Efficacy of Fungicides against *Bipolaris sorokiniana* under *in vitro* and *in vivo* Conditions

Pankaj Tiwari \(^a\), D. N. Shukla \(^b\), Ramesh Singh \(^a\) and Rohit Tiwari \(^c\)

\(^a\) Department of Plant Pathology, T.D. P.G. College, Jaunpur, India.
\(^b\) Department of Plant Pathology, RPCAU Pusa Samastipur, Bihar, India.
\(^c\) RML Awadh University, Ayodhya, India.

Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i530672

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:

https://www.sdiarticle5.com/review-history/84553

Received 03 January 2022
Accepted 07 March 2022
Published 12 March 2022

Original Research Article

ABSTRACT

Spot blotch of wheat caused by *Bipolaris sorokiniana* could be effectively and economically controlled by two foliar sprays of either Propiconazole or Hexaconazole @ 0.1 per cent at fifteen days interval but on the basis of cost- benefit ratio Hexaconazole had an edge over Propiconazole. The harmful effects of fungicides to human and environment, there have been proved useful and economical in the control of spot blotch. Non systemic and systemic foliar fungicides belonging to the dithiocarbamate and Triazoles are found to be effective. Foliar applications of systemic fungicides between heading and grain filling stages, are cost effective. Propiconazole, Hexaconazole and Difenacozazole + Propiconazole at 250 ppm completely inhibited the mycelial growth of *B. sorokiniana*. Carbendazim and Copper oxychloride also causes and complete inhibition but at 500 and 1000 ppm, respectively but Mancozeb could not give complete inhibition even at 1000 ppm.

Keywords: Bipolaris; sorokiniana; blotch; wheat.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) belonging to the family Graminae, is one of the oldest and most important cereal crops). *Triticum aestivum*, *Triticum durum*, and *Triticum dicoccum* are the three types of wheat grown in India [1]. In the warmer portions of the world, wheat is mostly

*Corresponding author: E-mail: pankajiwari3491@gmail.com, pankatiwari3491@gmail.com;
affected by a variety of diseases, including spot blotch or foliar blight caused by *Bipolaris sorokiniana* (Sacc.) Shoem. is one of the most important diseases in warm and humid regions of India and other South Asian countries due to its widespread incidence and growing severity [2]. In India, the spot blotch pathogen is prevalent throughout the wheat-growing regions of the country, more frequently in the North-eastern plains zone where it has assumed an epidemic proportion [3]. Later on Shamim et al., [4] estimated that about 10 million hectares of wheat growing belt in the Indian subcontinent is affected by the disease, out of which 9 million hectares belonged to Indo-Gangetic plains predominantly with rice-wheat cropping system. Rattu et al., [5] reported that in the year 2009 four diseases, viz. spot blotch, powdery mildew, yellow and leaf rust were prevalent in Punjab, Pakistan. Spot blotch was the most prevalent disease on varieties cultivated at farmer fields and no variety was found free of it.

Spot blotch of wheat has developed as a severe threat for wheat farming in warmer, humid regions of the world, such as India, Nepal, and Bangladesh [6,7]. Bipolaris sorokiniana caused major foliar disease in south Asian nations, according to Iftikhar et al., [8]. Spot blotch caused by Bipolaris sorokiniana is a major wheat disease in warm and humid countries of the globe, including South-east Asian countries such as India, Nepal, and Bangladesh, according to Bahadar et al., [9], and the disease is very significant, particularly in India’s North Eastern Plains Zone (NEPZ). Under warm and humid conditions, spot blotch is thought to play a substantial role in lowering the average yield of wheat crops. Malik et al., [10] tested the efficacy of foliar spray of different fungicides against spot blotch disease of wheat. Propiconazole and difenoconazole (0.1 and 0.2 per cent, respectively) were most effective and reduced the score of spot blotch up to 12 as compared to 79 score in unsprayed crop. The fungicidal sprays increased grain yield (40.1-46.3 per cent) and 1000-grain weight significantly as compared to the unsprayed check.

