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Pavan GS
Department of Plant Pathology, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Poonam Shete
Department of Plant Pathology, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Pavan GS
Department of Plant Pathology, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Symptomatology, etiology, epidemiology and management of Southern corn leaf blight of maize (*Bipolaris maydis*) (Nisikado and Miyake) Shoemaker

Pavan GS and Poonam Shete

Abstract
Southern corn leaf blight is one of the most serious disease-causing damage in entire country, the disease caused by *Helminthosporium maydis* by producing lengthy, cigar structured ovoid and greyish lesions on lower leaf parts. This article revealed that both in *in vivo* and *in vitro* Propiconazole proved trusty one against pathogen followed by Mancozeb, Carbendazim, Chlorothalonil and COC when compare to control. Also studied the efficiency of Bio-control agents and Botanicals in disease management, Garlic clove extract was proved best one against the *Helminthosporium maydis* and bio control agents like *Trichoderma spp.* Very efficient one in controlling the pathogen, bio control agents use antibiosis, enzyme production and mycoparasitism mechanism for inhibiting the growth of fungus, biocontrol agent's efficacy could exist for one month. *Trichoderma* isolates will induce resistance in plants against fungal pathogens.

Keywords: *Trichoderma* spp. *Helminthosporium maydis*, antibiosis, mycoparasitism

Introduction
Maize or corn (*Zea mays* L.) family poaceae most important annual cereal crop of the world. *Zea* means "sustaining life" derived from ancient Greek word and mays means "life giver" according to Taino language. The word "maize" by the Spanish connotation "maiz" which is the most suitable way of presenting the plant. Different other names like zea, silk maize, makka, barajovar, etc. are useful to identify the plant (Kumar & Jhariya, 2013) [23]. The crops accepted as a staple food source in the entire world. After rice and wheat, maize is the third main important crop in the world (Sandhu *et al*., 2007) [41]. Maize having starch (72%), protein (10%), and fat (4%), providing an energy at 365 Kcal/100g (Nuss *et al*., 2010) [36], maize contain lower amount of protein than rice and wheat. Maize gives B vitamins and important minerals including fibre content, but poor in remaining nutrients, like vitamin B_{12} and vitamin c, and contain less amount of calcium, folate, and iron. Daily food in the diet and other components, like vegetables, tea (e.g., oxalates), coffee (e.g., polyphenols), eggs (e.g., phosvitin), and milk (e.g., calcium) inhibit the absorption of nonheme iron content which is present in maize (Dale *et al*., 1982, Nuss *et al*., 2010) [10, 36].
According to the prediction of US Department of Agriculture (USDA), when compared to previous year the 2019-2020 maize harvest yield moderately decreased: in fact, the predicted speak of 1,108 million tonnes, as against to 1,124 million tonnes for 2018-2019.Major maize production mainly comes from 4 countries: The United States, China, Brazil and Argentina, these countries stand for two thirds of global production. Two continents of the world such as North America and Asia contain top 10 maize producing countries. Mexico and Canada production contributed to North America, China, India and Indonesia dominates in the production of maize in Asia continent (https://www.mccormick.it/as/all-the-latest-data-on-maize-production-around-the-world/). In India maize production was 28,000 thousand tonnes in 2020.In 1971 the maize production was 5,101thousand tonnes to 28,000 thousand tonnes in 2020 growing at 4.51% annual rate (https://knoema.com 2020).
Maize is grown through the country due to its broad range ecological adaptation; these are the major maize producing states Andhra Pradesh (20%), Karnataka (17%), Maharashtra (11%), Bihar (9%), Tamil Nadu (8%), Rajasthan (6%), Madhya Pradesh (6%), and Uttar Pradesh (5%). Up to 59% of the overall production is utilized as feed, 17% production of total production used as a industrial raw material, (10%) food, (10%) exports, and remaining purposes (4%) (Kumar *et al*., 2013) [24].

