrated disease management refers to use of multiple ways of practices to reduce the disease in optimum number and to eradicate them. This approach was established after the IPM strategy for the pest. The management tools used in the IDM can used individually but in this approach they need to be complementary and they will have the strong interaction between them to reduce the impact of the disease (Khoury et al., 2010). The management practices which will reduce the inoculums number will also reduce the disease incidence also in the soil. Some of the management practices are like using of soil organic amendments, fumigants, herbicides, tolerant crops within the crop sequence, solarization and tillage (Lodha et al., 2020). It also includes using of bioagents and others.

1. Resistance variety:

One of the methods is improving resistant varieties. Black gram 41 genotypes were screened and it was studied for the presence of resistance against the dry root Macrophomina phaseolina in blackgram. The study includes rDNA operon transcript sequence regions used to identify the M. phaseolina in black gram and also the morphological characters. The genotypes are studied with use of the paper towel method. The result shown CO-5, IPU 07-3 and MASH 1-1 are found with the moderate resistant against the disease. To confirm their resistance against the disease, they are once again been evaluated under the sick pot assay in the greenhouse. The CO-5 shown good results of incidence of disease with 13.4%, IPU 07-3 with 16.7% and the MASH 1-1 with 19.9% when compared with the susceptible varieties. Theses genotypes can be used to develop the resistant varieties against the M. phaseolina in the breeding programs of black gram (Elmerich et al., 2022).

Soybean cultivars which are under cultivation in the country were screened against charcoal rot caused by Macrophomina phaseolina in vivo condition, of high disease pressure and also by artificial cut stem inoculation technique using two aggressive isolates in poly house. In two years (2018 & 2019) field study, out of twenty two varieties, only three (JS 20-98, JS 20-34 and MAUS 162) were found to be absolutely/highly resistant whereas four (JS 20-69, MACS 450, NRC 86, PS 1225) showed moderately resistant reaction against the charcoal rot. Mortality varied from 0.0 to 97.4 per cent and 0.0 to 87.8 per cent during 2018 and 2019, respectively. In case of yield reduction, it was recorded cent per cent in most of plants affected with the charcoal rot (Amrate et al., 2020).

Lakhran and Ahir (2018) tested twenty nine cultivars/germplasms against chickpea dry root rot and among them none of cultivars found resistant. Germplasms, i.e. GNG 2299, H12-24, IPC 2002-31, GNG 1958, IPC 10- 134, IPCK 2009-165, PG 0104, GL 2003, IPC 2007-28, H 12-26, BG 0109 and CSJ 515 were found moderate resistance.

Mir et al. (2018) were evaluated maize inbred lines set at two different locations for stalk rot disease caused by Fusarium sp. (FSR) and Macrophomina sp. (MSR). As per line evaluation trials, resistant and susceptible lines were selected and used to cross by following a Diallel mating design IV to study the gene action for resistance to stalk rots and the estimating the joint ability of inbred lines. A 9 × 9 diallel (Diallel-A) produced 36 hybrids for studying FSR resistance, and a 12 × 12 diallel (Diallel-B) produced sixty six (66) hybrids to analyze the resistance with both Fusarium stalk rot and Macrophomina stalk rot. The same hybrids were tested at two locations for Macrophomina stalk rot and one location for Fusarium stalk rot with artificial inoculation. The hybrids varied significantly for Fusarium stalk rot ($p < 0.05$), as was the general combining ability

(GCA) effects ($p < 0.01$), while Specific combining ability (SCA) effects were found to be non-significant. The analysis of the trials under MSR, showed significant difference for GCA, SCA, GCA × environment ($p < 0.01$), and hybrid × environment ($p < 0.05$) while SCA × environment was non-significant. The Baker ratio, which shows the relative importance of GCA over SCA, changed into close to cohesion for both the stalk rots, and hence a important additive gene impact became inferred toward resistance to these sicknesses. even though the GCA × surroundings interaction changed into full-size for MSR, this have a look at recognized strains and their go combinations with excessive resistance and massive GCA and SCA effects across environments for FSR and MSR This gives scope for supply populace development for resistance to these stalk rots, as well as growing maize hybrids with strong resistance to publish flowering stalk rot.