Sarkar et al. [11] reported the efficacy of some newly synthesized organotin compounds against *B. sorokiniana*.

Kumar et al. [12] suggested that a combination of seed treatment by Carboxin (37.5 per cent) + Thiram (37.5 per cent WS) @ 2.5 g/kg seed + two foliar sprays of Propiconazole 25 per cent EC @ 0.1per cent one at boot leaf stage and another 20 days after 1st spray gave best result in reducing the spot blotch of wheat as well as increasing the 1000-grain weight and grain yield of wheat.

Singh et al., (2015) evaluated efficacy of fungicides against *Bipolaris sorokiniana*. They found minimum per cent disease intensity (37.28 per cent) with seed treatment with Vitavax @ 3g/kg of seed + foliar spray of Tilt @ 0.1 per cent at boot leaf or at the time of initiation of disease on flag-1 leaf. This was followed by seed treatment with Captol @ 3g/kg of seed + foliar spray of Folicur @ 0.1 per cent at boot leaf or at the time of initiation of disease on flag-1 leaf. Treatments were significantly superior over check in reducing the disease severity and increasing yield and yield contributing characters during a year.

According to Yadav et al., [13], two sprays of Carbendazim (0.1%) at the tillering and boot leaf stages reduced spot blotch incidence and severity the most, followed by two treatments of Propiconazole at the tillering and boot leaf stages. However, Carbendazim, Propiconazole and Hexaconazole were almost equally effective against spot blotch of wheat and may be used as an alternative to each other for management of disease. According to Mehboob et al., [14], Score (Difenoconazole) and Topsisn-M (Thiophanate methyl) were the most efficient in inhibiting *B. sorokiniana* mycelial growth, followed by AmistarTop (Azoxystrobin + Difenoconazole), and Halonil (Chlorothalonil) and Curzate-M (Cymoxanil + Mancozeb) were least effective.

Pradeep and Kalappanavar [15] on the basis of studies carried out during 2013-14 and 2014-15 reported that three sprays of Pyraclostrobin 13.3 per cent + Epoxiconazole 5 per cent @ 0.1 per cent, at an interval of 15 days from the date of appearance of typical symptoms gave maximum reduction of disease severity (88.27 per cent) with considerable increase in yield attributing traits and higher net returns (Rs. 20608/ha.) with incremental Benefit Cost ratio (IBCR) of 4.91. Next best fungicide was Propiconazole@ 0.1 per cent. They have advocated that above combi-product can be used as an alternate fungicide to triazoles especially Propiconazole for management of this disease.

Kavita et al., [16] evaluated efficacy of 15 fungicides at 0.5, 0.1 and 2 per cent for studying
their inhibitory effect on the mycelia growth of *Bipolaris sorokiniana* by using food poison technique and recorded, the maximum mycelial growth inhibition (87.77 per cent) with Propiconazole (0.1 per cent) followed by Propiconazole (0.05 per cent) which showed 81.57 per cent inhibition. Hexaconazole (0.2 per cent) and Hexaconazole (0.1 per cent) showed 77.98 per cent and 70.37 per cent mycelial growth inhibition, respectively.

2. MATERIAL AND METHODS

2.1 Effect of Fungicides on Radial Growth of *Bipolaris sorokiniana*

Six fungicides, namely Tilt, Contaf, Taspa, Bavistin, Blitox-50 and Indofil M-45 were evaluated against *B. sorokiniana* in vitro by the poison food technique. Their trade name, common name, formulation, chemical group and mode of action are given in Table 1.

