AATCC Review

22 March 2025: Received
13 May 2025: Revised
19 May 2025: Accepted
23 June 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

# An Integrated Approach to evaluate the efficacy of different fungicides, botanicals, bioagents and their combinations under field conditions against *Helminthosporium maydis*, the cause of Maydis Leaf Blight disease of Maize in Bihar

**Chandan Kumar[1], Phool Chand[2], C. S Choudhary[2], Mithilesh Kumar*[1], Gautam Kunal[3], Avinash Jha[4], Md Reyaz Ahmed[1], Anjana Arun[1], Shivam maurya[5]**

[1]*Department of Plant Pathology, VKSCoA, Dumraon, Buxar, BAU, Sabour, Bhagalpur-813210, India*
[2]*Department of Plant Pathology, RPCAU, Pusa, Bihar, India-848125, India*
[3]*Department of Entomology, VKSCoA, Dumraon, Buxar, BAU, Sabour, Bhagalpur-813210, India*
[4]*Department of Plant Breeding and Genetics, VKSCoA, Dumraon, Buxar, BAU, Sabour, Bhagalpur-813210, India*
[5]*Department of Plant Pathology, SAGR, Lovely Professional University, Jalandhar, Punjab, India*

## ABSTRACT

*Maize (Zea mays) is a global staple food crop grown worldwide after wheat and rice adapted to several biotic and abiotic stresses. Maize is a tropical crop, but also adapted to temperate conditions. Maydis leaf blight (MLB), also known as Southern corn Leaf Blight (SCLB), is a serious foliar fungal disease may cause up to 40% grain yield loss. The disease is prevalent in almost all maize growing areas including Bihar and is a major limiting factor in increasing yield. Therefore, field studies were conducted to evaluate the efficacy of different fungicides, botanicals, bioagents and their combinations to effectively manage the disease under field conditions for two seasons Kharif 2019 and 2020. Three chemicals (Propiconazole 25% EC, Mancozeb 75% WP and Carbendazim 12% WP + Mancozeb 63% WP), one bioagent i.e. Trichoderma harzianum (10 g kg$^{-1}$ seed) and two botanicals namely Azadirachtin (10%) and Lantana (10%) were tested alone and in combinations. Results on the application of different botanicals, fungicides and bio-agents alone and in combinations, revealed that comparatively lower disease incidence (31.62 % and 30.59 %), disease index (31.85 % and 30.37 %) and minimum AUDPC (253.12 mm$^2$ and 255.76 mm$^2$) with maximum grain yield (54.60 q ha$^{-1}$ and 52.52 q ha$^{-1}$) and test weight (204.49 g and 206.62 g) was recorded in T5 (Carbendazim +Mancozeb, (SAAF) ST + Propiconazole spray) treated plots during 2019 and 2020, respectively. The identified sources of management can be used further in strengthening plant protection in maize against the disease.*

**Keywords:** *Area Under Disease Progress Curve (AUDPC), Botanicals, Bio-agents, Disease Incidence (DI), Fungicides, Grain Yield, Infection rate (r), Maize, Mancozeb, Maydis leaf blight, Per cent disease index (PDI), Propiconazole, Test weight and Trichoderma harzianum*

## 1. INTRODUCTION

Maize (*Zea mays* L) is the most versatile, genetically diverse cereal crop grown under different environments untouched by any other crop for its multiple uses. Maize is a tropical crop, but also adapted to temperate conditions, and is widely grown in its warmer part and in humid subtropical regions around the world. The extension of maize to new environmental conditions continues due to its wide range of plasticity. It ranks third after wheat and rice in world food production [31]. As far as productivity is concerned, maize ranks first. On account of its growing demand for diversified uses, it is gaining significant importance especially in the industrial sector and for animal feed purposes. Maize contributes to food security especially in developing countries of the world. Its productivity (per unit area) is very high, due to its immense potentiality and that is why globally it is called as queen of cereals [20]. Diseases have remained one of the significant setbacks in achieving this crop's potential yield. More than 115 diseases in maize have been reported from all over the world so far whereas approximately 65 are known to occur in India leading to about 9% yield losses in maize due to different diseases [25] caused by different viruses, bacteria, fungi, and nematodes, in vivid regions of the world. Among foliar diseases, the Maydis leaf blight (MLB) also called Southern Corn Leaf Blight (SCLB)] is caused by the ascomycetous fungus *Cochliobolus heterostrophus* (Drechs.) [*anamorph Bipolaris maydis* (*Nisikado and Miyake*)]. The pathogen reported to have 3 races till now, viz race O, T and C. Race T is very specific and caused disease on Texas cytoplasm Male Sterile (TcMS) lines in which it is highly virulent, causing a devastating loss due to epidemic of southern corn leaf blight in the USA [52]. Sharma et al. (1978) reported a pathotype from India similar to race T [45]. However, race 'O' is more prevalent and widely distributed globally including India also. This disease is highly damaging in humid, hot, and tropical regions of the world. Drechsler (1925) first time reported this pathogen (*H. maydis*) from the USA [12].

**Corresponding Author: **Mithilesh Kumar***

*DOI: https://doi.org/10.21276/AATCCReview.2025.13.03.255*

Munjal and Kapoor (1960) for the first time reported it from the Maldah district of West Bengal [35]. Increased incidence of MLB has also been observed in maize crops in different districts of Bihar. Now it has been considered one of the most devastating diseases and finally attained the status of an economically important disease.

Maydis leaf blight disease of maize is a multiple-cycle disease, i.e. repeated inoculations are needed for the development of the disease and so that dependent upon sporulation from other spots or lesions in warm (20-30 $^0$C) and humid environments. The fungus overwinters as mycelium, chlamydospores, and conidiophores on crop residues, especially on soil surfaces which act as an initial source of disease infection. The fungus has high saprophytic ability so that level of primary inoculum is high and in areas with high disease occurrence [6]. Though, management strategies are available, yet there is a need to further refine them under field conditions. Effective management of MLB in maize is possible only when the pathogen is eliminated completely or the propagules are brought down below economic threshold limits at the field level. Earlier work has been done on the management of MLB, but keeping in view the present damaging status of the diseases, there is a need to develop eco-friendly management practices. Previously the use of fungicides was rare, but during the last decade application of foliar fungicides has been extensively used to increase maize production. Reddy et al. (2013) conducted some management studies against Turcicum leaf blight of maize and found that Mancozeb (0.25%) and Carbendazim + Mancozeb (0.25%) were significantly superior over other tested fungicides [41]. Hulagappa (2012) tested eight fungicides against maydis leaf blight of maize and recorded a minimum percent disease index (PDI) in the case of crop sprayed with Propiconazole at 0.10% [18]. In recent years area under maize cultivation has also been increased with quinine outside inhibitors (QoIs) such as Strobilurins thereby encouraging the use of foliar fungicides in the corn belt of America [7]. To control the maydis leaf blight, a combination of fungicides is often more potent than using individual fungicides [54]. The fungicide in combination with plant growth regulators and bio-agents reduces the severity and incidence [3, 34]. Disease management through biological agents and botanical extracts is also of great importance. Several workers have reported their efficacies against the pathogen. Kumar et al. (2009) evaluated some plant extracts against maydis leaf blight under field conditions and recorded significantly higher grain yield in plots sprayed with garlic clove extract (17.0 and 18.0 q ha$^{-1}$), tulsi leaf extract (13.5 and 14.5 q ha$^{-1}$) and neem leaf extract (16.0 and 15.3 q ha$^{-1}$) as compared to unsprayed plots [27]. The bio-agents in combination with the botanicals reduce the incidence and severity of many plant diseases [16].