2. Biological agents:

Trichoderma harzianum (Gams and Meyer, 1998) and T. viride (Jaklitsch et al., 2006) were used to study against the M. phaseolina (Tassi.) Goid under the field and glass house condition. The Trichoderma which are used in this experiment are carried in Talc and gypsum carriers. They also used along with the Rhizobium (Beck et al., 1993). The use of Trichoderma reduced the 50% incidence of the M. phaseolina in the blackgram when used solely and also in mixture with the biofertilizer Rhizobium. The seeds with treatment of T. viride (biomass formulation) + Rhizobium have the best shoot length of 36.93 cm. T. harzianum (gypsum formulation) + Rhizobium has the good grain yield of 661.66 kg/ha. T. harzianum (biomass formulation) + Rhizobium treated seeds has the good root length of 22.26 cm. T. viride + Rhizobium treated seed has increased nodulation of 22.33 nodules per plant. By this we could come to know that Trichoderma reducing the dry root rot of M. phaseolina at upmost level (Indira et al., 2003).

Isolates Endo 2 and Endo 35 of Pseudomonas fluorescens protection effect of black gram (Bhowmik et al., 2002) from the dry root rot M. phaseolina have been studied under the glasshouse. The dry root pathogen has been inoculated to the black gram which has been bacterized with P. fluorescens. The PAL (phenylalanine ammonia lyase), PO (peroxidase) and PPO (polyphenol oxidase) were stimulated in the plant and also phenolics and the lignin accumulation also observed in the plant. After one day of the pathogen inoculation, the black gram tissues have been found with the phenolics accumulation and it reached maximum after the three days of the inoculation of the pathogen. The lignin accumulation in the black gram also had shown the same result. The activity of the PAL, PPO and PO are reached the maximum activity after 24 hr, 48 hr and 72 hrs of the inoculation of the pathogen into the black gram. But in the P. flurorescens untreated plants the above shown defense mechanism enzymes are formed on the first day f pathogen inoculation but after three days their effect shown decreasing in number. From this study, we can come to know that the defense enzyme stimulation can reduce the disease effect in the plants (Karthikeyan et al., 2005).

When T. viride used along with the neem cake, it is found to increase the shoot length and higher germination percentage. It provides better result when compared to their individual use. The TNAU isolate T. viride and the soil amendment effect of the neem cake reduced the disease incidence in the soil. The experiment pot with the T. viride antagonist and the neem cake soil amendment showed the reducing effect of the disease (Tetali et al., 2016).

An endophytic Klebsiella pneumonia isolate HR1 was isolated from the Vigna mungo root nodules. They will produce IAA, HCN and siderophores and they will also solubilize the phosphate and zinc. This isolate can with strand the cadmium a heavy metal and they will produces protease, chitinase and amylase. It is found that this isolate reduced the incidence of the M. phaseolina in a pot case study. It also increased the shoot and dry weight, shoot and root length and their germination percentage in the plant which is treated with the isolate HR1 when compared with the healthy plant and diseased on under the green house study. Disease incidence of M. phaseolina was in lower percentage when the isolate of K. pneumoniae was applied in the seed bacterization and soil drenching application. Chitinase, phenylalanine ammonia lyase defense enzymes were increased after the application of K. pneumoniae (Dey et al., 2016).

Bioagents and their concentration suggested by the researchers:

Bioagents for M. phaseolina	Concentration used	Reference
Trichoderma harzianum	0.6%	Uchade et al., 2020
Trichoderma viride	0.6%	
Trichoderma hamatum	0.6%	
Trichoderma viride + Carbendazim	4gm/kg + 2gm/kg	Lakhran and Ahir, 2018

Talc formulation of Trichoderma viride was experimented against the M. phaseolina. It is found that the Zinc and boron mixed T. viride which suppressed the M. phaseolina. It also increases the length of root, length of shoot, boron and their zinc uptake, increased yield and vigor index. It significantly reduced the M. phaseolina incidence from disease plant 73.54% to12.50%. Black grams zinc and boron uptake was more in the plant treated with boron and zinc enriched T. viride which was in applied as talc formulation (Pavani et al., 2015).

