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Evaluation of Fungicides, Botanicals and Biocontrol Agents for Management of Southern Leaf Blight of Maize (*Bipolaris maydis*) with Effective Benefit Cost Ratio

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ABSTRACT

Southern leaf blight of maize (*Bipolaris maydis*) is one of the major disease in many countries including India. An experiment was conducted for two consecutive years during *rabi* 2019 and 2020 to develop an integrated management of southern leaf blight of maize using fungicides, botanicals and bioagents under natural field conditions. Propiconazole was found to be the best and showed 100% mycelial growth inhibition *in vitro* at 0.1%. Among the botanicals, citronella showed 99.70% mycelial growth inhibition and *Trichoderma harzianum* was found to be the best with 84.26% mycelial growth inhibition among the biocontrol agents. The results of the field trials showed the highest yield performance (2601.71 kg ha^{-1}) and percent reduction in disease severity over control of 61.70 % in the treatment comprising of seed treatment+spraying with propiconazole 25% EC @ 1% which was followed by treatment comprised of spraying with citronella @ 0.1% (2445.33 kg ha^{-1}) and spraying with propiconazole 25% EC @ 0.1% (2349.26 kg ha^{-1}). Highest BC ratio was obtained in seed treatment+spraying with propiconazole 25% EC @ 1% (4.05) followed by spraying with *Trichoderma harzianum* @ 4 g (3.71) and seed treatment+spraying with *Trichoderma harzianum* @ 4 g (3.69). The results showed that seed treatment+spraying with propiconazole 25% EC @ 1% was significantly superior over other treatments.

KEYWORDS: Benefit cost ratio, IDM, Leaf blight, Maize, *Bipolaris maydis*

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1. INTRODUCTION

Maize (*Zea mays* L.) is the third important cereal crop in India after wheat and rice and can be cultivated throughout the year. It is primarily used as as feed (63.0%), food (23.0%), in starch industries (12.0%), seed, including miscellaneous uses (2.0%) in India (Malik et al., 2018). The demand for starch is growing at 10–12% every year due to rising consumption in the food and pharma industry. It has greater calorific value and rich in amino acids with less toxins compared to grains like millet and broken rice (Modi, 2014). In India, maize occupies an area of 9.89 m ha having a production of 31.65 mt with average productivity of 3199 kg ha^{-1} (Anonymous, 2022). Maize is the most potential and predominant crop in rainy season particularly in the hills of the North Eastern Region of India (Das et al., 2010). However, maize can also be grown successfully in rainy (*kharif*), winter (*rabi*) and summer/spring (*zaid*) seasons. Maize diseases have been a major problem in increasing the productivity. Maize is attacked by as many as 112 diseases in the world posing major constraints in realizing the potential yield of maize. In India, about 35 diseases reported from different locations and predominantly of fungal and bacterial origin. Under favourable environmental conditions, these diseases play havoc and cause immense losses both in quantity and quality as well (Ali and Yan, 2012). The crop is affected by several fungal diseases of which, southern leaf blight (also called maydis leaf blight) caused by *Bipolaris maydis* is the most common resulting in premature death and cause yield reduction up to 83 (Shekhar and Kumar, 2013). It is a serious fungal disease of maize throughout the world where maize is grown under warm and humid conditions (White, 1999). It can cause yield losses of up to 40% (Fisher et al., 1976, Gregory at al., 1979, Byrnes et al., 1989) and may go up to 70% yield loss in severe condition (Wang et al., 2001).