Due to the non-availability of stable sources of resistance to the diseases, Integrated Disease Management is the only means to avoid considerable crop losses. Therefore, there is a need to identify suitable integrated management module through such rational approaches. Attempts were made in the present study to find out the suitable combinations for effective management of maydis leaf blight disease.

## 2. MATERIALS AND METHODS

Field experiments were conducted during *Kharif* 2019 and 2020 at the Research Farm of TCA Dholi, Muzaffarpur. The location of the experimental plot was at 25.98$^0$ N latitude and 85.60 $^0$ E longitude with an altitude of 52.18 meter above mean sea level. The climate is tropical with hot and humid weather along with the summer and cold winters. Experiments were laid out in Randomised Block Design (RBD) using susceptible variety, CML 186.

### 2.1. Testing the efficacy of different fungicides, botanicals, bio-agents and their combinations under field conditions

Deep ploughing of the field up to 20-25 cm depth with MB plough, 2-3 harrowing and planking were done to make the field smooth and well levelled. One pre-sowing irrigation was given to ensure a good moisture level in the soil. NPK fertilizers were applied @ 160 kg ha$^{-1}$, 100 kg ha$^{-1}$ and 40 kg ha$^{-1}$, respectively. Weeding was done manually and also with the help of hoe regularly after crop growth. Fifteen treatments viz., seed treatment with *Trichoderma harzianum*, SAAF and foliar spray with Mancozeb, Propiconazole, Neem and Lantana alone and in combination were made. The plot size was 4.5 m x 4.2 m with spacing 75 x 20 cm and replicated thrice. This experiment was laid out in Randomised Block Design (RBD). Under the various treatments, the maize seeds were treated with *T. harzianum* (10g kg$^{-1}$ seeds), SAAF @ 3g kg$^{-1}$ seed. Foliar spray with Mancozeb (0.25%), Propiconazole (0.1%) and plant extracts (10%) were initiated immediately after the first appearance of the disease and 2$^{nd}$ spray done at 15days after first spraying**.**

#### 2.1.1 Maydis leaf blight assessment

***Table 1: Treatments used for testing efficacy of different fungicides, botanicals, bio-agent and their combination***

| Treatment No. | Treatments |
|---|---|
| T1 | Mancozeb + Carbendazim @ 3g kg$^{-1}$ seed (Seed Treatment) |
| T2 | T1+ Neem @ 10% (Spray) |
| T3 | T1+ Lantana@ 10% (Spray) |
| T4 | T1+ Mancozeb @ 0.25% (Spray) |
| T5 | T1+ Propiconazole @ 0.1%(Spray) |
| T6 | *Trichoderma harzianum* @ 10g kg$^{-1}$ seed (Seed Treatment) |
| T7 | T6+ Neem @ 10% (Spray) |
| T8 | T6+ Lantana @ 10% (Spray) |
| T9 | T6+ Mancozeb @ 0.25% (Spray) |
| T10 | T6+ Propiconazole @ 0.1% (Spray) |
| T11 | Only Neem spray @ 10% |
| T12 | Only Lantana spray @ 10% |
| T13 | Only Mancozeb spray @ 0.25% |
| T14 | Only Propiconazole spray @ 0.1% |
| T15 | Untreated / Check |

First appearance of disease and its further progress was recorded using the new disease rating scale which was given by Balint-Kurti et al. (2006), Mitiku et al. (2014) and Chung et al. (2010), [4, 10 and 33] represented in Table No. 3.6.

**2.1.1a Disease Incidence (DI)** Maydis leaf blight incidence was assessed visually at weekly interval from 1$^{st}$ appearance of disease in all the plots. The mean value of per cent disease incidence of every treatment was obtained from the three replicates. Wheeler (1969) given the formula to calculate the incidence [55].

Disease incidence = (No. of diseased plant/ total no. of plant examined) × 100

**2.1.1b Disease Index (PDI)**

Observations on severity of the disease were recorded according to the scale mentioned in Table No. 3.6. Observations were recorded at weekly interval from 1$^{st}$ appearance of the disease for each treatment.

Randomly twenty-five plants were selected from each plot and assessed for disease score and then PDI was recorded. PDI was calculated by the following formula given by Wheeler, 1969.

Per cent Disease index = (Sum of all the numerical ratings / (No. of plants examined x Maximum grade)) x 100

*Table 2: Standard Disease rating scale for maydis leaf blight of maize*

| Rating scale | Degree of infection (Per cent DLA*) | PDI** | Disease reaction |
|---|---|---|---|
| 1 | Nil to very slight infection (≤ 10%). | ≤11.11 | |
| 2 | Few lesions scattered on two lower leaves (10.1-20%). Slight infection, | 22.22 | Resistant (R) (Score: ≤3.0) (DLA: ≤ 30%) PDI: ≤33.33) |
| 3 | Moderate number of lesions scattered on four lower leaves, Light infection, (20.1-30%). | 33.33 | |
| 4 | Moderate number of lesions scattered on lower leaves, a few lesions scattered on middle leaves below the cob (30.1-40%), Light infection | 44.44 | Moderately resistant (MR) (Score: 3.1- 5.0) (DLA: ≤ 30.1-50%) PDI: 33.34 -55.55) |
| 5 | Moderate infection, abundant number of lesions scattered on lower leaves, moderate number of lesions scattered on middle leaves below the cob (40.1-50%). | 55.55 | |
| 6 | Heavy infection, moderate infection on middle leaves, abundant number of lesions scattered on lower leaves, and a few lesions on two leaves above the cob (50.1-60%). 66 | 66.66 | Moderately susceptible (MS) (Score: 5.1- 7.0) (DLA: ≤ 50.1-70%) PDI: 55.56 -77.77) |
| 7 | Heavy infection, abundant number of lesions scattered on lower and middle leaves (60.1-70%). | 77.77 | |
| 8 | Very heavy infection, lesions abundant scattered on lower and middle leaves and spreading up to the flag leaves (70.1-80%). | 88.88 | Susceptible (S) (Score: > 7.0) (DLA:>70%) PDI: >77.77) |
| 9 | Very heavy infection, lesions abundant scattered on almost all the leaves, plants prematurely dried and killed (>80%). | 99.99 | |

** DLA- Diseased leaf area; **Per cent disease index (PDI)*

### 2.1.1c Infection rate

Vander plank, 1963 given the formula to calculate Infection rate at weekly interval [53] by using following formula:

$r = (2.3/t_2-t_1) \log x_2/x_1$

Where,

r = apparent infection rate

$x_1$ = PDI at time $T_1$

$x_2$ = PDI at time $T_2$

$t_2$-$t_1$ = time interval in days between two observations

### 2.1.1d Area Under Disease Progress Curve (AUDPC)

Further, the area under disease progress curve (AUDPC) calculated by using the formula given by Madden et al. (2007) [28].

$AUDPC = \sum^{k}_{i-1} 1/2\ (S_i + S_{i-1})\ (T_i - T_{i-1})$

Where,

Si = Per cent Disease index at the end of time i

k = Number of successive evaluations

Ti – Ti-1 = Time interval between two evaluations i and i-1 of the disease

### 2.1.2 Yield parameter

### 2.1.2a Plot Yield

Yield was recorded for each treatment during both the years *Kharif* 2019 and 2020. When the maize was completely matures on the field then each plot is harvested and packed in bags. Thereafter, before drying of grains threshing was done manually. Data of yield per plot (kg $plot^{-1}$) was recorded and then converted the yield in t $ha^{-1}$. The final weighing was done to determine the actual yield. The data were extrapolated to kg $ha^{-1}$ by multiplying a constant (529.10) obtained from the ratio of the area of a hectare (10,000 $m^2$) to the area of the plot per treatment (4.5 × 4.2 $m^2$).