Pseudomonas fluorescens, Trichoderma viride and Bacillus subtilis antagonists were used the seed borne fungi of the black gram with the help of dual culture technique. P. fluorescens performed well in per cent mycelial growth inhibition of M. phaseolina by 62.41% and Fusarium oxysporum by 59.97% (Ashwini et al., 2016).

Trichoderma viride had shown good inhibition against the M. phaseolina disease by 81.55%. In case of poison food technique and agar well method, T. viride (Tv6) culture filtrate shown good reduction of the disease and it also promoted the growth at in vitro and increased the shoot length, root length, less disease incidence, number of pods in vivo condition. It performed well against the other isolates. This study proven that we can use them against the M. phaseolina as an alternative management thing for chemical control (Raj et al., 2021).

Trichoderma viride isolates which have been multiplied in substrates like coir pith, press mud and groundnut shell have found to be very effective against M. phaseolina. They have been applied in row manner for the condition acid soil. The groundnut shell had shown its effect by increasing the number of chlamydospores, good root nodulation, higher yield and reduction in disease incidence when compared to press mud and coir pith (Raguchander et al., 1993).

Trichoderma harzianum @ 0.6% shown lesser growth of the seed borne fungi. After this T. viride at 0.6% and T. hamatum @ 0.6% shown good result. They also increased their seedling vigor and seed germination (Uchade et al., 2020).

The M. Phaseolina disease incidence was reduced upto 79.23%, very less disease incense of 13.50%, had more 24 nodules per plant and had 14.8 quintals per hectare were observed in treatment T13 consist of T. harzianum and Rhizobium treated as seed treatment. P. fluorescens and Rhizobium were used in the treatment T14 shown good result followed by treatment T13 as inhibition of disease by 71.54%, grain yield of 13.4 quintals per hectare, reduced disease incidence by 18.50% and had 21 nodules per plant which has been applied as seed treatment and soil application (Kumar et al., 2021).

Streptomyces sp. found to be control the root rot of mung bean by direct pathogen inhibition and also through the induced resistance by the Streptomyces sp. They increase the peroxidase and polyphenol oxidase activies in the plant. They have been applied as soil treatment as well as seed treatment (Adhilakshmi et al., 2014).

The dry root rot caused by M. phaseolina (Tassi.) Goid was reduced by the T. viride in sand maize medium upto 60% in the pot experiment and also increased the root and shoot length of the plant (Tetali et al., 2015).

The Pseudomonas fluorescens (Palleroni, 1984) and Rhizobium M10 showed maximum inhibition (76.65%) of the disease M. phaseolina in green gram. The isolate BK1 of Bacillus subtilis shown more reduction in disease than the control plots. The B. subtilis applied as soil drenching and also by seed soaking. Seed soaking of the P. florescens also inhibited in maximum number against the M. phaseolina. The antagonistic organisms not only reduce the disease, wit that they also increased the shoot length, root length and the grain yield (Moumita et al., 2008).

The T. viridae talc powder formulation reduced the root rot incidence of the mungbean in significant number in both field condition and in the artificial condition (Ramakrishnan et al., 1994).

Glomus aggregatum, an Arbuscular mycorrhizal found to be reducing the dry root rot disease of the black gram (Basandrai et al., 2021).

Crude algal (Calothrix sp.) extracts were treated with green gram seeds, the results shown that it has reduction in amount of the dry rot disease than the control (Basandrai et al., 2021).

The M. phaseolina on the cluster bean and Fusarium on cumin was reduced by the soil amendment and biocontrol applied plots with or without the polythene plants than the no amendment added plot. The result of the oil cake amendment and mustard residue has shown nearly equal to the polythene mulching result (Israel et al., 2005).