Approximately 47% of the maize production have been used for poultry feed. And the remaining produce in which 13% is utilized for livestock feed and for food consumption, 12% for industries, starch industry utilized 14%, 7% have been used for processed food and 6% for export and remaining presuppose (https://iimr.icar.gov.in/india-maze-scenario/).

Symptomolgy, etiology and epidemiology of *Bipolaris maydis*

Maize crop being attacked by about 65 pathogens those are fungi, bacteria and virus (Rahul and Singh, 2002) [38]. Fungal, nematodes, bacterial diseases have been reported 9 percent loss in maize crop around the world in 2001-03 (Oerke, 2005) [37].

The yield loss in individual states of United States and Ontatrio, Canada was evaluated by university plant pathologists it has been reported 7.5 to 13.5% grain production from 2012 to 2015 (Mueller *et al.*, 2016) [31]. In United States the annual yield loss has been reported from 2 to 15% (Munkvold and White, 2016) [33].

The southern corn leaf blight of maize *(Bipolaris maydis* T.) (Before called as *Helminthosporium maydis* T.) spread epidemic portion in the United States and southern Canada, reported 15% devastating in crop and expected loss of $1.0 Billions at that period (Ullstrup, 1972) [48]. It was not unusual for few farmers to bear 80 to 100% losses and average losses of about 35 and 50% have been reported in corn belts.

The crop being infected with Race O exhibit symptoms like small minute lesions and later on converted to triangle shape and become rectangular on maturing (Ali *et al*., 2011b) [4].

Maize cultivar with Texas male-sterile cytoplasm being infected with mostly race T pathogen usually. The epidemic occurred in USA in 1970 and 1971 by this pathogen race only. Leaves, husks and ears also being infected with this pathogen could produce minute lesions on maize (Ullstrup, 1972) [48].

Damage of leaf photosynthetic area so it could leads poor grain filling. Later on lodging of plant takes place, which happened when plant redirect sugars from the stalk for grain filling while disease is in severe condition (Kaur *et al*. 2014b) [19].

The plant parts like leaf, ears, shanks, ear husks, cobs, sheaths and stalks were infected by the pathogen. If shank of the plants attacked by pathogen in early stages so resulting in ear may rid off. Kernels are affected by SCLB are covered by felty, black mold, resulting in con rot. Ear rot is most common for the plants of cms-T cytoplasm which were infected by race T pathogen very easily (Calvert *et al*., 1973) [8].

The lesion symptom of race O confined to leaves of the maize crop. The lesions are about range of 2 to 6 mm wide and 3 to 22 mm long. Race T could produce lesions which are tan in colour with chlorotic halos or yellow-green. The plant parts include stem, ear and sheath and all the aerial parts were found with symptoms like red lesions to dark brown margins. The race T lesions are oval to elliptical are bigger than the lesion symptoms of race O, at about 6 to 12 mm wide by 6 to 27 mm long. Wilt symptoms of seedlings exhibited by race T and plants will die between three to four weeks (Anon. 2012) [5].

Race C could cause necrotic lesions which are about 5 mm in length and leads to wilt of the plant (Wei *et al*., 1988) [50].

Southern corn leaf blight causing race O pathogen could produce minute tan colour lesions on leaf blade of the plants the lesions are about 0.6 to 2.5 cm (Agrios, 1997) [1].

They can produce plenty of lesions on leaves it would cover the entire leaf and leads to defoliation of the plant (Munkvold *et al*., 2016) [34]

The fungus by producing leaf spots it will reduce the photosynthetic area of leaf along with that it will increase the respiration of affected tissue and suppress the yield of crop (Kosuge, 1978) [22].

SCLB produce symptoms first appeared in spindle shape and primarily having size of 2- 6mm in length and then in further cases brown chocolate-coloured lesions on big plants the lesions were 2.5 to 20cm in size. The older leaves having extra lengthen and oval shaped burning areas (Akonda *et al*., 2015) [2].

