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Biological management of charcoal rot of maize caused by *Macrophomina phaseolina* by using *Trichoderma*: A review

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Abstract
Maize (*Zea mays* L.) is one of the most adaptive developing crops, able to grow in a wide range of agroclimatic conditions. *Macrophomina phaseolina* is a species of *Macrophomina* (Tassi) Goid is a maize pathogen that causes serious charcoal rot disease, which results in severe output losses. Three native *Ascomycetes, Trichoderma harzianum, T. viride,* and *T. hamatum*, as well as two Meliaceae members, *Melia azedarach L.* and *Azadirachta indica L.*, were tested for antifungal activity against the pathogen. It usually survives in the soil as microsclerotia, which germinate repeatedly during the crop-growing season. Sclerotia survival is harmed by a low C:N ratio in the soil, as well as a high bulk density and high soil moisture content. Agricultural methods, organic amendments, seed treatment, and genetic host resistance can all help to manage the illness to some extent.

Keywords: Maize *Zea mays*, charcoal rot**,** *Macrophomina phaseolina*, *Trichoderma sp*.

Introduction

Maize (*Zea mays* Linn.), a recent New World graminaceous grain, has a special place in world agriculture, ranking third in both region and production after rice and wheat. It is the ultimate fruit, animal feed, and commercial crop . Maize ranks third in terms of region and development in Asia like the rest of the country, which is marked by 34 nations (R. C. Sharma*, Carlos De Leon t and M. M. Payak 1993). Maize is grown in 6 ma/ha with an output of 11.2 mt, putting it in fifth place in terms of region and third in terms of production in India (Anonymous, (1998). The grain, leaves, stalk, tassel, and cob are all useful parts of the maize plant that may be utilized to make a range of food and non-food products. It was once mostly used for food in India, but due to a substantial shift in its utilization in the last five to six years, it is now mostly utilized for feed (60%). (Kumar *et al*., 2012)

Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, and Andhra Pradesh are the largest maize-growing states (in decreasing order). Gujarat, Himachal Pradesh, Jammu and Kashmir, Orissa, Karnataka, Maharashtra, and Haryana are all states of India. Together, they make up 94.5 percent of the entire maize area and 95.1 percent of total grain output; the national 1346 kg/ha is the average (Payak, M.M. and Sharma, R.C. (1985). The annual depletion of grain due to maize diseases has been estimated to be 13.2 percent (Payak, M.M. and Sharma, R.C. (1985). The pathogen *Macrophomina phaseolina (Rhizoctonia bataticola)* causes charcoal rot, which is one of the most commercially significant maize diseases.

In addition to disease control, biocontrol treatments enhance plant development, resulting in increased yield. Current plant disease management methods rely heavily on the creation of resistant cultivars and the application of synthetic pesticides. Biological control is gaining popularity owing to its low cost and environmentally safe application.

Trichoderma spp. has been shown to create a number of hazardous metabolites *in vitro*, and there is evidence that these metabolites are also formed in soil pieces of organic matter.

Diseases of maize

16 out of 61 diseases have been identified as prominent ones based on research work over the last 20 years or so, and are mentioned below. As defined by Renfro and Ullstrup, (1976), these diseases happen in both tropical and temperate regions.

1. **Charcoal rot** [*Macrophomina phaseolina* (Goid.) Tassi]. Distribution: JK, WB, Punjab, Haryana, Delhi, UP, MP, AP, Karnataka. Tamil Nadu.
2. **Turcicum leaf blight:** [*Setosphaeria turcica* (Luttrell) Leon & Suggs. = Exserohilum turcicum (Pass) Leon & Suggs.]
   Distribution: Jammu and Kashmir (JK), Himachal Pradesh (HP), Sikkim, West Bengal (WB), Meghalaya, Tripura, Assam, Rajasthan, Uttar Pradesh (UP), Bihar, Madhya Pradesh (MP), Gujarat, Maharashtra, Andhra Pradesh (AP), Karnataka, Tamil Nadu.
3. **Maydis leaf blight:** [*Cochliobolus heterostrophus* (Drechsl.) Drechsl. = Drechslera maydis Nishikado].
   Distribution: JK, HP, Sikkim, WB, Meghalaya, Punjab, Haryana, Rajasthan, Delhi, UP, Bihar, MP, Gujarat, Maharashtra, AP.
4. **Common rust:** (*Puccinia sorghi Schw*. II, III stages only).
   Distribution: JK, HP, Sikkim, WB. Punjab (winter), Haryana (winter), Rajasthan, Delhi, UP, Bihar, MP, Maharashtra, AP, Karnataka, Tamil Nadu.
5. **Phaeosphaeria leaf spot:** [*Phaeosphaeria maydis* (P. Henn.) Rane, Payak & Renfro].
   Distribution: Sikkim, WB, UP.
6. **Chrysanthemi stalk rot:** [*Erwinia chrysanthemi p.v. zeae* (Sabet) Victoria, Arboleda & Munoz].
   Distribution: HP, Sikkim, WB, Punjab, Haryana, Rajasthan. Delhi, UP, Bihar, MP. AP.
7. **Pythium stalk rot:** [*Pythium aphanidermatum* (Eds.) Fitzp. = P. butleri Subram.]. Distribution: Sikkim, WB, Punjab, Haryana, Rajasthan, Delhi, UP, Bihar.