The T. viride and neem cake mixture inoculation in the Macrophomina phaseolina infested acid soil shown very less disease incidence when compared with the T. viride and pathogen inoculation and the Neem seed and pathogen inoculation. So the mixture of the neem cake and the T. viride will show less disease affectance (Babu et al., 2002).

Neem control plus T. viride IJ biocontrol in the infested acid soil of black gram shown minimum disease incidence of 6.47%. It is very less incidence when compared with them solely (Babu, 2002).

Penicillium spp. and T. harzianum were the fungal agents which were used against the M. phaseolina and it shown good germination percentage and increased the other growth of the seedlings. The Aspergillus flavus also had shown good result in the inhibition of mycelia growth the M. phaseolina (Hyder et al., 2022).

The efficacy of biocontrol agent T. viride; Organic amendment, neem cake; plant extract, garlic; and fungicide, carbendanzim applied as seed treatment and soil application were tested against the M. phaseolina, cause of root rot disease of chickpea. Various alternative combinations of high effective treatments that evaluated in pot for controlling chickpea root rot exhibited. Among the different treatments soil application with neem cake @ 25g/pot + seed treatment with carbendazim @ 2g/kg seed (16.66 and 20.00%) found best followed by seed treatment with T. viride @ 4g/kg seed + carbendazim @ 2g/kg seed (20.00 and 20.83%) to reduced root rot incidence over control at 40 and 60 days after sowing, respectively (Lakhran and Ahir, 2018).

3. Cultural practices:

I. Water stress:

The disease incidence was reduced in the soil where the soil moisture was higher in the soil. They prevented the infection of M. phaseolina by controlling the densities of the microsclerotia at certain level (Marquez et al., 2021).

The consequences of irrigation utility and soil water stress on M. phaseolina microsclerotia (MS) density in the soil and root of soybean have been studied in 1988, 1989, and 1990. Soybean CVs. Davis and Lloyd acquired irrigation till flowering (TAR2), after flowering (IAR2), full season (FSI), or no longer at all (NI). Soil water metric potentials at 15 and 30 cm depths were recorded for whole the growing season and used to schedule irrigation. Soil microsclerotia densities were resolute at the beginning of each season. Root microsclerotia densities were resolute periodically all over the growing season. Microsclerotia were found present in the irrigated soybean plants roots as well as non-irrigated at after 6 weeks of planting. At vegetative growth stage V-13, these density of microsclerotia per gram of dry root rot reached relatively stable levels in the NI and FSI treatments (2.23 to 2.35 and 1.35 to 1.63 log, respectively) due to reproductive growth stage R-6. After R-6, irrigation was stopped and root density of microsclerotia increased in all treatments. Inception (IAR2) or completion (TAR2) of irrigation at R-2 resulted in significant changes in root microsclerotia density, with densities reaching levels interfacing between those of FSI and NI treatments. Year wise differences in root colonization reflected variation in soil moisture by rainfall. The rate of root colonization in reflection to soil moisture stress shrink with plant age. Root colonization was significantly greater in Davis than Lloyd at R-5 and R-8. This was reflected in a trend toward higher M. phaseolina density in soil at planting in plots, planted with Davis than in plots planted with Lloyd. Although, charcoal rot signs had been now not determined on plant in this study, these consequences published that water management can limit, however no longer forestall and colonization of soybean through M. phaseolina that cultivars range in colonization, and that these differences may additionally have an effect on soil densities of the fungus (Kending et al. 2000).

Non-inoculated and inoculated plants of Monterey, Albion, Camarosa and Sabrina were maintained with no irrigation and full irrigation regimes, under greenhouse conditions for testing of Stem water potential (SWP) and stomatal conductance (gs). The disease infection was recorded for seven weeks on weekly basis. The disease found affected the water relations in Sabrina, Albion and Monterey. A significant correlation was found between the tested parameters and the disease severity. The disease incidence increases in plants without irrigation, regardless of cultivar. The infection caused by M. phaseolina increases the negative effects of water stress, depending on the genotype, and that the cultivars were able to maintain more stable water relations to respond better against the disease (Sanchez et al. 2018).