It is the most prevalent in tropical and subtropical maize-growing areas such as the southeastern United States and parts of Asia and Africa, where it could cause nearly 70% of production losses under favorable environmental conditions (Carson et al., 2004, Fisher et al., 1976, Kumar et al., 2016, Singh and Srivastava, 2016, Tatum, 1971, Ullstrup, 1972). Southern leaf blight caused the epidemic in the year 1970–1971 in North America and destroyed 15% of the crop at a cost of US$1.0 billion (Bruns, 2017, Agrios, 2005). The southern leaf blight of maize has now become one of the most prevalent and severe diseases in Pakistan, India, Nepal, Kampuchea, Philippines, Indonesia, Vietnam and China. Munjal and Kapoor (1960) first reported its presence in India. The disease has been reported from all the maize growing regions of India in mild to severe form. In India, it has now become serious disease particularly in Jammu & Kashmir, Himachal Pradesh, Sikkim, Meghalaya, Punjab, Haryana, Rajasthan, Delhi, UP, Bihar, MP, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu (Singh and Srivastava, 2016). The symptoms developed by "O" strain of the fungus appears as young small and diamond shaped lesions between the vein at initial stage (Singh and Srivastava, 2016). The symptoms began as small, brown, water-soaked lesions on young leaves and later became larger (1–8 mm long), dark brown and necrotic. (Dai et al., 2016).

Management of southern leaf blight of maize requires an integrated approach comprising of cultivation of resistant variety , agronomic practices targeted towards reducing inoculum build-up and application of fungicides (Lai et al., 2016, Shukla et al., 2012, Wang et al., 2015). Earlier workers developed the management strategies of southern leaf blight of maize with chemical fungicides. There is an urgent need to develop integrated disease management practices with the emphasis on biological control and use of botanical extracts Due to the non-availability of durable sources of resistance to the diseases, controls by chemical and biological means are important to avoid crop losses. Several workers developed the integrated disease management the crops like pulses (Marak et al., 2020) wheat (Devi et al., 2021), Mustard (Mahapatra et al., 2022). But on maize there was little information in this aspect. Therefore, there is an immediate need to identify the suitable method of management through integrated approaches and also to examine their efficacy. . Keeping the economic importance of southern leaf blight disease in view, the present investigation was made to find out the suitable chemicals, botanicals and biological control measures for effective management of the disease.

2. MATERIALS AND METHODS

The experiment was conducted on integrated management of southern leaf blight of maize in the field during *rabi* season of 2010 and 2020 (December, 2019–April, 2020 and December, 2020–April, 2021).

2.1. Collection of isolates

The pathogen, *Bipolaris maydis* used for the entire course of experiment was isolated from maize plant grown in the farmer's field of Char Jadubati (P), Nadia District, West Bengal.

2.2. In vitro evaluation of fungicides against Bipolaris maydis

Five fungicides were tested against *Bipolaris maydis* on the PDA medium using poison food technique (Nene and Thapliyal, 1979) under *in vitro* condition. The concentration of different fungicides used for poison food technique were as follows: Mancozeb: 0.15%, 0.2% and 0.25% Propiconazole and Tebuconazole: 0.05%, 0.1% and 0.2%, Azoxystrobin: 0.03%, 0.05% and 0.1%, Azoxystrobin + Tebuconazole: 0.05%, 0.1%, and 0.15%. The per cent inhibition of growth was calculated by using the formula given by Vincent (1947).

Percent inhibition, I=(C-T)/C×100 ....(1)

Where, I=Inhibition percentage of the mycelium

C=Growth of the test fungus in control (mm)

T=Growth of the test fungus in treatment (mm)

2.3. In vitro evaluation of botanicals extracted oils against Bipolaris maydis

Botanicals viz. onion oil, garlic oil, neem oil, citronella oil and lemongrass oil at 0.1%, 0.2% and 0.3% were used for the experiment to evaluate the antagonistic or fungitoxic properties. The plant oils collected from Chemical Industrial Development Company (CID) were stored in dark glass bottles. Emulsifiers (0.1% Tween-80)were used for emulsification of plant oils.. Various concentrations were obtained by adding necessary volume of oil emulsion to sterilized PDA medium in conical flasks. The experiment was carried out by using poison food technique (Nene and Thapliyal, 1979). Each treatment was replicated 3 times. Inoculated plates were incubated at 28±1°C temperature in B.O.D. incubator. Radial growth of the fungus was recorded by measuring the colony diameter after 10 days of inoculation and percentage mycelial growth inhibition was calculated as described by Vincent (1947).