Maydis leaf blight (MLB) is been reported in every maize growing areas. It is even called as Southern corn leaf blight (SCLB) and causal organism is *Bipolaris maydis* (Y. Nisik., & C. Miyake) Shoemaker, (Teleomorph: *Cochliobolusheterostrophus* (Drechsler) Drechsler. This is disease has been reported as a most destructive disease in the wold where presence of hot and humid, tropical and temperate climate. In India *H. maydis w*as first found in Maldah district in West Bengal by Munjal *et al*., 1960) [32]. Outbreak of Helminthosporium *maydis* has been found in Ludhiana and Rajasthan (Sharma *et al*., 1978) [44].

Bipolaris species were previously known as *Helminthosporium.* In many taxonomic classifications, *Helminthosporium* species were differentiated to four genera: *Curvularia, Bipolaris, Exserohilum and Drechslera* (Sivanesan, 1987; Manamgoda *et al*., 2011) [45, 28]. All the above genera called helmintho sporioid fungi because of their marphologically similar appearance.

The causal organism *B. maydis* (Telomorph: *Cochliobolusheterostrophus* (Drechsler) Drechsler) having three races, such as race 'T', 'O' and 'C'. Race 'T' is particular, bring disease on Texas Male Sterility (TMS) sources which is extremely virulent, epidemic of leaf blight occurs in USA due to the susceptibility and wider utilization of Texas Male Sterility lines (Misra, 1979) [30]. Pathogen type similar to race 'T' found in India (Sharma *et al*., 1978) [44]. Around the world and even in India race 'O' is mostly occurred and wider in distribution.

Favourable conditions for the survival and spread of the SLCB mainly depend on rainfall amount, RH (relative humidity) and temperature conditions of the area (Sumner and Littrell, 1974) [46]. Prolonged sunny days with dry weathers are not suitable for disease progress (Schenck *et al*., 1974) [42]. Causal organism survives in diseased maize debris on the surface of soil or inside seed, but failed survive in debris which were buried at 5- 20 cm (Ullstrup, 1972) [48]. Relationship between temperature and conidia germination in *in vitro* condition given by (Aylor, 1975) [6]. The temperature range of 20-28 °C when presence of continues light and 28 °C in total dark for race 0 necessary for conidia sporulation, 20 °C and 24 °C for race T, sequentially. *Helmithosporium maydis conidia* are detached only in presence of wind speed at 18 km/h.

MLB symptoms depend on host germplasm and race of the pathogen. *Bipolaris maydis* Race T leaf blight symptoms are bigger when compare to symptoms of Race O (6- 12 × 6-27 mm). Lesions having dark brown border. The above ground parts like ears and sheaths shown lesion symptoms due to Race T it can also cause ear rots. Seedlings which were affected with Race T will wilt and die between 3 to 4 weeks. If disease occurrence is severe before silking the lesions on

leaves coalesce or combine, blighting the whole leaf area. In such circumstances, sugars may be head off from stalk to grain filling and consequently make prone the plant to lodging. The plants affected by Race O express diamond-shaped and primarily small lesions. On mature the lesions elongate and the further development of lesions inhibited by leaf veins. Final mature lesions are rectangular in shape (2-6 × 3-22 mm) and tan colour in appearance. The plants infected by Race O exhibit lesion symptoms on leaves which are specially confined to leaves only. Race C exhibit necrotic lesions which are up to 5 mm in length and they might exhibit wilt (Ali *et al*., 2011) [3].

Management of *Bipolaris maydis* or *Helminthosporium maydis*

Botanicals in management of SCLB

The garlic clove extracts are very effective in suppressing the growth of *H. maydis* it is found that 66.5, 73.8 and 83.9% growth suppression at 2,5 and 10% (Sanjeev *et al*., 2009)

Both in field as well as in laboratory condition's 8 botanicals tested against the pathogen *Rhizoctonia solani*(banded leaf and sheath blight of maize) in which proved that garlic clove extract *(Allium sativum)* at 5% concentration fully suppressed the mycelial development mean while the neem leaf extract at 10% proved very good against the pathogen (Meena *et al*., 2003) [29].