II. Crop rotation:

The crop rotation in soyabean wasn’t work much in the case of M. phaseolina as they have wider host preference. But this crop rotation will reduce the inoculums density in the soil when the soybean used very less in the crop rotation (Marquez et al., 2021).

Monocropping of cowpea or biannual rotation of cowpea and millet, and intercropping of cowpea and millet contributed to the damage caused by M. phaseolina in these areas. Our data suggest that acceptable charcoal rot control in cowpea at high inoculums densities in adverse Sahelian environments, can be achieved partly through use of non hosts as fonio and (to a lesser degree) millet. Farmers could plant fonio or millet continuously for three years to reduce soil inoculum of M. phaseolina to a level safe for cowpea production under conditions of moderate and high soil infestation. In case of very high soil infestation, millet rotation is not efficient for a rapid reduction of soil inoculum, but fonio can reduce inoculum to acceptable levels within four years of monocropping (Mbaye Ndiaye, 2007).

III. Intercropping:

The M. phaseolina root rot was found low in the sesame crop which was intercropped with the green gram than the solo cropping of the sesame (Marquez et al., 2021).

Consolidated ffects of 15 crop rotations and combinations on total number of sclerotia of M. phaseolina in soil were determined during the fifth year of Vertisol cropping system experiment at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) Center in Patancheru, India. Higher numbers of sclerotia were detected in the intercropping systems of sorghum (Sorghum biocolor) or cowpea (Vigna sinensis) with pigeonea (Cajanus cajan) than in single-cropping system. The maximum number of sclerotia were detected in plots were continuously intercropping of pigeonpea with sorghum in both the rainy and post rainy seasons. An increase in populations of sclerotia was also recorded when rainyseason sorghum was followed by either sunflower (Carthamus tinctorius) od chickpea (Cicer arietium). Cropping system with fallow in the rainy season, followed by sorghum or chickpea in the post-rainy season, stabilized the inoculums density of M. phaseolina (Singh et al., 1990).

4. Inorganic salts:

The control of M. phaseolina was done with some inorganic salts in place of the synthetic fungicides. Salts like sodium carbonate at 1.5%, sodium bicarbonate at 2.0% and ammonium molybdate at 4.0% found effective against the M. phaseolina fungal growth. Seed priming with these salts will also reduce their seed borne infection (Indra et al., 2019).

Dry rot caused by M. phaseolina causes post-harvest infection in ginger during storage. The study revealed that potassium silicate at 2.5% concentration restricted the mycelial growth of M. phaseolina and also showed alteration in hyphal morphology with constrained growth of mycelia as observed by bsright field and SEM analysis. Cell wall structure variation resulted due to alteration in glycerol and EPS content with silicate was detected in biochemical analysis. The lipid peroxidation and the cell permeability were also higher for silicate treated mycelium. In plant and field studies revealed that the growth of potassium silicate increase in treated plants and also reduce dry rot disease incidence. Increase in organic matter and nutrient availability in silicate treated soil was depicted by physicochemical analysis. These findings suggest the possibility of using potassium silicate as an alternative to fungicides against dry rot disease (Nasser and Suseela Bhai, 2021).

5. Phyto extract:

The Launea nudicaulis leaf and stem extract found to have the antifungal activity against the disease M. phaseolina. The leaf has the methanolic properties. The plant belongs to the family Asteraceae. The leaf, stem and root of the plant L. nudicaulis were dried and methanolic were extracted from them for 2 weeks. This has been used against the M. phaseolina. The leaf extract has the good number of methanol and exhibit the good antifungal property and followed by it stem , root and inflorescence has the good antifungal property (Javaid and Banaras, 2015).