### 2.1.2b Determination of per cent yield increase over check

The per cent yield increase over check was determined by using the following formula:

Per cent yield increase = (X-Y/X) ×100

Where,

X: average yield of treated plot

Y: average yield of untreated check plot

### 2.1.2c Thousand grain weight

Thousand grains weight of each treatment in all three replications were counted separately and then weighed.

### 2.1.2d Benefit: Cost Ratio (BCR)

Total cost incurred for cost of fungicides including application of fungicides and labours were calculated. Additional benefit due to increased yield in each treatment over check was worked out and benefit cost ratio was calculated using additional benefits and total costs. It is calculated by following formula:

B: C = Net return / Total cost of cultivation

## 3. RESULTS

### 3.1 Effect of different fungicides, botanicals, bio-agent and their combinations on maydis leaf blight assessment

### 3.1a Disease incidence

Field trial was carried out during *Kharif* 2019 and 2020 to observe the effect of different fungicides, botanicals, bio-agent and their combinations on maydis leaf blight incidence (Table 3).

During 2019, it is evident from the data (Table 3) that almost all of the treatments significantly reduced the incidence compared to check where 56.69 per cent disease incidence was recorded. T5 (Carbendazim + Mancozeb (SAAF) ST + Propiconazole spray) was found most effective and significantly superior among all the treatments where 31.63 per cent disease incidence was recorded followed by T10 (*T. harzianum* ST + Propiconazole spray) and T14 (Propiconazole spray), where 38.62 and 39.65 per cent disease incidence was recorded. During 2020, a similar trend was been observed.

### 3.1b Disease index

During 2019, it is evident from the data (Table 3) that minimum disease index (31.85%) was recorded in T5 (Carbendazim + Mancozeb ST +Propiconazole spray) followed by T10 (*T. harzianum* ST + Propiconazole spray) and T14 (Propiconazole spray) where (37.03%) and (45.18%) % disease index were recorded.

All the treatments were significantly superior over check (78.51%). During 2020, minimum disease index (30.37%) was recorded in T5 (Carbendazim + Mancozeb ST + propiconazole spray) followed by T10 (*T. harzianum* ST +Propiconazole spray) where (34.07%) disease index was recorded. (Table 3).

### 3.1c Infection rate

All treatments showed that there was an increase and decrease in infection rate from r 1 to r 5. During 2019, the data (Table 4) shows that minimum infection rate (0.013) was recorded in T9 (*T. harzianum* ST + Mancozeb spray) followed by T4 (Carbendazim + Mancozeb ST + Mancozeb spray), T5 (Carbendazim + Mancozeb ST + Propiconazole spray) and T10 (*T. harzianum* ST + Propiconazole spray) in comparison to control where maximum infection rate (0.032) was observed. During 2020, similar pattern of infection rates was observed.

### 3.1d Area Under Disease Progress Curve (AUDPC)

During 2019, highest AUDPC (638.08 $mm^2$) was recorded in control. Minimum AUDPC (253.12 $mm^2$) was recorded in T5 (Carbendazim + Mancozeb ST + Propiconazole spray) followed by T10 (*T. harzianum* ST + Propiconazole spray) (284.72 $mm^2$), T14 and T4. (Table 4). Similarly, during 2020, Maximum AUDPC (700.33 $mm^2$) was observed in check while, minimum AUDPC (255.76 $mm^2$) was recorded in T5 (Carbendazim + Mancozeb ST + Propiconazole spray).

## 3.2 Effect of different fungicides, botanicals, bio-agent and their combination on yield parameters

### 3.2a Grain yield

The grain yield differed significantly among the treatments and grain yield is presented in Table 6. During 2019, maximum yield (54.60 q $ha^{-1}$) was recorded in T5 (Carbendazim+Mancozeb (SAAF) ST + Propiconazole spray) followed by T10 (*T. harzianum* ST + Propiconazole spray) (52.17 q $ha^{-1}$) and T14 (51.87 q $ha^{-1}$) which was significantly superior over check where minimum yield (40.40 q $ha^{-1}$) was recorded (Table 6). During 2020, similar results were obtained, maximum yield (52.52 q $ha^{-1}$) was recorded in T5 (Carbendazim + Mancozeb ST + Propiconazole spray).

The reduction in the disease resulted in increased grain yield. A per cent increase in grain yield over check-in pool data was calculated. The maximum per cent increase in grain yield (35.66%) was observed in T5 (Carbendazim + Mancozeb ST + Propiconazole spray) followed by T10 (*T. harzianum* ST + Propiconazole spray) (34.87%) while minimum per cent increase in grain yield (0.63%) was observed in T1 (Carbendazim + Mancozeb spray)

### 3.2b Thousand grain weight

During 2019, maximum 1000 grain weight (204.49 g) was recorded in T5 (Carbendazim +Mancozeb ST + Propiconazole spray) followed by T10 (*T. harzianum* ST + Propiconazole spray) (201.10 g) and T14 (199.26) while minimum 1000 grains weight (171.29 g) was recorded in control (Table 6). A similar trend was been observed during the year 2020.

Pooled data of 2019 and 2020 showed that a maximum per cent increase in test weight (20.23%) was recorded in T5 (Carbendazim + Mancozeb ST + Propiconazole spray) (Table 6).

## 3.3 Effect of different fungicides, botanicals, bio-agents and their combination on economics

The economics of benefit cost ratio for mean value of two experimental years has been worked out for different treatments employed and are presented in Table 7. Cost Benefit ratio (CBR) has also been calculated and presented in Table 7.

### 3.3a Benefit cost ratio (BCR)

It is the ratio of net return and total cost of cultivation. Benefit cost ratio for both experimental years was calculated. The results revealed that, T6 (*T. harzianum* ST) gave more benefit cost ratio (5.6:1) followed by T1 (Carbendazim + Mancozeb (SAAF) ST), T4, T5 and T10.

*Table 3: Effect of fungicides, botanicals, bio-agent and their combinations on maydis leaf blight assessment during Kharif 2019 and 2020*