Percent inhibition, I=(C-T)/C×100 …………….(2)

Where, I=Inhibition percentage of the mycelium

C=Growth of the test fungus in control (mm)

T=Growth of the test fungus in treatment (mm)

2.4. Poison food technique

The poison food technique (Nene and Thapliyal, 1979) was followed to test the efficacy of the above mentioned fungicides. The pathogen *Bipolaris maydis* was grown on PDA medium in petriplates for 10 days prior to setting the experiment. Fungicide suspension was prepared in PDA by adding required quantity to obtain the desired concentration on the basis of active ingredient present in the chemical. 20 ml of poisoned medium was poured in each of the sterilized petriplates. Mycelial disc of 5 mm taken from the periphery of 10-day old culture was placed in the centre of the petriplates and incubated at 28±2°C. Suitable checks were also maintained without addition of any fungicide and three replications were maintained for each treatment. The mycelial growths were recorded after every 48 h interval until the growth of the fungus in control plate was complete (90 mm). The diameter of the colony was measured in two directions and average was worked out. The percentage inhibition of growth was calculated by using the formula given by Vincent (1947).

2.5. In vitro evaluation of bioagents against Bipolaris maydis

The fungal biocontrol agent, *Trichoderma harzianum, T. viride,* and the bacterial biocontrol agents, *Pseudomonas fluorescens* and *Bacillus subtilis* were tested to find out the antagonistic efficacy against *Bipolaris maydis* by dual culture technique.

2.6. Isolation of fungal biocontrol agents

Soil sample collected from the field was air dried under shade, ground and sieved through 0.25 mm mesh. *Trichoderma* were isolated by soil dilution technique (Dhingra and Sinclair, 1995) using *Trichoderma* specific medium (TSM) (Elad and Chet, 1983) modified by Saha and Pan (1997). *Trichoderma* colonies developed on TSM were identified based on taxonomic keys and monograph of Domsch et al. (1980) and Bissett (1991).

2.7. Collection of bacterial bio-control agents

The isolates of *Bacillus subtilis* and *Pseudomonas fluorescens* were collected from Survey, Selection and Mass Production Unit, BCKV, Mohanpur, Nadia, West Bengal and maintained at PDA and nutrient agar medium.

2.8. Dual Culture Test

Mycelial disc (5 mm) was cut from the edge of a 4-day old colony of bio-control agents and the pathogens and placed simultaneously on the edge of each PDA plate at opposite direction. Four replicate plates were used for each isolate. The plates inoculated with the pathogen were served as control. The petriplates were incubated at 28±1°C temperature in B.O.D. incubator for 8 days. The diameter of both the biocontrol agent, viz., *Trichoderma harzianum*, *T. viride*, *Pseudomonas fluorescens* and *Bacillus subtilis* and the pathogen was measured in two directions and average was recorded. The percentage inhibition of mycelial growth of pathogens was calculated by using the formula as suggested by Morton and Stroube (1955) and Vincent (1947):

Percent inhibition, I=(C-T)/C×100 ....……….(3)

Where, I=% inhibition in mycelia growth

C=Growth of pathogen in control plates

T=Growth of pathogen in dual culture plates

2.9. Application and evaluation of biocontrol agents, botanicals and fungicides in field conditions

The field trials were conducted for two consecutive years during *rabi* (December, 2019–April, 2020 and December, 2020–April, 2021) in the Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya at Jaguli, Nadia, West

Bengal (location: 22°56'48"N latitude and 88°32'20"E longitude at an elevation of 9.75 metre above mean sea level). The experiments comprising of nine treatments with three replications were laid out in Randomized Block Design in a plot size of 3×2.5 m^2 and spacing of 60×20 cm^2. The maize variety Kaveri-50 was used for the experiment. Disease incidence and severity data was recorded at 45 DAS and at 7 days interval. The details of the treatment combinations are stated below.