The Azadirachta indica will reduce the disease in green gram by 58.33%, then Nigella sativa by 57.50 % and by the Carum copyicum by 51.67%. Lawsonia inermis, Foeniculum vulgare and Nicotiana tabacum showed very less effectively against the disease as 32.5%30.83% and 30%. Apart from the disease incidence reduction, A. indica also showed the very good emergence of black gram seedling by 73.33% at 10% concentration. With 1% concentration of the Foeniculum vulgare, the seedlings emergence was increased to 20% more. The seedling emergence of the green gram was directly linked with the concentration of the medicinal plants. The increased number of seedling emergence of the all plants shown during the use of 10% of the decocation of the plants (Iqbal et al., 2021).

The neem @ 20% and garlic clove extract @ 15% shown good result in the mungbean against the M. phaseolina. They reduced the mycelia growth in the plant as 92.46% and 100%. Followed by the extracts of the neem and garlic clove, eucalyptus and lantana also shown the good result. The nerium, bougainvillea, tulsi, euphorbia and menthe had shown very lesser reduction of the disease in the plants (Khaire et al., 2018). The garlic clove extract shown great inhibition of 77.3 % and 77.3% of reduction in microsclerotia formation of M. phaseolina in soybean. Followed by the garlic clove extract, extract of Parthenium leaf 15% concentration also shown 75.2% inhibition. When the garlic clove extract @15% concentration provided as soil drenching for soybean also shown the reduction in the disease incidence by 13.5% and produced higher yield of 14.6 quintal/hectare (Kumar et al., 2020).

Ocimum sanctum acidic extract, Calotropis procera alkaline extract and

Astragalous tribuloides acidic extract were shown lesser growth of the M. phaseolina where as the Ocimum sanctum alkaline extract, Astragalous tribuloides alcoholic extract and the Caltropis procera acidic growth shown the maximum growth of the M. phaseolina (Gupta et al., 2015).

Thombre and Kohire (2018) reported both the botanicals and plant extracts decreasing the mycelial growth percentage of M. phaseolina. Momordica charantia (4.34cm) had the maximum inhibition percent while Ficusas perifolia (5.69cm), Anacardium occidentals (5.59cm), and Psidium guajava (5.55cm), which had a average inhibitory effect against pathogen. The combination of four plants has the main importance in controlling the pathogen. Garlic extracts @ 0.5% results 75 per cent seed germination. Among all the seed treatments seed with carbendazim @0.2% results most effective. Fungicidal treatment with seeds results seedling vigour index by 26.75% over control treatment. Garlic extract @ 1% results in controlling soil borne pathogens and increasing the seed vigour index and also the field emergence. Datura metal and Azadirachta indica leaf extracts has best antifungal activity but Datura metal has the best inhibitory effect over Azadirachta indica (Lakshmeesha et al., 2013). When compared to chloroform extracts, methanol extracts had a higher level of antifungal activity. Allium cepa and Alliums ativum has the small colony diameter and large mycelial growth inhibition and results the mean percentage disease occurrence was 26.40 and 29.34 per cent and 27.12 and 30.37 percent, respectively. Against M. phaseolina, the botanicals Allium sativum (34.73 and 32.91 per cent) and Allium cepa (35.44 and 32.97 per cent) provided the best disease prevention.

Green gram root rot was found reduced when using the garlic extract at 1.0% for its contol. They also increased the seed germination, field emergence and the seedling vigour. Next to the garlic extract, turmeric extract and neem leaf extract also found very useful in reducing the green gram root rot disease. Datura metal leaf extract and neem leaf extract found to have a very strong fungicidal effect over the M. phaseolina (Ahmed et al., 2021).

Azadirachta indica, Datura metel, Allium species, Eucalyptus camaldulensis, Adenocalymma alliaceum leaf extracts were used as the botanicals against the M. phaseolina. Palma rosa and Launaea nudicaulis essential oils found in reducing the legumes dry rot of the legumes (Basandrai et al., 2021).