| Treatment No. | Treatments | Disease Incidence (%) | | Pooled data (2019-20) | % disease control over check | Per cent Disease index (PDI) | | Pooled data (2019-20 | % disease control over check |
|---|---|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | | | 2019 | 2020 | | |
| T1 | Mancozeb + Carbendazim (SAAF) (ST) | 52.59 (46.46) | 54.41 (47.51) | 53.50 (47.00) | 6.18 | 63.18 (52.79) | 66.66 (54.61) | 64.92 (53.50) | 16.12 |
| T2 | T1 + Neem (Spray) | 48.62 (44.19) | 47.13 (43.45) | 47.87 (43.82) | 16.06 | 51.84 (45.90) | 50.36 (45.28) | 51.1 (45.69) | 33.97 |
| T3 | T1 + Lantana (Spray) | 50.69 (45.38) | 51.18 (45.66) | 50.93 (45.51) | 10.69 | 60.18 (52.09) | 60.37 (51.04) | 60.27 (50.82) | 22.13 |
| T4 | T1 + Mancozeb (Spray) | 41.49 (40.07) | 39.53 (38.93) | 40.51 (39.50) | 28.96 | 47.40 (43.57) | 39.99 (39.02) | 43.69 (41.23) | 43.55 |
| T5 | T1 + Propicoonazole (Spray) | 31.62 (34.18) | 30.59 (33.55) | 31.1 (34.07) | 45.46 | 31.85 (34.23) | 30.37 (33.47) | 31.11 (34.05) | 59.80 |
| T6 | *T. harzianum* (ST) | 55.51 (48.15) | 54.63 (47.64) | 55.07 (47.89) | 3.43 | 63.70 (51.02) | 67.40 (55.22) | 65.55 (54.20) | 15.31 |
| T7 | T6 + Neem (spray) | 48.52 (44.13) | 46.55 (42.99) | 47.53 (43.56) | 16.65 | 56.36 (48.62) | 50.66 (45.28) | 53.51 (47.02) | 30.86 |
| T8 | T6 + Lantana (Spray) | 50.55 (45.29) | 50.63 (45.34) | 50.59 (45.32) | 11.29 | 62.21 (52.24) | 60.73 (51.10) | 61.47 (51.70) | 20.58 |
| T9 | T6 + Mancozeb (Spray) | 41.63 (40.16) | 40.58 (39.54) | 41.10 (39.85) | 27.93 | 48.88 (44.17) | 45.18 (42.39) | 47.03 (43.47) | 39.23 |
| T10 | T6 + Propiconazole (Spray) | 38.64 (38.40) | 34.40 (35.89) | 36.52 (37.11) | 35.96 | 37.03 (37.62) | 34.07 (35.93) | 35.55 (36.54) | 54.06 |
| T11 | Only Neem (Spray) | 49.76 (44.84) | 47.43 (43.50) | 48.59 (44.17) | 14.79 | 59.99 (50.61) | 54.81 (47.59) | 57.4 (49.33) | 25.83 |
| T12 | Only Lantana (Spray) | 51.70 (45.96) | 51.48 (45.83) | 51.59 (45.89) | 9.53 | 60.73 (51.19) | 64.44 (53.37) | 62.58 (52.20) | 19.14 |
| T13 | Only Mancozeb (Spray) | 44.71 (41.94) | 42.59 (40.72) | 43.65 (41.33) | 23.46 | 50.36 (45.31) | 46.66 (43.02) | 48.51 (44.00) | 37.32 |
| T14 | Only Propiconazole (Spray) | 39.66 (39.01) | 37.45 (37.69) | 38.55 (38.45) | 32.40 | 45.18 (42.35) | 40.32 (39.46) | 42.75 (40.58) | 44.76 |
| T15 | Untreated/Check | 56.69 (48.83) | 57.37 (49.23) | 57.03 (49.03) | - | 78.51 (62.24) | 76.29 (61.04) | 77.4 (61.64) | - |
| | **Mean** | **46.82** | **45.73** | **46.27** | - | **54.49** | **52.55** | **53.52** | - |
| | **SEm ±** | **1.42 (0.81)** | **1.93 (1.12)** | **1.36 (0.79)** | - | **2.17 (1.27)** | **1.47 (0.86)** | **1.75 (1.01)** | - |
| | **CD at 5%** | **4.15 (2.38)** | **5.62 (3.27)** | **3.97 (2.30)** | - | **6.32 (3.71)** | **4.30 (2.51)** | **5.11 (2.95)** | - |

*Values in parentheses are angular transformed values*

***Table 4: Effect of fungicides, botanicals, bio-agent and their combinations on infection rate (r) and AUDPC during Kharif 2019***

| Treatment No. | Treatments | Infection rate | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Rate of spread (r) | | | | | 'R' Value /Average r (AIR) | 'A' Value (AUDPC) |
| | | r 1 | r 2 | r 3 | r 4 | r 5 | | |
| T1 | Mancozeb + Carbendazim @ 3g/kg seed (ST) | 0.124 | 0.017 | 0.005 | 0.003 | -0.002 | 0.029 | 544.17 |
| T2 | T1 + Neem @ 10% (Spray) | 0.087 | 0.015 | 0.013 | 0.011 | -0.003 | 0.024 | 428.44 |
| T3 | T1 + Lantana @ 10% (Spray) | 0.098 | 0.021 | 0.017 | 0.010 | -0.002 | 0.029 | 524.08 |
| T4 | T1 + Mancozeb @ 0.25% (Spray) | 0.051 | 0.022 | 0.006 | 0.006 | -0.007 | 0.015 | 368.74 |
| T5 | T1 + Propicoonazole @ 0.1% (Spray) | 0.062 | 0.011 | 0.005 | 0.009 | -0.005 | 0.016 | 253.12 |
| T6 | *T. harzianum* @ 10 g/kg seed (ST) | 0.095 | 0.012 | 0.011 | 0.014 | -0.001 | 0.026 | 479.67 |
| T7 | T6 + Neem @ 10% (spray) | 0.064 | 0.014 | 0.012 | 0.009 | -0.009 | 0.018 | 383.21 |
| T8 | T6 + Lantana @ 10% (Spray) | 0.114 | 0.012 | 0.005 | 0.002 | -0.001 | 0.026 | 459.67 |
| T9 | T6 + Mancozeb @ 0.25% (Spray) | 0.032 | 0.024 | 0.013 | 0.007 | -0.012 | 0.013 | 414.95 |
| T10 | T6 + Propiconazole @ 0.1% (Spray) | 0.057 | 0.013 | 0.008 | 0.008 | -0.004 | 0.016 | 284.72 |
| T11 | Only Neem @ 10% (Spray) | 0.109 | 0.012 | 0.009 | 0.008 | -0.004 | 0.027 | 534.17 |
| T12 | Only Lantana @ 10% (Spray) | 0.128 | 0.013 | 0.007 | 0.004 | -0.001 | 0.030 | 568.37 |
| T13 | Only Mancozeb @ 0.25% (Spray) | 0.084 | 0.015 | 0.012 | 0.002 | -0.005 | 0.022 | 431.88 |
| T14 | Only Propiconazole @ 0.1% (Spray) | 0.081 | 0.013 | 0.008 | 0.005 | -0.003 | 0.021 | 284.74 |
| T15 | Untreated/Check | 0.097 | 0.030 | 0.022 | 0.024 | -0.003 | 0.032 | 638.08 |

*ST = Seed treatment; 'R' Value = Apparent infection rate; 'A' Value = Area under Disease Progress Curve (AUDPC in $mm^2$)*

***Table 5: Effect of fungicides, botanicals, bio-agent and their combinations on infection rate (r) and AUDPC during Kharif 2020***

| Treatment No. | Treatments | Infection rate | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Rate of spread | | | | | 'R' Value /Average r **(AIR)** | 'A' Value **(AUDPC)** |
| | | r 1 | r 2 | r 3 | r 4 | r 5 | | |
| T1 | Mancozeb + Carbendazim @ 3g kg-1 seed (ST) | 0.137 | 0.008 | 0.004 | 0.004 | -0.002 | 0.030 | 665.78 |
| T2 | T1 + Neem @ 10% (Spray) | 0.105 | 0.003 | 0.002 | 0.008 | -0.004 | 0.023 | 434.89 |
| T3 | T1 + Lantana @ 10% (Spray) | 0.127 | 0.006 | 0.004 | 0.007 | -0.002 | 0.029 | 632.87 |
| T4 | T1 + Mancozeb @ 0.25% (Spray) | 0.067 | 0.009 | 0.006 | 0.006 | -0.005 | 0.016 | 409.86 |
| T5 | T1 + Propicoonazole @ 0.1% (Spray) | 0.073 | 0.005 | 0.003 | 0.004 | -0.001 | 0.017 | 255.76 |
| T6 | *T. harzianum* @ 10 g kg-1 seed (ST) | 0.128 | 0.004 | 0.002 | 0.008 | -0.003 | 0.027 | 564.36 |
| T7 | T6 + Neem @ 10% (spray) | 0.084 | 0.007 | 0.009 | 0.002 | -0.003 | 0.020 | 392.81 |
| T8 | T6 + Lantana @ 10% (Spray) | 0.107 | 0.009 | 0.007 | 0.006 | -0.005 | 0.025 | 553.85 |
| T9 | T6 + Mancozeb @ 0.25% (Spray) | 0.061 | 0.007 | 0.008 | 0.004 | -0.004 | 0.015 | 322.74 |
| T10 | T6 + Propiconazole @ 0.1% (Spray) | 0.087 | 0.005 | 0.002 | 0.003 | -0.003 | 0.018 | 281.76 |
| T11 | Only Neem @ 10% (Spray) | 0.124 | 0.005 | 0.010 | 0.008 | -0.002 | 0.029 | 598.00 |
| T12 | Only Lantana @ 10% (Spray) | 0.143 | 0.005 | 0.006 | 0.005 | -0.002 | 0.031 | 673.45 |
| T13 | Only Mancozeb @ 0.25% (Spray) | 0.106 | 0.002 | 0.005 | 0.006 | -0.002 | 0.023 | 532.40 |
| T14 | Only Propiconazole @ 0.1% (Spray) | 0.095 | 0.006 | 0.006 | 0.004 | -0.002 | 0.022 | 381.38 |
| T15 | Untreated/Check | 0.133 | 0.007 | 0.016 | 0.014 | -0.004 | 0.033 | 700.33 |