For poison food technique, potato dextrose agar medium was used as a basal medium and stock solution of 5000 ppm strength of each fungicide was prepared by dissolving 2.5 g or 2.5 ml in 500 ml sterilized distilled water. To obtain the desired concentration of fungicides in the medium, amount of stock solution to be added in potato dextrose agar was calculated by using following formula:

\[
C_2V_1 = C_2V_2
\]

Where,

- \(C_1\) = Concentration of stock solution (ppm)
- \(C_2\) = Required concentration of the fungicide (ppm) in plate
- \(V_1\) = Volume (ml) of the stock solution to be added
- \(V_2\) = Final volume (ml) of PDA after adding stock solution

Required amount of stock solution of various fungicides were poured in 100ml of sterilized melted PDA to get final concentration of 50, 100, 200, 250, 500 and 1000 ppm of each fungicide. PDA poisoned with each fungicide was poured into four sterilized Petri-plates @ 20 ml/plate and allowed to solidify. Plates containing PDA without fungicide served as check. After solidification, 5 mm disc of seven days old culture of *Bipolaris sorokiniana* were placed in the center of the Petri-plates and incubated at 28 ± 1°C. Observation on radial growth of test fungus was recorded after 5 and 7 days as per method described earlier. Recorded data on radial growth was converted into per cent growth inhibition by using following formula:

\[
\text{Per cent growth inhibition } I = \left( \frac{C - T}{C} \right) \times 100
\]

Where,

- \(C\) = Colony diameter (mm) in check plate
- \(T\) = Colony diameter (mm) in the treated plate

The per cent inhibition data was transformed into Arccsine \(\sqrt{\%}\) Percentage transformation and then analysed statistically using completely randomized design (CRD).

| Trade name | Common name | Chemical group | Mode of action |
|------------|-------------|----------------|---------------|
| Tilt 25% EC | Propiconazole | 25 EC | Triazole | Systemic |
| Contaf 5EC | Hexaconazole | 5 EC | Triazole | Systemic |
| Taspa | Difenaconazole + Propiconazole | Propiconazole 13.9% + Difenaconazole 13.9% | Systemic |
| Bavistin 50WP | Carbenazim | 50 WP | Benzimidazole | Systemic |
| Blitox-50 | Copper oxychloride | 50 WP | Copper compound | Contact |
| Indofil M-45 | Mancozeb | 75 WP | Dithiocarbamate | Contact |

2.2 Effects of Spraying of Fungicides on Spot blotch of Wheat

To see the effects of foliar spray of fungicides on spot blotch of wheat, field trials were conducted during *Rabi* 2018-19 and 2019-20. The trial was laid out as per details given below:
Design : Randomized Block Design (RBD)
Treatments : Fungicides
T1 : 2 spray of Tilt @ 0.1% at 15 days interval
T2 : 2 spray of Contaf @ 0.1% at 15 days interval
T3 : 2 spray of Taspa @ 0.1% at 15 days interval
T4 : 2 spray of Bavistin @ 0.1% at 15 days interval
T5 : 3 spray of Blitox-50 @ 0.25% at 15 days interval
T6 : 3 spray of Indofil M-45 @ 0.25% at 15 days interval
T7 : Check (water spray)
Replication : 4
Variety : HD-2733
Plot size : 5 m × 2 m
Seed rate : 120 kg/ha
Row to row distance : 20 cm
Fertilizer : 120 kg N : 60kg P₂O₅ : 40 kg K₂O per ha
Date of sowing : 28th November 2018 and 25th November 2019

Observations on disease severity were recorded at dough stage following Saari-Prescot in 0-9 scale. The yield and 1000-grain weight were recorded after harvest of the crop. Data was analyzed statistically.

3. EXPERIMENTAL FINDING

3.1 Effect of Fungicides on Radial Growth of Bipolaris sorokiniana

Six fungicides namely, Propiconazole (Tilt), Hexaconazole (Contaf), Difenaconazole + Propiconazole (Taspa), Carbendazim (Bavistin), Copper oxychloride (Blitox-50) and Mancozeb (Indofil M-45) were evaluated against B. sorokiniana by recording their effect on radial growth by poison food technique on potato dextrose agar medium. Fungicides were tested at 50, 100, 200, 250, 500 and 1000 ppm concentrations to find out the concentration of fungicides at which complete inhibition of radial growth B. sorokiniana can be achieved. Data on the effect of six concentrations of six fungicides on inhibition of radial growth of B. sorokiniana is presented in Table 2.