6. Compost:

The M. phaseolina disease incidence was very less of 4.9% with the compost of 3.5 t/ha Prosopis juliflora and 0.5 t/ ha weed compost. The compost of Indian mustard and weed composed reduced the disease incidence by 5.2%, where as the control has 10.1 % disease incidence. The antagonistic actinomycetes against the M. phaseolina were more in the compost of Indian mustard + weed compost by 37%. The disease incidence reduction was more (86.3%) in the soil with Indian mustard + weed and after that mustard compost is placed. It is found that combination of using any weed compost with other compost will significantly reduced the disease incidence (Saxena et al., 2014).

The efficacy of five composts i.e. Prosopis juliflora (Swartz) DC, Calotropis procera (Willd) Dryland, Azadirachta indica, Azadiracta juss, Acacia nilotica (Linn) Willd ex. Del. and on-farm weeds wastes residues prepared and experimented against severity and microbial population dynamics, microbial activity of Macrophomina phaseolina causing dry root rot of guar was ascertained. In general, compost amended plots were retained 16 % higher soil moisture compare to non-amended plots at crop growth stage. Population number of total fungi, bacteria and actinomycetes increased in the amended plots. The highest population of total fungi, actinomycetes and bacteria were recorded in treatments amended with A. nilotica, P. juliflora and weeds compost, respectively. In case of microbial activity 26.1% was also higher in amended plots with compared to without amended plot. Amendment of soil with composts resulted in increases in the concentration of micronutrients and significant reduction in plant mortality due to dry root rot. Effects of composts were also found positive in yield promotion where 40 per cent in the seed yield increase was recorded in plot amended with P. juliflora compost. In India on arid region, diseases caused by Macrophomina can be effectively control and beside crop productivity can be improved by utilizing some on-farm wastes (Bareja et al., 2012).

Trichoderma viridae in vermicompost and in banana compost found to have good suppression of disease M. phaseolina in green gram. This compost is also act as the organic amendments by serves as the excellent source for the nutrition need and they are controlling the disease considerably. The Trichoderma in theses compost act as an antagonistic and suppressing their growth. The incidence of the disease is highest when the T. viridae was place in the Calotropis compost (Choudhary et al., 2011).

Macrophomina phaseolina, a heat tolerant pathogen, causing dry root rot disease of cluster bean (Cyamopsis tetragonoloba), and their survival was studied by residue of pearl millet (Pennisetum glaucum) and cluster bean. The infected residue samples were incorporated and retrieval at various stages of the composting process. During the heating phase, temperatures varied from 48–51°C at 30cm and 60–62°C at 60cm depth in compost pits. Survival of M. phaseolina propagules was found significantly higher (13 to 23%) in the 4% urea-N enriched residues which was kept at 60cm compared to 2% urea-N kept at 30cm. However, M. phaseolina propagules were not completely eradicate at heat phase (48–62°C) from infected residues. Effects of composts were ascertained beneficial on dry root rot intensity, densities of M. phaseolina, Nitrosomonas and antagonists in soil and seed yield of cluster bean (Lodha et al., 2002)

7. Soil solarization:

Soil solarizarion has found to reduce the soil pathogens like Pythium spp., M. phaseolina, Fusarium spp., etc. It will be a useful tool in reducing the soil borne pathogen in cost effective manner. But it will depend on the climate and also it takes long amount of time to happen (Singh et al., 2014).

Amendments plus soil solarisation increased the soil temperature than the non amended and non solarized plot. This treatment reduced the M. phaseolina in the soil. Soil solarisation plus mustard pod residue also reduced the pathogen in the soil upto 30 cm depth (Israel et al., 2005).

Solarization will be used to reduce the effect on top soil and if they used with the other approaches they can reduce the deep soil infestation also. Biological methods also can be used to reduce their infestation with soil amendments and may also after the solarization management (Lodha et al., 2020).

The soil solarization with chicken manure has reduced the disease incidence of the M. phaseolina in strawberry. It have reduced significant amount of reduction in disease incidence and shown results similar to the chemical fumigation. So, this can be done to reduce the infection of the disease (Chamorro et al., 2015).