T_0=Control (untreated); T_1=Seed treatment with *Trichoderma harzianum* (@ 4 g kg^{-1} seed); T_2=Seed treatment with Citronella (@ 0.1%), T_3=Seed treatment with Propiconazole (@ 0.1%), T_4=Spraying with *Trichoderma harzianum* (@ 4 g), T_5=Spraying with Citronella (@ 0.1%), T_6=Spraying with Propiconazole (@ 0.1%), T_7=Seed treatment+spraying with *Trichoderma harzianum* (@ 4 g), T_8=Seed treatment+spraying with Citronella (@ 0.1%), T_9=Seed treatment+spraying with Propiconazole (@ 0.1%)

2.10. *Assessment of disease severity*

Ten numbers of plants after 45 days of sowing were randomly selected from each plot to record the disease severity avoiding the border areas. It was assessed using the 1–5 standard disease scoring scale recommended by Shekhar and Kumar (2012) and disease severity was calculated as percentage disease index (PDI) per replication using the following formula (Wheeler, 1969)-

PDI=(Total sum of individual rating/(No. of leaves examined×Maximum rating)×100..........................(4)

2.11. *Assessment of benefit cost ratio*

The benefit cost (B:C) ratio was calculated by the following formula,

BC ratio=Gross return/gross cost ....(5)

Where, Gross return=Monetary value of total crop produced per unit area

Gross cost=Monetary value of total cost of production per unit area

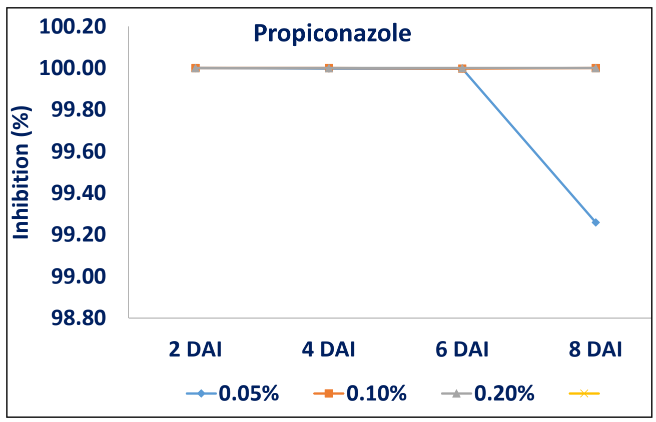
2.12. *Statistical analysis of result*

The experimental results were statistically interpreted through calculation of 'Analysis of Variance' by a standard method (Gomez and Gomez, 1984) and the significances of different treatments were tested by "Error mean square by Fisher and Sbedicor's F Test" at probability level 0.05. For determination of critical difference (CD) at 5% level of significance Fisher's and Yate's tables were consulted.

3. RESULTS AND DISCUSSION

3.1. *In vitro evaluation of fungicides against Bipolaris maydis*

Five fungicides viz. Mancozeb, Propiconazole, Azoxystrobin, Azoxystrobin+ Tebuconazole and Tebuconazole were evaluated against the test pathogen, i.e. *Bipolaris maydis* under *in vitro* condition (Figure 1 and Plate 1) with poisoned food technique in different concentrations (0.1%, 0.15%, 0.2% and 0.25%). Significant increased in inhibition percentage of mycelial growth were observed with the increase in concentration of fungicides. The inhibition percentage was found to be decreased with increase in the number of days of inoculation particularly at 6 days and 8 days. Among the fungicides, Propiconazole showed the highest inhibition percentage of mycelial growth (100%) at 0.1% followed by Tebuconazole (99.26%) and lowest in Azoxistrobin (62.41%) at 0.05%. Pavan and Shete (2021) also reported that Propiconazole was found to be the best in inhibition of mycelial growth of *Bipolaris maydis* in comparation to other tested fungicides. Malik et al. (2018) also found that propiconazole at 0.1% gave the best control of maydis leaf blight. Based on the results of *in vitro* experiment, , Propiconazole was selected for application in field condition.