Biology of pathogen

The severity of disease induced by *M. phaseolina* in many hosts is linked to high soil temperatures (30-42 °C) and poor moisture, as well as when the plant is stressed by unfavorable climatic circumstances. During the post-flowering phase, plants that are subjected to moisture stress experience the most infection. Sclerotia, which are spherical and black in color, are produced in enormous numbers by the fungus. On the stems and stalks, it can generate pycnidia. Disease development is aided by post-flowering conditions such as high plant population or dryness, as well as large nitrogen fertilizer treatments, hail, or insect damage. During exceptionally hot and dry seasons, the condition is most prevalent.

Charcoal rot overwinters or lives in the form of resting structures (microsclerotia) on lower stem leftovers left in the field after harvesting. The transportation of soil contaminated with microsclerotia on tractors, ploughs, and other farm machinery and packing material poses the greatest danger of spread. The alternative hosts are also a significant source of inoculum, which causes infection in subsequent seasons. Seedborne illness is uncommon, and there is no solid evidence that it is transmitted by seeds.

Symptoms

The withering signs appear on the damaged plants. A grey stripe can be seen on the stalks of diseased plants. The pith becomes shredded, and minute sclerotia appear on the vascular bundles in a greyish black color. The inside of the stalk is frequently shredded, causing stalks to break at the crown area. The afflicted plant's crown develops a black coloration. Root bark shredding and root system disintegration are frequent symptoms. Post Blooming Stalk Rot is the disease caused by a pathogen that attacks the plant after it has finished flowering (PFSR). A greyish stripe can be seen on the stalks of affected plants. The pith becomes shredded, and minute sclerotia appear on the vascular bundles in a greyish black color. The inside of the stalk is frequently shredded, causing stalks to break at the crown area.

Epidemiology

Microsclerotia are fungal structures that appear as microscopic black specks underneath the epidermis of lower stem and tap root tissues. The fungus survives the winter as microsclerotia on crop detritus. Microsclerotia may live in dry soil for years, but just a few weeks in moist soil. Infection of plants can happen at any point throughout the growth season. For 2-3 weeks, hot and dry weather with soil temperatures of 80 to 95 degrees Fahrenheit promotes symptom development. The virus that causes charcoal rot has been shown to infect soybean seedlings, lowering their germination rate. The leaves begin to droop and become yellow, then brown. In most cases, the fading leaves stay connected to the leaf stem. The bottom stem and tap roots of infected soybean plants have a stripe of light grey or silver when split open. Small black specks are commonly found underneath the epidermis in the outer stem tissue (microsclerotia).

Management

- **Cultural Control:** The most popular and easiest technique is to use resistant hybrids; hybrids with good resistance or tolerance to Fusarium and Diplodia stem rots usually have strong resistance to Charcoal rot as well. Certain hybrids, maybe due to drought tolerance, provide some resistance. Although maize, sorghum, and cotton are pathogen hosts, they maintain fewer microsclerotia numbers in soil than soybean. Three years of maize rotation may help lower populations, but it will not eradicate the disease from the soil. Rotation with a weak host like cotton or non-host plants like minor grains like wheat or barley may only take one or two years to lower inoculum levels.
- **Biocontrol:** Six isolates of *Trichoderma harzianum* were investigated for their efficiency against *Macrophomina phaseolina*, a maize charcoal rot pathogen, using a dual culture plate methodology and inhibition with volatile compounds. *T. harzianum* isolates from Hyderabad suppressed *M. phaseolina* Niger's radial growth by 62.34 percent. whereas Coimbatore, Dharwad, Delhi, and Pantnagar isolates suppressed radial development by 58 percent, 56 percent, 53 percent, and 51 percent, respectively, above control. The impact of these biocontrol agents on sclerolia production and size was also investigated. In comparison to other isolates, the Hyderabad isolate was shown to be the most effective, resulting in a 69.48 percent reduction in sclerotia generation and a 57.36 percent reduction in sclerotial size above control. The impact of these bioagents' volatile metabolites on M. phaseolina's radial growth, sclerotia size, and production was also investigated.