8.Herbicides

Herbicides like EPTC, dinoseb, flurodifen, alachlor and flurometuon have found to be cause in decline in the population number of M. phaseolina in the soil. The dinoseb reduced the M. phaseolina in higher number than others. Followed by it flurodifen, EPTC, and flurometuron shown the decline in the amount of the disease in the soil. This shown that the herbicide and soil interaction shown decrease in the disease incidence (Edgar Filho et al., 1980).

9. Chemical control:

The M. phaseolina cause some discolourized spot in the hypocotyls region of the black gram seedlings. Then the plant will shrink and they will decolorize to black in colour. They will be spread to the both side of the radical and the plumule. Then it will cause the complete collapse of the black gram seedlings. Then the five fungicides have been used against this disease in vitro condition. The results suggest that thiram, vitavax, ceresin and benlate shown very good result against the disease and it also reduced the disease colonization of the fungus in the seed (Reddy et al., 1981).

Carbendazim @ 0.2% was found to be very effective in reducing the seed borne diseases of the black gram. Followed by the carbendazim, mancozeb @ 0.2% and captan @0.2% provided good result against them (Uchade et al., 2020).

Along with carbendazim, captan, propineb, tebuconazole and thiram+carbendazim also had shown full inhibition of the M. phaseolina growth (Ashwini et al., 2015).

Carbendazim, thiram, copper oxychloride, chlorothalonil, thiophanate methyl and mancozaeb were used against the black gram isolates at 0.1%, 0.15% and 0.2% placed in agar medium. The Carbendazim and thiophanate methyl showed good inhibition against the disease (Devi et al., 1997).

Tubeconazole and trifloxystrobin is chemical composition of one fungicide and Chlorothalonil and metalexyl is chemical composition of another fungicide. Both the fungicides give good result when they are applied at the rate of 6mM. salicylic acid also shown good reduction in the disease at 6mM concentration. Tubeconazole and trifloxystrobin shown good result when compare to the others against the M. phaseolina (Rehman et al., 2021).

When the carbendazim applied soil drenched @ 0.1% concentration for the soybean crop, they shown the minimum incidence of the M. phaseolina by 5.36% and it helps to increasing in the yield. The both carbendazim and thiphanate methyl @ 0.1 % concentration controlled the M. phaseolina in soybean by 100% in vitro condition (Kumar et al., 2020).

Chemicals and their concentration suggested by the researchers:

Chemicals for Macrophomina phaseolina	Concentration	References
Carbendazim (Soil drenched)	0.1%	Kumar et al., 2020
Carbendazim + Thiphanate methyl	0.1%	
Carbendazim	0.1%	Devi et al., 1997
Copper oxy chloride	0.15%	
Thiphanate methyl	0.2%	
Mancozeb	0.2%	Uchade et al., 2020
Captan	0.2%	

Conclusion:

The Macrophomina phaseolina is a heat-tolerant soil borne pathogen which is able to causes diseases in the different crops viz., black gram, gram, groundnut, soybean, maize, sorghum, green gram at any stage of crops. As it is soil inhibiting as well as air borne pathogen, its management is very difficult by using of one control or management practices. That may cause serious damage in yield loss up to cent per cent in infected crops. Use of bio-control agents like Trichoderma sp., Pseudomonas sp. as a seed treatment, a soil application or/and foliar spray it always found effective against pathogen and also improved growth of crops. Following of cultural practices i.e., water stress management, crop rotation, inter-cropping proved effective to reduce inoculums and infection of M. phaseolina. Adding of an inorganic slats and compost in the soil has shown improvement of crop growth status and helps to remove inoculums. Combinations of phyto extract with chemical fungicides and also individual use favors reduction in rate of disease infection. When multiple approaches are performed to control the disease in the different crops, it will reduce the disease incidence in significant number which will not cause any yield reduction. Also, the integrated disease management approach is mainly focused on the sustainable thing sometimes.

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