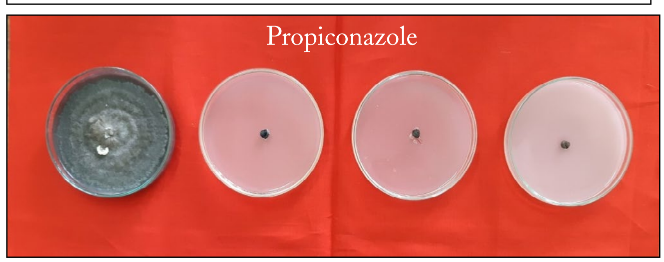
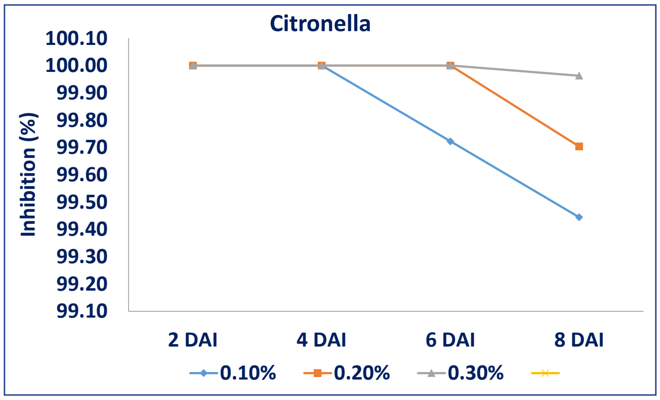


Figure 1 and Plate 1: Effect of Propiconazole on inhibition percentage of mycelial growth of *Bipolaris maydis*

3.2. *In vitro evaluation of different botanicals against Bipolaris maydis*

The essential oil of botanical origin viz., oils of onion, garlic, neem, citronella and lemongrass at different concentrations i.e. 0.1%, 0.2%, 0.3% were evaluated against *Bipolaris maydis* under *in-vitro* condition. Results (Figure 2 and Plate 2) indicated that with increased concentrations of the essential oils, there was a significant increased in inhibition percentage of mycelial growth of the pathogen. Efficacy of inhibition was found to be



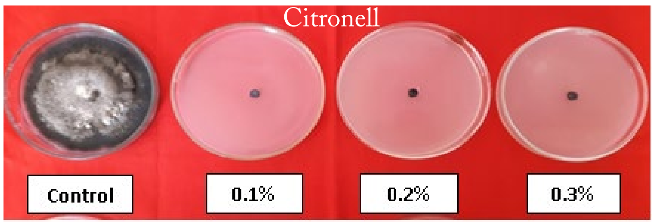
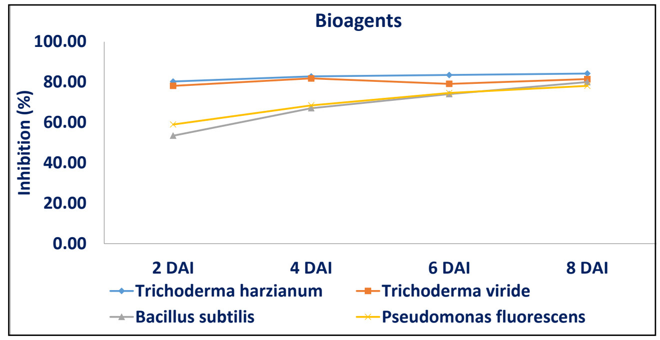


Figure 2 and Plate 2: Effect of Citronella oil on inhibition percentage of mycelial growth of *Bipolaris maydis*