*ST = Seed treatment; 'R' Value = Apparent infection rate; 'A' Value = Area Under Disease Progress Curve (AUDPC in $mm^2$)*

***Table 6: Effect of different fungicides, botanicals, bio-agent and their combinations on yield parameters during Kharif 2019 and 2020***

| Treatment No. | Treatments | Grain yield (q ha-1) * | | Pool data (2019-20) | % increase in yield over check | 1000 grain seed wt. (gm)* | | Pool data (2019-20) | % increase in 1000 grain wt. over check |
|---|---|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | | | 2019 | 2020 | | |
| T1 | Mancozeb + Carbendazim (ST) | 38.62 | 40.45 | 39.73 | 0.63 | 178.10 | 174.23 | 176.16 | 3.04 |
| T2 | T1 + Neem (Spray) | 43.45 | 47.33 | 45.39 | 14.96 | 188.16 | 189.20 | 188.68 | 10.37 |
| T3 | T1 + Lantana (Spray) | 42.84 | 44.73 | 43.78 | 10.89 | 184.23 | 180.51 | 182.37 | 6.68 |
| T4 | T1 + Mancozeb (Spray) | 55.67 | 49.55 | 52.61 | 33.25 | 198.11 | 199.60 | 198.85 | 16.32 |
| T5 | T1 + Propicoonazole (Spray) | 54.60 | 52.52 | 53.56 | 35.66 | 204.49 | 206.62 | 205.55 | 20.23 |
| T6 | *T. harzianum* (ST) | 40.43 | 38.49 | 39.85 | 0.93 | 174 | 172.40 | 173.2 | 1.31 |
| T7 | T6 + Neem (spray) | 41.09 | 47.23 | 44.16 | 11.85 | 187.16 | 187.50 | 187.33 | 9.58 |
| T8 | T6 + Lantana (Spray) | 43.28 | 43.46 | 43.37 | 9.85 | 181.36 | 177.63 | 179.49 | 4.99 |
| T9 | T6 + Mancozeb (Spray) | 53.70 | 49.82 | 51.76 | 31.10 | 193.23 | 195.79 | 194.51 | 13.78 |
| T10 | T6 + Propiconazole (Spray) | 52.17 | 54.32 | 53.25 | 34.87 | 201.10 | 203.27 | 202.18 | 18.26 |
| T11 | Only Neem (Spray) | 43.80 | 43.89 | 43.85 | 11.06 | 187.20 | 184.63 | 185.91 | 8.75 |
| T12 | Only Lantana (Spray) | 45.05 | 41.23 | 43.14 | 9.27 | 179.03 | 178.30 | 178.66 | 4.51 |
| T13 | Only Mancozeb (Spray) | 51.33 | 51.39 | 51.36 | 30.09 | 191.23 | 192.26 | 191.74 | 12.16 |
| T14 | Only Propiconazole (Spray) | 51.87 | 53.96 | 52.91 | 34.01 | 199.26 | 198.44 | 198.85 | 16.32 |
| T15 | Untreated/Check | 40.40 | 38.56 | 39.48 | - | 171.29 | 170.62 | 170.95 | - |
| | **Mean** | **46.55** | **46.46** | **46.50** | - | **187.86** | **187.4** | **187.62** | - |
| | **SEm±** | **1.41** | **1.31** | **1.65** | | **4.75** | **4.57** | **4.36** | - |
| | **CD at 5%** | **4.10** | **3.82** | **4.80** | - | **13.83** | **13.31** | **12.70** | - |

***Table 7: Effect of different fungicides, botanicals, bio-agent and their combination on economics and calculation of BCR.***

| Treatment | Yield (q/ha.) | Price of maize grain Rs.1400/q | Dosages of fungicides | Cost of fungicide/kg | Total cost of chemical& Labour | No. of labour for spray/ ha. | Total labour cost for spray @368/labour | Total cost (fungicide/chemical + labour) | Net returned | C.B. Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| **T1:** Mancozeb + Carbendazim (ST) @ 3g/Kg seed | 39.52 | 55,328 | 60gm | Rs.1000 | Rs.60 | - | - | Rs.60 | Rs.238 | **1:3.96** |
| **T2:** T1 + Neem (Spray) @ 10% | 45.39 | 63,546 | 60gm +200 lit. in 2 spray | Rs.1000 + 5 labour for preparation of solution) | Rs.60 + 1840 @ Rs.368/ labour | 10 labour for 2 spray | Rs.3680 | Rs.5,580 | Rs.8,456 | **1:1.51** |
| **T3:** T1 + Lantana (Spray) @ 10% | 43.80 | 61,320 | 60gm + 200 lit. in 2 spray | Rs.1000+ 5 labour for preparation of solution) | Rs.60 + 1840@ Rs.368/ labour | 10 labour for 2 spray | Rs3680 | Rs.5,580 | Rs.6,230 | **1:1.11** |
| **T4:** T1 + Mancozeb (Spray) @ 0.25% | 52.60 | 73,640 | 60gm +5.0 kg. in 2 spray | Rs.1000 + 500 | Rs.60 + 2500 | 10 labour for 2 spray | Rs.3680 | Rs.6,240 | Rs.18,550 | **1:2.97** |
| **T5:** T1 + Propicoonazole (Spray) @ 0.1% | 53.55 | 74,928 | 60gm +2lit. in 2 spray | Rs.1000 +1500 | Rs.60 +3000 | 10 labour for 2 spray | Rs.3680 | Rs.6700 | Rs.19,838 | **1:2.96** |
| **T6:** *T. harzianum* (ST) @ 10 g/Kg seed | 39.45 | 55,230 | 200 g. | Rs.125 | Rs.25 | - | - | Rs.25 | Rs.140 | **1:5.6** |
| **T7:** T6 + Neem (spray) @ 10% | 44.15 | 61,810 | 200 g. +200 lit. in 2 spray | Rs.125 + 5 labour for preparation of solution) | Rs.25 + 1840@ Rs.368/ labour | 10 labour for 2 spray | Rs.3680 | Rs.5,545 | Rs.6,720 | **1:1.21** |
| **T8:** T6 + Lantana (Spray) @ 10% | 43.39 | 60,746 | 200 g. +200 lit. in 2 spray | Rs.125 + 5 labour for preparation of solution) | Rs.25 + 1840@ Rs368/ labour | 10 labour for 2 spray | Rs.3680 | Rs.5,545 | Rs.5,656 | **1:1.02** |
| **T9:** T6 + Mancozeb (Spray) @ 0.25% | 51.75 | 72,450 | 200 g. + 5.0 kg. in 2 spray | Rs.125 +500 | Rs.25 + 2500 | 10 labour for 2 spray | Rs.3680 | Rs.6,205 | Rs.17,360 | **1:2.80** |
| **T10:** T6 + Propiconazole (Spray) @ 0.1% | 53.25 | 74,550 | 200g. + 2lit. in 2 spray | Rs.125 +1500 | Rs.25 + 3000 | 10 labour for 2 spray | Rs.3680 | Rs.6,705 | Rs.19,460 | **1:2.90** |
| **T11:** Only Neem (Spray) @ 10% | 43.85 | 61,390 | 200 lit. in 2 spray | 5 labour for preparation of solution) | Rs.1840@ Rs.368/ labour | 10 labour for 2 spray | Rs.3680 | Rs.5,520 | Rs.6,300 | **1:1.14** |
| **T12:** Only Lantana (Spray) @ 10% | 43.15 | 60,410 | 200 lit. in 2 spray | 5 labour for preparation of solution | Rs.1840 @ Rs.368/ labour | 10 labour for 2 spray | Rs.3680 | Rs.5,520 | Rs.5,320 | **(-) 0.96** |
| **T13:** Only Mancozeb (Spray) @ 0.25% | 51.35 | 71,890 | 5.0 kg. in 2 spray | Rs.500 | Rs.2500 | 10 labour for 2 spray | Rs.3680 | Rs.6,180 | Rs.16800 | **1:2.71** |
| **T14:** Only Propiconazole (Spray) @ 0.1% | 52.90 | 74,060 | 2lit. in 2 spray | Rs.1500 | Rs.3000 | 10 labour for 2 spray | Rs.3680 | Rs.6,680 | Rs.18970 | **1:2.83** |
| **T15: Untreated/Check** | 39.35 | 55,090 | - | - | - | - | - | **55,076** | - | - |