Efficiency of different botanicals like bael (*Agelemarmelos*), garlic (*Allium sativum*), neem (*Azadirachta indica)* and onion *(Allium cepa)* was checked individually. Above the all-individual extracts are evaluated against the spore growth of *H. maydis* all extracts were found good in inhibition of spore germination at the range of 50% to 100% when compared to control (Jha *et al*., 2004) [17].

The extracts of *Agelemarelos* were found toxic to *H. maydis fungi* (Karande *et al*., 2007) [18].

The different extracts like Neem, Ginger, Garlic, Turmeric and Eucalyptus were tested against *H. maydis* in which neem found best one (Gurjar *et al*., 2012) [12].

Allium sativum evaluated against *H. maydis* in which 72.65% mycelial development suppression found (Khamari *et al*., 2015) [20].

Bio control agents in controlling SCLB

The *Trichoderma spp.* are suppressing the growth of of *Bipolaris maydis* by the action such as multiplication in the rhizosphere of the soil and acts against the pathogen by antagonistic action and also by mycoparasitism action. Soil borne pathogens are suppressed by bio control agents mainly by antibiosis, enzyme production and also mycoparasitism (Harmon, 2000; Chet, 1987) [14, 9].

Trichoderma spp. isolates suppress the mycelial growth of *Bipolaris sorokiniana* by producing secondary metabolites which were antifungal in nature (Salehpour *et al*., 2005) [40]. *Trichoderma harzianum* inhibited the mycelial growth of *Drechslera oryzae* by 55.3% in dual culture method (Biswas *et al*., 2008) [7].

Coil mechanism was used by the *Trichoderma spp.* to inhibit the growth of SCLB pathogen (*H. maydis*) on leaf area. *Trichoderma spp.* Were proved very trust one in controlling plant disease by ISR mechanism. Various *Trichoderma* isolates can induce ISR mechanism in plant to develop resistance against disease (Segarra *et al*., 2007; Tucci *et al*., 2011) [43, 47].

Chemical management

Many scientists have been proved many chemicals such as carbendazim, chlorothalonil, mancozeb and propiconazole were proved best against *H. maydis* (Harlapur *et al*., 2007; Sanjeev Kumar *et al*., 2009) [27].

Khedeker *et al*., 2012; Waghe *et al*., 2015) [49]. Maize yield has been increased and southern corn leaf blight inhibited when propiconazole was used for seed treatment and foliar spray (Kumar, 2010) [25].

When propiconazole was used at 0.10% the disease index of southern corn leaf blight has been reduced in maize crop (Hulagappa, 2012).

The disease severity of turicum leaf blight has been greatly reduced due to the chemical such as mancozeb 0.25% and carbendazim + mancozeb 0.25% (Reddy *et al*., 2013) [39]. in *in vivo* evaluation fungicides tested against *Exserohilum turicum* the two fungicides show best result such as propiconazole (0.1%) and chlorothalonil (0.2%) (Nasir *et al*., 2012) [35].

The lowest disease severity and more yield found good under propiconazole and then chlorothalonil was found best against SCLB (Vaibhav *et al*., 2011).

Conclusion

Southern corn leaf blight of corn caused by *Helminthosporium maydis* which can control efficiently by spraying chemicals like Propiconazole, Mancozeb, Chlorothalonil etc. But these chemicals could cause damage to non-target organisms so here we can use alternative choices like botanicals and biocontrol agents in which garlic extract and neem extract are worthy trust one for controlling disease and bio control agents like *Trichoderma spp.* Isolates will control disease by mechanisms such as antibiosis, enzyme production and mycoparasitism.

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