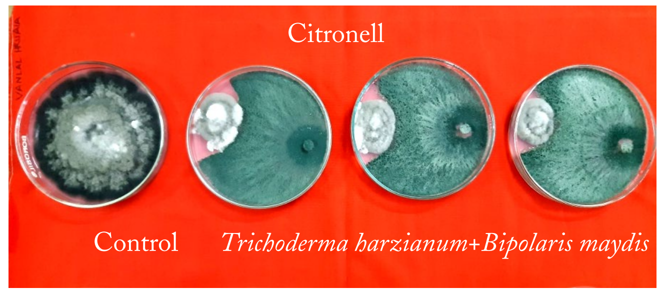


Figure 3 and Plate 3: Dual Culture of *Trichoderma harzianum* against *Bipolaris maydis*

reduced with the advancement in days after inoculation. Among the essential oils, citronella @ 0.2% showed the highest inhibition (99.70%) followed by lemongrass (90.37%). Onion oil, garlic oil andneem oil @ 0.3% showed the mycelial inhibition in the range of 22–56%. Kumar et al. (2009) reported that Garlic clove extract inhibited the mycelial growth of *Helminthosporium maydis* was maximum at 83.9% whereas, Neem leaf extract caused 65% inhibition of mycelial growth of *Helminthosporium maydis*. So, citronella oil was selected for application in field condition.

3.3. In vitro evaluation of bioagents against Bipolaris maydis

The results of four bioagents viz. *Trichoderma harzianum, T. viride, Bacillus subtilis* and *Pseudomonas fluorescens* with respect to the inhibition of mycelia growth of *Bipolaris maydis* was shown in Figure 3 and Plate 3.*Trichoderma harzianum* showed the highest percentage inhibition of mycelial growth (84.26%) followed by *Trichoderma viride* (81.48%), *Bacillus subtilis (*80%). The lowest was observed on *Pseudomonas fluorescens* (78.15%). Similar observation was also noticed by Kumar et al. (2009). These may be due to *Trichoderma* sp. Isolates suppress the mycelial growth of *Bipolaris sorokiniana* by producing secondary metabolites which were antifungal in nature (Salehpour et al., 2005). So, *Trichoderma harzianum* was selected for application in field condition.

3.4. Integrated application under field conditions

3.4.1. Disease severity

The results of the pooled data (Table 1) indicated the least percentage of disease index (11.76%) in the T_6 (spraying with Propiconazole 25% EC @ 0.1%) and statistically at par with T_9 (Seed treatment + spraying with Propiconazole 25% EC @ 1%) (Disease Index=12.06%) followed by T_8 (Seed treatment+spraying with Citronella @ 0.1%) (Disease Index=15.62%). Maximum disease severity was observed in T_4 (spraying with *Trichoderma harzianum* @ 4 g) (21.58%) followed by T_2 (seed treatment with Citronella @ 0.1%) (19.60%) and T_1 (seed treatment with *Trichoderma harzianum* @ 4 g) (19.23%) and their differences were statistically significant and superior over untreated control (31.77%).

Highest percentage reduction in disease over control was recorded in the treatments like T_6 (spraying with Propiconazole 25% EC @ 0.1%) (62.08%) followed by T_9 (Seed treatment+spraying with Propiconazole 25% EC @ 0.1%) (61.70%), T_8 (Seed treatment+spraying with Citronella @ 0.1%) (50.31%), T_5 (spraying with citronella @ 0.1%) (42.70%), T_7 (Seed treatment+spraying with *Trichoderma harzianum* @ 4 g) (40.31%), T_3 (Seed treatment with Propiconazole 25% EC @ 0.1%) (39.17%). The least percentage reduction in disease over control was recorded in T_4 (spraying with *Trichoderma harzianum* @ 4 g) (31.80%), followed by T_2 (seed treatment with Citronella @ 0.1%) (37.80%) and T_1 (seed treatment with *Trichoderma harzianum* @ 4 g) (38.77%).