## DISCUSSION

The fungicide in combination with plant growth regulators and bio-agents reduces the severity and incidence [3, 34]. The bio-agents also in combination with the botanicals reduce the incidence and severity of many plant diseases. Among the tested treatments, T5 (Carbendazim + Mancozeb (SAAF) ST + Propiconazole spray) was found most effective and significantly superior among all the treatments where 31.63 and 30.24 per cent disease incidence was recorded during the year 2019 and 2020 respectively followed by T10 and T14. Similarly, during 2019 and 2020, the minimum disease index (31.85% and 30.37% respectively) was recorded in T5 (Carbendazim + Mancozeb ST +Propiconazole spray) followed by T10 (*T. harzianum* ST + Propiconazole spray) and T14 (Propiconazole spray).

The results were in accordance with the findings of (Marlatt and Knauss, 1974; Rush et al. 1976; Issa, 1983; Singh et al. 2011; Hulagappa et al. 2013) who observed that Propiconazole found effective in reducing the severity of Helminthosporium blight in cereal crops [29, 43, 21, 49, 19]. The ST with Carboxin + thiram or benomyl + thiram followed by three foliar applications of mancozeb found highly effective in integrated disease management effort against MLB [32, 44, 38, 36]. To control the maydis leaf blight, a combination of fungicides is often more potent than using individual fungicides [54].

The different plant extracts from *Azadirachta indica* (neem), *Allium cepa* (onion), *Aegle marmelos* (bel) and *Allium sativum* (garlic) and extracts of herbals of some medicinal plants found effective in minimising severity of disease and incidence of *H. Maydis* due to their fungitoxicity [39, 23, 50, 27, 5]. These botanicals were found effective against germination of spore of fungi in the induction of resistance [8, 30, 46, 47]. Rodriguez and Sanabria (2005) reported that ethanolic extracts of *Phyllanthus niruri*, *Lippia origanoides*, and *Heliotropium indicum* were found effective against *B. maydis* [42]. Dey et al. (2015) studied and reported the integrated management (by using fungicides and botanicals) of common rust caused by *Puccinia sorghi* [11].

The efficacy of *T. viride* and *T. harzianum* has also been demonstrated to possess antagonistic action against the pathogen *E. hawaiiensis* causing leaf blight of wheat [26, 37]. The seed treatments with *T. harizianum* in combination with neem cake and castor effectively controlled the post-flowering stalk rot and gave a better cost-benefit ratio [25].

Infection rate represents the increase or decrease of disease per unit time. Infection rate is a sensitive indicator for progression of the disease, influenced by many pathogens, host and climatic factors [9]. Infection rate quantify the effects of fungicide and host resistance and gave prediction of rates of fungicides application for resistant and susceptible cultivars [14]. During 2019, the minimum infection rate (0.013) was recorded in T9 (*T. harzianum* ST + Mancozeb spray) followed by T4 (Carbendazim + Mancozeb ST + Mancozeb spray), T5 (Carbendazim + Mancozeb ST + propiconazole spray) and T10 (*T. harzianum* ST + Propiconazole spray) in comparison to control where maximum infection rate

(0.032) was observed. During 2020, similar pattern of infection rates was observed. Similar results were obtained by (Kachapur and Hegde, 1988; Sharma and Mishra, 1988; Goulart, 1993) who suggested infection rate and severity were reduced and the increased grain yield of mancozeb and hexaconazole-treated plants.

Slow blighting is the result of an increase and decrease in apparent infection rate. Slow blighting is a form of resistance where a susceptible host reaction is observed but the disease development rate is very slow [40, 17]. Jacobsen and Backman (1993) suggested that using fungicides with bio-agents to achieve stable control by minimizing the infection rate and the most common combination of bio-agents with fungicides is with seed treatments.

AUDPC is an important parameter and plays a vital role in analytical epidemiology [48]. This is being used for crop yield forecasters in place of disease severity. AUDPC accounts both for duration of the development of the disease and the severity of the disease as well. Both these factors are closely related to crop yield losses and the amount of damage [22, 51]. During 2019, the highest AUDPC (638.08 $mm^2$) was recorded in control. Minimum AUDPC (253.12 $mm^2$) was recorded in T5 (Carbendazim + Mancozeb ST + propiconazole spray) followed by T10 (*T. harzianum* ST + propiconazole spray) (284.72 $mm^2$), T14 and T4. During 2020, similar results were obtained, minimum AUDPC (255.76 $mm^2$) was recorded in T5 followed by T10, T14, T7 and T4. The data on AUDPC calculated for both the experimental years in different treatments revealed lots of variability. As compared to treated plots, check plots had significantly more AUDPC for both the years which resulted in more disease damage and more yield loss. The results of the present finding are in accordance with other researchers [2,13].

During 2019 and 2020, maximum yield (54.60 q $ha^{-1}$ and 52.52 q $ha^{-1}$) was recorded in T5 (Carbendazim + Mancozeb ST + propiconazole spray) respectively followed by T10 (*T. harzianum* ST + propiconazole spray) and T14 which was significantly superior over check. A per cent increase in grain yield over check-in pool data was calculated. The maximum per cent increase in grain yield (35.66%) was recorded in T5 (Carbendazim + Mancozeb ST + Propiconazole spray). During 2019 and 2020, maximum 1000 grain test weight (204.49 g and 206.62 g) was recorded in T5 (Carbendazim + Mancozeb ST + propiconazole spray) respectively followed by T10 (*T. harzianum* ST + propiconazole spray) (201.10 g) and T14 (199.26) while minimum 1000 grains weight (171.29 g) was recorded in control. Pooled data from 2019 and 2020 showed that a maximum per cent increase in test weight (20.23%) was recorded in T5 (Carbendazim + Mancozeb ST + Propiconazole spray) followed by T10 (*T. harzianum* ST + Propiconazole spray) (18.26%). The economics of the benefit-cost ratio for the mean value of two experimental years has been worked out for different treatments employed. The benefit-cost ratio for 2 experimental years was calculated. The results revealed that, T6 (*T. harzianum* ST) gave more benefit-cost ratio (5.6:1) followed by T1 (Carbendazim + Mancozeb (SAAF) ST), T4, T5 and T10.