One of the most economically important diseases of maize is charcoal rot caused by *Macrophomina phaseolina* (*Rhizoctonia bataticola*). Since the pathogen is both seed and soil carried, chemical treatment alone is difficult to manage because it does not provide protection throughout the crop's life cycle. As a result, an effort was made to find an appropriate *Trichoderma viride* isolate for disease control in the field. *Trichoderma spp*. has been shown to create a number of hazardous metabolites *in vitro*, and there is evidence that these metabolites are also formed in soil pieces of organic matter. Many of them have been isolated and chemically characterised. Pentaketiles, Terpenoides, Octaketides, and Peptaibols are the antifungal metabolites of *Trichoderma*. The biocontrol agents also improve plant growth in addition to disease control resultsing in higher yield. Wells el al. *T. harzianum's* activity against *Rhizoctonia spp*. was first demonstrated in the field. In seasamum, mungbean, and jute, seed treatment with *T viride* and *T harzianum* decreased the incidence of rot *Trichoderma* species were identified using a dilution plate approach using *Trichoderma* selective medium (TSM) from the rhizosphere of healthy maize plants (Elad and Chet, 1983). Only one *T viride* (MR) was chosen from the nine isolates utilising the dual plate technique. The Indian Type Culture Collection (ITCC), Division of Plant Pathology, IARI, New Delhi, provided seven isolates of *T viride*, *viz*. T.v. 2109 (Assam), T.v. 2185 (Solan), T.v. 2211 (New Delhi,), T.v. 3235 (Solan), T.v. 3277 (Shandilya), T.v. 3798 (New Delhi and T.v. 4282 (Jammu). The isolate T.v. (TN) was obtained from Tamil Nadu Agricuitural University, Coimbatore. **.**

In the lab, the effects of volatile and non-volatile metabolites were investigated. After 24, 48, 72, and 96 hours after inoculation, the plates were placed in an incubator at 28 °C and the pathogen's radial growth was measured. Finally, the pathogen's percent inhibition was computed.

Maize seedlings were treated with carbendzim (Bavistin 50 WP) at 4 g/kg and talc-based powder formulations of fungal antagonists at 4, 8, and 12 g/kg. The treated seeds were stored for 24 hours before being planted in the field. The percent germination was calculated seven days after seeding. At the post-flowering period, bio-metric observations were done. The charcoal rot incidence was recorded after splitting open the stalks longitudinally following the I to 10 scale developed by Payak and Sharma. *In vitro*, all nine isolates of T viride were shown to generate inhibitory volatile compounds, and all nine isolates were observed to diminish the pathogen's radial development when compared to a control group. All of the treatments outperformed the control in terms of growth and dry matter production. The *T viride* (MR) - 12 g/kg treated plots had the greatest shoot length (180.8 ern), dry matter (624.5 g), and grain weight of 10 cobs (9 10.5 g), but both treatments were statistically equal. In the case of 1000 grain weight and yield, the same pattern was visible.

Similar outcomes were reported by a large number of workers. In mungbean and peanut, seed treatment with *T viride* enhanced root length, shoot length, nodulation, and yield. *T viride* treatment boosted blackgram yield by 97 percent, according to Raguchander *et al*. due to improved root, shoot, and nodulation development. *Trichoderma* strains have been shown to increase growth and biocontrol activity in lettuce.

Conclusion

The disease described above are detrimental to maize production in across the world since they are prevalent in maize-growing areas. It has been highlighted that the maize diseases discussed above cause significant economic losses and pose a risk to humans and animals. *Trichoderma harzianum* is an effective biocontrol agent of *Sclerotium rolfsii*, *Rhizoctonia solani*. For effective disease management, an integrated strategy involving agronomic, nutritional, or chemical measures should be used. The development of resistant cultivars using both traditional and biotechnological means would aid in the control of these dangerous illnesses, which remain a challenge even after several years of discovery.

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