Data presented in Table 2 clearly indicates that all the fungicides, at all the six concentrations tested inhibited the growth of B. sorokiniana in vitro. After seven days of incubation, Propiconazole, Hexaconazole and Difenaconazole + Propiconazole completely inhibited the growth of B. sorokiniana in vitro at a concentration of 250 ppm or more. Carbendazim produced cent per cent inhibition at a concentration of 500 ppm or more whereas copper oxychloride produced it at 1000 ppm only. Mancozeb even at 1000 ppm concentration could not completely inhibit the growth of B. sorokiniana in vitro. Cent per cent inhibitions of mycelial growth of B. sorokiniana produced by Propiconazole, Hexaconazole and Difenaconazole + Propiconazole even at 250 ppm were significantly superior than their lower concentrations. Cent per cent inhibition produced by Carbendazim and Copper oxychloride, respectively at 500 and 1000 ppm which were also statistically superior than their lower concentrations.

Six fungicides were further evaluated against B. sorokiniana at selected concentrations of fungicides for confirmation. Systemic fungicides (Propiconazole, Hexaconazole, Difenaconazole + Propiconazole and Carbendazim) were tested at 50, 100, 200 and 250 ppm concentrations whereas; contact fungicides (Copper oxychloride and Mancozeb) were tested at 100, 200, 500 and 1000 ppm concentrations. Data on the effect of four concentrations of six fungicides on the radial growth of B. sorokiniana is presented in Table 2.

Data presented in Table 2 clearly indicates that all the fungicides, at all the four concentrations tested inhibited the radial growth of B. sorokiniana in vitro. After seven days of incubation, Propiconazole, Hexaconazole, and Difenaconazole + Propiconazole at 250 ppm and copper oxychloride at 1000 ppm concentration completely inhibited the growth of B. sorokiniana in vitro in this experiment.
Table 2. Effect of fungicides on radial growth of *Bipolaris sorokiniana*

| Fungicide                                      | Concentration (ppm) | 5 days  | 7 days  | Growth inhibition over check (%)* |
|-----------------------------------------------|---------------------|---------|---------|----------------------------------|
| Propiconazole (Tilt 25 EC)                    | 50                  | 15.02   | 20.70   | 76.98                            |
|                                               | 100                 | 14.40   | 16.35   | 78.04                            |
|                                               | 200                 | 7.84    | 11.70   | 88.04                            |
|                                               | 250                 | 0       | 0       | 100.00                           |
| Hexaconazole (Contaf 5 EC)                    | 50                  | 23.60   | 27.60   | 63.65                            |
|                                               | 100                 | 18.64   | 22.84   | 71.46                            |
|                                               | 200                 | 14.40   | 16.70   | 78.14                            |
|                                               | 250                 | 0       | 0       | 100.00                           |
| Difenaconazole + Propiconazole (Taspa)        | 50                  | 21.70   | 27.02   | 66.94                            |
|                                               | 100                 | 19.23   | 22.84   | 70.84                            |
|                                               | 200                 | 17.04   | 20.35   | 73.94                            |
|                                               | 250                 | 0       | 0       | 100.00                           |
| Carbendazim (Bavistin 50WP)                   | 50                  | 38.70   | 40.40   | 40.61                            |
|                                               | 100                 | 33.35   | 38.30   | 48.70                            |
|                                               | 200                 | 29.04   | 35.20   | 55.42                            |
|                                               | 250                 | 10.60   | 11.85   | 83.85                            |
| Copper oxychloride (Blitox-50)                | 50                  | 33.35   | 38.20   | 48.76                            |
|                                               | 200                 | 28.80   | 30.80   | 55.56                            |
|                                               | 500                 | 18.35   | 19.20   | 71.74                            |
|                                               | 1000                | 0       | 0       | 100.00                           |
| Mancozeb (Indofil M-45)                       | 50                  | 37.02   | 42.85   | 42.89                            |
|                                               | 200                 | 30.85   | 35.20   | 52.69                            |
|                                               | 500                 | 21.02   | 24.85   | 67.70                            |
|                                               | 1000                | 17.20   | 21.04   | 73.89                            |
| Check                                         | 65.15               | 79.20   | 0       | 0                                |
| CD 5%                                         |                     | 3.82    | 2.72    | 1.34                             |
| SE(m)                                         |                     | 1.34    | 0.97    |                                  |