## 5. CONCLUSION

Maize is called as queen of cereals due to its high genetic yield potential. Due to increasing demand, production of maize in India was 27.23 million tonnes with an area of 9.18-million-hectare area with a productivity of 2965 kg $ha^{-1}$ during 2018-19 [1].

Many diseases occur in maize in various parts of the country leading to cent per cent loss in yield if not managed properly. In India, although 18 foliar diseases are reported to occur, Maydis leaf blight caused by *Helminthosporium maydis* (Nisikado) is considered to be the major disease. Maydis leaf blight is a limiting factor for maize cultivation. Hence, systematic studies on *in vivo* management of disease using botanicals, fungicides and bio agents for the efficient management of the disease were carried out and the results thus obtained are summarised here under.

Studying the results on different botanicals, fungicides and bio-agents and their combination, for the management of disease, revealed that comparatively lower disease incidence (31.62 % and 30.59 %), disease index (31.85 % and 30.37 %) and minimum AUDPC (253.12 $mm^2$ and 255.76 $mm^2$) with maximum grain yield (54.60 q $ha^{-1}$ and 52.52 q $ha^{-1}$) and test weight (204.49 g and 206.62 g) was recorded in T5 (Carbendazim + Mancozeb, (SAAF) ST + Propiconazole spray) treated plots during 2019 and 2020, respectively. Economics for the mean yield of two experimental years showed that, Benefit-cost ratio for 2 experimental years was calculated. The results revealed that, T6 (*T.harzianum* ST) gave more benefit-cost ratio (5.6:1) followed by T1 (carbendazim + mancozeb ST), T4, T5 and T10.

**Future scope of the study:** The study mainly highlighted on the integrated management of Southern corn leaf blight disease of maize under field conditions. The study well explored the uses of bio control agents (BCA) and botanicals along with chemicals and managed the disease in eco-friendly and sustainable manner. The present study helps in further investigations to find out more suitable combinations to manage the disease and farmer's education and awareness is also crucial for the judicious use of the chemical fungicides.

**Declarations**

**Acknowledgement-** I am very grateful to the Chairperson of the Department of Plant Pathology and the Institution (Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar) who provided the immense support during my research work.

**Ethical Approval -** Not applicable

**Competing interests -** No conflict of Interest

**Authors' contributions**

Phool Chand and CS Choudhary - My Advisor and Co-advisor during my research work

Mithilesh Kumar, Gautam Kunal, Reyaz Ahmed, Anjana Arun and Shivam Maurya - They also worked on the Evaluation of the fungicides, bio-agents and botanicals both under laboratory and field conditions as they are also expertise in the specified field.

Avinash Jha – Helped me in writing the paper.

**Funding -** Self-funded

**Availability of data and materials** Not applicable

## REFERENCES


1. Agricultural Statistics at a Glance.2019. Directorate of Economics & Statistics, Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers.

Ali, F., Muneer, M., Xu, J., Lu, Y., Hassan, W., Ullah, H. and Yan, J. 2012. Accumulation of desirable alleles for southern leaf blight (SLB) in maize (*Zea mays* L.) under the epiphytotic of' *Helminthosporium maydis*. Australian Journal of Crop Science, 6(8): 1283-1289.

Avis, T.J., Martinez, C. and Tweddell, R.J. 2010. Minireview/Minisynthèse Integrated management of potato silver scurf (*Helminthosporium solani*), Canadian Journal of Plant Pathology, 32(3): 287-297.

Balint-Kurti, P.J., Krakowsky, M.D., Jines, M.P., Robertson, L.A., Molnár, T.L and Goodman, M.M. 2006. Identification of quantitative trait loci for resistance to southern leaf blight and days to anthesis in a maize recombinant inbred line population. Phytopathology, 96:1067-1071.

Begum, A.S., Patnaik, A., Basha, S.A., Raghavendra, G., Pandey, S.K. and Sarma, B.K. 2011. Effect of leaf extracts and steroidal saponin of *Cestrum diurnum* L. on spore germination and mycelial growth of some fungi. Electronic Journal of Environmental Agricultural and Food Chemistry, 10(11): 3097-3103.

Blanco, M. H. and Nelson, R. R. 1972 Relative survival of populations of race T of *H.maydis* on corn hybrid in normal cytoplasm. Plant Disease Reporter.56: 889-891.

Bradley, C. A. 2012. Factors considered when making corn foliar fungicide application decisions in Illinois. The Journal of Extension, *50*(3), 59.

Chatterjee, M.R., Chatterjee, M. and Chowdhury, A. 1996. Antifungal activities of some fractions of extract from *Coriarian epalensis* on growth of three plant pathogenic fungi. Journal of Mycopathological Research, 34(1): 53-57.

Chiarappa, L., Chiang, H.C. and Smith, R.F. 1972. Plant pests and disease: assessments of crop losses. Science, 174: 769-773.

Chung, C L., Jamann, T., Longfellow, J and Nelson, R. 2010. Characterization and fine-mapping of a resistance locus for northern leaf blight in maize bin 8.06. Theor. Appl. Genet, 121:205-227.

Dey, U., Harlapur, S.I., Dhutraj, D.N., Suryawanshi, A.P. and Bhattacharjee, R. 2015. Integrated disease management strategy of common rust of maize incited by *Puccinia sorghi* Schw. African Journal of Microbiology Research, 9(20): 1345-1351.

Drechsler, C. 1925. Leaf spot of maize caused *Ophiobolus hetrostrophus*, the asciogerous stage of *Helminthosporium* exhibiting bipolar germination. Journal of Agricultural Research, 31: 701-726.

1. Durrishahwar, H.U.R., Shah, S.M.A., Khalil, I.A. and Ali, F. 2008. Recurrent selection for yield and yields associated traits under leaf blight (*Helminthosporium maydis*) stress in maize. Sarhad Journal of Agriculture, 24(4): 599-605.

Fry, W.E. 1978. Quantification of general resistance of potato cultivars and fungicide effects for integrated control of potato late blight. Phytopathology, 68:16501655.

Goulart, A.C.P. 1993. Treatment of maize (*Zea mays* L.) seeds with fungicides. Revista Brasileira-de-Sementes, 15(2): 165-169.

Hafez, S.I.A, Abo-Elyousr, K.A. and Abdel-Rahim, I.R. 2014. Effectiveness of plant extracts to control purple blotch and Stemphylium blight diseases of onion (*Allium cepa* L.) in Assiut, Egypt. Archives of Phytopathology and Plant Protection, 47(3): 377-387.

Harlapur, S.I. 2005. Epidemiology and management of turcicum Leaf blight of maize caused by *Exserohilum turcicum* (pass.) Leonard and suggs. Ph.D. (Plant Pathology). Thesis, University of Agricultural Sciences, Dharwad. pp. 50-65.

Hulagappa, 2012. MSc thesis. University of Agricultural Sciences; Dharwad: Studies on maydis leaf blight of maize caused by *Drechslera maydis* (Nisikado) Subram. and Jain.