Efficacy of botanicals and bioagents against *Bipolaris maydis* was reported earlier workers like Kumar et al. (2009a), Kumar et al. (2009b), Gautam et al. (2015), Malik et al. (2018). Malik et al. (2018) found that propiconazole

Table 1: Integrated disease management of southern leaf blight of maize during *rabi*, 2019-20, 2020-21 and Pooled data

Treatments	Percent disease index (%)			% reduction in disease over control	Grain yield (kg ha^{-1})			% increase in grain yield over control	Additional yield (kg ha^{-1})	B:C ratio
	2019-2020	2020-2021	Pooled		2019-2020	2020-2021	Pooled			
T_1: Seed treatment with *Trichoderma harzianum* @ 4 g kg^{-1} seed	14.67 (22.49)	23.78 (29.19)	19.23 (26.00)	38.77	2962.53	1433.32	2197.93	48.34	1062.37	3.61
T_2: Seed treatment with Citronella @ 0.1%	16.55 (24.00)	22.65 (28.41)	19.60 (26.27)	37.80	2785.82	1684.12	2234.97	48.24	1078.20	3.19
T_3: Seed treatment with Propiconazole @ 0.1%	15.81 (23.38)	22.49 (28.31)	19.15 (25.94)	39.17	2503.64	1755.89	2129.76	46.36	987.44	3.29
T_4: Spraying with *Trichoderma harzianum*	20.38 (26.83)	22.78 (28.51)	21.58 (27.68)	31.80	2896.96	1625.19	2261.07	49.78	1125.57	3.71
T_5: Spraying with Citronella @ 0.1%	13.22 (21.28)	22.72 (28.46)	17.97 (25.08)	42.70	3133.68	1756.99	2445.33	52.62	1286.68	3.49
T_6:Spraying with Propiconazole @ 0.1%	5.33 (13.21)	18.18 (25.23)	11.76 (20.05)	62.08	2950.91	1747.61	2349.26	51.61	1212.49	3.64
T_7: Seed treatment+ spraying with *Trichoderma harzianum*	16.37 (23.86)	21.28 (27.47)	18.83 (25.72)	40.31	2692.62	1811.51	2252.07	49.53	1115.46	3.69
T_8: Seed treatment+ spraying with Citronella @ 0.1%	12.34 (20.56)	18.90 (25.72)	15.62 (23.26)	50.31	2875.00	1819.08	2347.04	51.77	1215.13	3.39
T_9: Seed treatment+ spraying with Propiconazole @ 0.1%	10.00 (18.38)	14.12 (22.06)	12.06 (20.31)	61.70	3165.85	2037.58	2601.71	56.74	1476.29	4.05
Control	33.12 (35.13)	30.43 (33.47)	31.77 (34.31)		1095.97	1171.39	1133.68			1.89
SEm±	0.88	0.53	0.43		279.62	102.52	124.24			
CD (p=0.05)	2.62	1.58	1.29		837.22	304.60	372.00			

Figures in parenthesis are angular transformed values

at 0.1% gave the highest disease control in their studies. Marak et al. (2021) found that combinations of single spraying of Propiconazole 25% EC @ 0.1% along with one spraying of garlic oil @ 0.15% with one spraying of *T. harzianum* @ 4 g kg^{-1} gave minimum disease severity (8.20%).

3.4.2. Grain yield

The pooled data (Table 1) showed the maximum grain yield in T_9 (seed treatment + spraying with Propiconazole 25% EC @ 1%) (2601.71 kg ha^{-1}) and it was significantly superior over other treatments and the lowest yield was recorded in untreated control (1133.68 kg ha^{-1}). The higher yield was also observed in T_5 (spraying with citronella @ 0.1%) (2445.33 kg ha^{-1}) statistically at par with T_6 (spraying with Propiconazole 25% EC @ 0.1%) (2349.26 kg ha^{-1}) and their differences were statistically significant. Other treatments *viz.*, T_8 (Seed treatment+spraying with Citronella @ 0.1%) (2347.04 kg ha^{-1}) were statistically at par with T_4 (spraying with *Trichoderma harzianum* @ 4 g) (2261.07 kg ha^{-1}) and T_7 (seed treatment+spraying with *Trichoderma harzianum* @ 4 g) (2252.07 kg ha^{-1}) and their differences were statistically significant. The lowest yield was obtained in T_3 (seed treatment with Propiconazole 25% EC @ 0.1%) (2129.76 kg ha^{-1}) and statistically at par with T_1 (seed treatment with *Trichoderma harzianum* @ 4 g) (1433.32 kg ha^{-1}) and T_2 (seed treatment with Citronella @ 0.1%) (2234.97 kg ha^{-1})