*Average of 4 replications

3.2 Effect of Foliar Spraying of Fungicides on Spot Blotch, Yield and 1000-grain Weight of Wheat

The experiment was conducted in Randomized Block Design with four replications during *Rabi* 2018-19 and 2019-20 to find out the effect of foliar spraying of fungicides on disease, yield and 1000-grain weight of wheat. Six fungicides namely, *Propiconazole*, *Hexaconazole*, *Difenaconazole + Propiconazole*, *Carbendazim*, *Copper oxychloride* and *Mancozeb* were tested in field conditions. *Propiconazole*, *Hexaconazole*, *Difenaconazole + Propiconazole* and *Carbendazim* were sprayed @ 0.1% whereas *Copper oxychloride* and *Mancozeb* were sprayed @ 0.25 % in the field.

3.3 Effect on Progress of Spot Blotch of Wheat

During *Rabi* 2018-19 and 2019-20, five observations on the Percent Disease Index (PDI) and leaf blotch score (dd) were recorded at fifteen and seven day intervals, respectively. Table 3 shows the results of the foliar spraying of fungicides on the disease progression of wheat spot blotch.

The data in Table 3 clearly shows that there was initially little variation in PDI detected in different fungical treatments in both years. In *Rabi* 2018-19 and 2019-20, at initial stage PDI ranged from 8.39 to 12.80 and 8.06 to 10.88 per cent, respectively; however, at final stage PDI ranged from 29.12 to 80.40 and 25.80 to 82.19 per cent, respectively in different fungical treatments. In both the years maximum PDI was recorded in untreated check which ranged from 11.98 to 80.40 and 10.36 to 82.19 per cent in 2018-19 and 2019-20, respectively and minimum PDI was recorded in plots given sprays of *Propiconazole* and *PDI ranged from 10.29 to 29.08 and 8.33 to 25.75 per cent in 2018-19 and 2019-20, respectively. In both the years, PDI was higher at final stage in all
treatments including check in comparison to initial stage.

Similarly, at the start of both years, the leaf blotch scores (dd) in different treatments were closely similar. At the start of Rabi 2018-19 and Rabi 2019-20, leaf blotch score (dd) varied from 11 to 12 and 11 to 13, respectively. As the crop season progressed, the leaf blotch score (dd) grew, ranging from 36 to 67 percent in 2018-19 and 35 to 66 percent in 2019-20, respectively. During both the years maximum leaf blotch score (dd) was recorded in untreated check which ranged from 12 to 67 and 13 to 66 in 2018-19 and 2019-20, respectively and minimum leaf blotch score (dd) was recorded in plots given sprays of Propiconazole which ranged from 11 to 36 and 11 to 35 in 2018-19 and 2019-20, respectively. In both the year leaf blotch scores (dd) were higher at final stage in all treatments including check as compared to initial stage.

Data presented in Table 3 clearly indicates that initially in the both years, almost similar PDI and leaf blotch scores were observed in different fungicidal treatments but with advancement of season development of disease was different in different treatments and finally in both the years differences in PDI as well as leaf blotch score in different fungicidal treatments were prominent or visible.