Hulagappa, Harlapur, S.I., Roopa, R.S. and Venkatesh, M. 2013. Field Evaluation of Fungicides for Management of Maydis Leaf Blight of Maize Caused by *Drechslera maydis* (Nisikado) Subram. and Jain. Trends in Biosciences, 6(6): 789-791.

Hulmani S, Salakinkop SR, Somangouda G 2022. Productivity, nutrient use efficiency, energetic, and economics of winter maize in south India. PLoS ONE 17(7): e0266886 (PMID: 35862389; PMCID: PMC9302768).

Issa, E. 1983. Chemical control of *Helminthosporium turcicum* Pass. on maize. Biologico, 49(2): 41-44.

James, W.C. 1974. Assessment of plant diseases and losses. Annual review of Phytopathology, 12: 27-48.

Jha, M.M., Kumar, S. and Hasan, S. 2004a. Effects of botanicals on maydis leaf blight of maize in vitro. Annals of Biology, 20(2): 173-176.

Kachapur, M.R. and Hegde, R.K. 1988. Studies on turcicum leaf blight of maize caused by *Exserohilum turcicum* with special reference to crop loss assessment. Plant Pathology Newsletter, 6: 33-35.

Khokhar, M.K., Hooda, K.S., Sharma, S.S. and Singh,V. 2014. Post Flowering Stalk Rot Complex of Maize - Present Status and Future Prospects. Maydica Electronic Publication, 59: 226-242.

Kolte, S.O., Korekar, V.B. and Lokhande, M.W. 1994. Biocontrol of die back and fruit rot of chilli caused by *Colletotrichum capsici* under field conditions. Orissa Journal of Agricultural Research, 7: 30-84.


 

1. Kumar, S., Rani, A. and Jha, M.M. (2009). Evaluation of plant extracts for management of maydis leaf blight of maize. Annals of Plant Protection Sciences, 17(1): 130- 132.

Madden, LV., Hughes G and Van Den Bosch F, 2007. The study of plant disease epidemics. Saint Paul, USA: APS Press.

Marlatt, R.B. and Knauss, J.F. 1974. A new leaf disease of *Aechmea fasciata* caused by *Helminthosporium rostratum*. Plant Disease Reporter, 58(5): 445-448.

Maurya, S., Singh, R. and Singh, U.P. 2010. Antifungal activity of ethanolic extract of Archu (Rheum emodi) on powdery mildew (*Erysiphe cichoracearum*) and its role in the induction of resistance in balsam (*Impatiens balsamania*). Archives of Phytopathology and Plant Protection. 43(16/18): 1589-1595.

Meena, O.P. and R.A.K. Meena. 2006. Maize: 'Queens of Cereals'. Agrobios Newsletter.

Miller, P.R. 1970. Southern corn leaf blight. Plant Disease Reporter, 54: 1099-1136.

Mitiku, M., Yesuf, E and Wondewosen S. 2014 Evaluation of Maize Variety for Northern Leaf Blight (*Trichometasphaeria turcica*) in South Omo zone. World Journal of Agricultural Research, 2(5):237-239.

Morsi, M.E.M.A. and Monaim, M.F.A. 2015. Effect of bio-agents on pathogenic fungi associated with roots of some deciduous fruit transplants and growth parameters in New Valley Governorate, Egypt. Journal of Plant Protection Research, 55(2): 117-219.

Munjal, R.L and Kapoor, J.N. 1960. Some unrecorded diseases of sorghum and maize from India. Current Science, 29: 442-443.

Pakki, S. 2005. Epidemiology and control of corn leaf blight disease caused by *Helminthosporium* sp. Journal Penelitiandan Pengembangan Pertanian. 24(3): 101-108.

Patil, V.S. 2000. Epidemiology and management of leaf blight of wheat caused by *Exserohilum hawaiienesis* (Bugnicourt) Subram and Jain, Ex. Ellis, M.B. Ph.D. Thesis, University of Agricultural Science, Dharwad.

Payak, M.M. and Sharma, R.C. 1985. Maize diseases and their approach to their management. Tropical Pest Management, 31: 302-310.

Raju, K., Manian, S. and Anbuganapathi, G. 2004. Effects of certain herbal extracts on the rice brown leaf spot pathogen. Journal of Ecotoxicology and Environmental Monitoring, 4(1): 31-37.

Reddy, P.N. and Khare, M.N. 1988. Components of resistance in groundnut cultivars in *Puccinia arachidis* Speg. Journal of Oil Seeds Research, 5: 153-154.

Reddy, T. R., Reddy, P. N., Reddy, R. R., & Reddy, S. S. 2013. Management of turcicum leaf blight of maize caused by *Exserohilum turcicum* in maize. International journal of scientific and Research Publications, 3(10), 1-4.

1. Rodriguez, D.A. and Sanabria, M.E. 2005. Effect of the extract of three wild plants on Rhizoctonia and southern corn leaf blight diseases of corn and on their pathogens. Interciencia, 30(12): 739-744, 785-787.

Rush, M.C., Lindberg, G.D. and Shahjahan, A.K.M. 1976. Fungicidal control of rice foliar and stem diseases. 68th annual progress report, Rice Experiment Station, Crowley, Louisiana. pp. 214-221.

Schenck, N.C. and Stelter, T.J. 1974. Southern corn leaf blight development relative to temperature, moisture and fungicide applications. Phytopathology, 64(5): 619 624.

Sharma, R.C., Lilaramani, J. and Payak, M.M. 1978. Outbreak of a new pathotype of *Helminthosporium maydis* on maize in India. Indian Phytopathology, 31(1): 112-113.

Singh, A., Singh, A., Kesherwani, M., Singh, T.D., Singh, V.P., Pandey, V.B. and Singh, U.P. 2010a. The mixture of tertiary and quaternary alkaloids isolated from *Argemone ochroleuca* inhibits spore germination of some fungi. Archives of Phytopathology and Plant Protection, 43(13): 1249-1253.

Singh, A., Singh, S., Kesherwani, M., Singh, T.D., Singh, V.P., Pandey, V.B. and Singh, U.P. 2010b. Jatrorrhizine and columbamine alkaloids isolated from *Argemone mexicana* are inhibitory to spore germination of some plant pathogenic fungi. Archives of Phytopathology and Plant Protection, 43(15): 1450-1453.

Singh, B.P., Singh, P.H. and Bhattacharya, S.K. 1999. Epidemiology, In: Potato late blight in India, CPRI Technical Bulletin, p. 27.

Singh, V.K, Nasir A and Singh A. 2011 Effect of seed treatment and one foliar spray on Maydis leaf blight severity and yield of maize. Pestologica.; 35(3):32-35.

Srivastava, S., Ray, D.P. and Singh, R.P. 2007. Chemical examination and antifungal activity of curry leaf (*Murraya koenigii* (L.) Spreng.). Pesticide Research Journal, 19(2): 149-151.

Teng, P.S. 1983. Estimating and interpreting disease intensity and loss in commercial fields, Phytopathology, 73: 1587-1590.

Ullstrup, A.J. 1972. The impacts of southern corn leaf blight epidemics of 1970-1971. Annual Reviews of Phytopathology, 10: 37-50.

Van der Plank, J.E. 1963. Plant Disease: Epidemics and Control. Academic Press, New York, pp. 35-71.

Wang, X., Ma, J., Li, X., Zhao, X., Lin, Z., Chen, J. and Shao, Z. 2015. Optimization of chemical fungicide combinations targeting the maize fungal pathogen, *Bipolaris maydis*: a systematic quantitative approach. IEEE Transactions on Biomedical Engineering, 62(1): 80-87.

Wheeler, B. E. J. 1969. An introduction to plant disease. John Wiley Sons Limited London. pp. 301.

 