Highest percentage increase in grain yield was observed (Table 1) in T_9 (Seed treatment+spraying with Propiconazole 25% EC @ 1%) (56.74%) followed by T_5

(spraying with citronella @ 0.1%) (52.62%) and T_8 (seed treatment+spraying with Citronella @ 0.1%) (51.77%). Percentage increase in grain yield were also higher in other treatments as T_6 (spraying with Propiconazole 25% EC @ 0.1%) (51.61%) followed by T_4 (spraying with *Trichoderma harzianum* @ 4 g) (49.78%) and T_7 (seed treatment+spraying with *Trichoderma harzianum* @ 4 g) (49.53%). The least percentage increase in grain yield was observed in T_3 (seed treatment with Propiconazole 25% EC @ 0.1%) (46.36%) followed by T_2 (seed treatment with Citronella @ 0.1%) (48.24%) and T_1 (seed treatment with *Trichoderma harzianum* @ 4 g) (48.34%).

Efficacy of botanical (citronella), bioagent (*Trichoderma harzianum*) and fungicide (Propiconazole) in controlling southern leaf blight of maize and yield enhancement were also reported by earlier scholars (Vaibhav et al., 2011, Kommedahl and Lang, 1973, Nasir et al., 2012). Malik et al. (2018) also found that propiconazole at 0.1% gave the best control of maydis leaf blight and significantly increased the grain yield. Marak et al. (2021) found that combinations of single spraying of Propiconazole 25% EC @ 0.1% along with one spraying of garlic oil @ 0.15% with one spraying of *T. harzianum* @ 4 g gave highest grain yield (7.89 q ha^{-1}).

3.4.3. Benefit cost ratio (BCR)

The highest mean BC ratio of two years was obtained (Table 1) in T_9 (Seed treatment+spraying with Propiconazole 25% EC @ 1%) (4.05) followed by T_4 (spraying with *Trichoderma harzianum* @ 4 g) (3.71) and T_7 (Seed treatment+spraying with *Trichoderma harzianum* @ 4 g) (3.69). The lowest BC ratio was observed in T_2 (seed treatment with Citronella @ 0.1%) (3.19) followed by T_3 (seed treatment with Propiconazole 25% EC @ 0.1%) (3.29) and T_8 (Seed treatment+spraying with Citronella @ 0.1%) (3.39). The BC ratio in untreated control was 1.89. Marak et al. (2020) also found that three sprays of fungicide (Propiconazole 25 EC @ 0.1%) resulted in minimizing the disease and maximizing the profit by high benefit cost (B:C) ratio in greengram. Similar result was also obtained by Devi et al., (2022) and on wheat against the same group of fungus causing spot blotch of wheat.

4. CONCLUSION

All the tested fungicides, botanicals and bio-agents significantly reduced the inhibition percentage of mycelial growth of *Bipolaris maydis* under in vitro condition. However, propiconazole, citronella oil and *Trichoderma harzianum* showed the highest inhibition percentage of mycelial growth. Under field condition, seed treatment+single spray of Propiconazole 25% EC @ 0.1% showed the highest grain yield and benefit cost ratio. Therefore, seed treatment+single spray of Propiconazole 25% EC @ 0.1% can be recommended for management of southern leaf blight of maize caused by *Bipolaris maydis* in eastern and northeastern India for better economic return.

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