3.4 Effect on Yield and 1000-grain Weight of Wheat

Data on the effect of spraying of six fungicides, namely Propiconazole, Hexaconazole, Difenaconazole + Propiconazole, Carbendazim, copper oxychloride and Mancozeb on yield and 1000-grain weight along with Per cent Disease Index (PDI) and per cent disease control during Rabi 2018-19 and 2019-20 is presented in Table 4.

Data presented in Table 4 reveals that in both years all the fungicides tested significantly reduced the disease (PDI) when compared with untreated check. Propiconazole @ 0.1 per cent (two sprays) showed minimum PDI of 29.02 and 25.80 per cent and maximum disease control of 63.74 and 68.40 per cent over check during Rabi 2018-19 and 2019-20, respectively and was statistically superior to other treatments. Hexaconazole @ 0.1 per cent ranked second best in reducing the PDI and gave 54.20 and 54.20 per cent disease control over check in 2018-19 and 2019-20, respectively. Other fungicides could produce less than 50 per cent disease control over check. Minimum disease control of 12.20 and 7.80 per cent was observed during 2018-19 and 2019-20, respectively by two sprays of Mancozeb, indicating that Mancozeb was least effective in controlling spot blotch. Yield and 1000-grain weight observed in Propiconazole and Hexaconazole, two best fungicides, were statistically at par during both the years. Yield was 42.70 and 42.83 q/ha in case of Hexaconazole and Propiconazole in 2018-19 and 39.02 and 41.60 q/ha in 2019-20, respectively. Similarly 1000-grain weights were 45.01 and 46.02 g in 2018-19 and 44.01 and 45.20 g in 2019-20.

Table 3. Effect of foliar spraying of fungicides on disease progress of spot blotch of wheat

| Fungicides                 | Per cent Disease Index (PDI)* | Leaf blotch score (0-9dd)* |
|---------------------------|------------------------------|--------------------------|
|                           | 2018-19 Initial | 2019-20 Initial | 2018-19 Final | 2019-20 Final | 2018-19 Initial | 2019-20 Initial | 2018-19 Final | 2019-20 Final |
| Propiconazole             | 10.30 | 29.08 | 8.39 | 25.80 | 11 | 36 | 11 | 35 |
| Hexaconazole              | 12.80 | 37.72 | 10.71 | 37.70 | 12 | 44 | 12 | 46 |
| Difenaconazole + Propiconazole | 10.02 | 46.40 | 9.50 | 48.36 | 11 | 44 | 11 | 46 |
| Carbendazim               | 8.80 | 50.90 | 10.76 | 52.80 | 12 | 46 | 12 | 56 |
| Copper oxychloride        | 11.96 | 58.40 | 10.87 | 64.23 | 11 | 55 | 11 | 57 |
| Mancozeb                  | 8.50 | 70.64 | 8.08 | 75.80 | 12 | 57 | 12 | 56 |
| Check                     | 11.98 | 80.40 | 10.36 | 82.19 | 12 | 66 | 13 | 66 |
| CD 5%                     | 2.14 | 1.76 | 1.86 | 2.36 |
| SE(m)                     | 0.74 | 0.57 | 0.65 | 0.76 |

*Average of 4 replications
Table 4. Effect of foliar spraying of fungicides on Per cent Disease Index (PDI), yield and 1000-grain weight of wheat

| Fungicides                        | Dose (%) | PDI (%) | Disease control over check (%) | Yield (q/ha) | 1000-grain weight (g) |
|-----------------------------------|----------|---------|-------------------------------|--------------|-----------------------|
|                                   |          | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 |
| Propiconazole (Tilt 25 EC)        | 0.1      | 29.02   | 25.80   | 63.74   | 68.40   | 42.83   | 41.60   | 46.04   | 45.29   |
| Hexaconazole (Contaf 5 EC)        | 0.1      | 37.60   | 37.89   | 54.20   | 54.20   | 42.70   | 39.02   | 45.01   | 44.01   |
| Difenaconazole + Propiconazole (Taspa) | 0.1   | 47.02   | 48.20   | 42.30   | 41.16   | 40.02   | 36.40   | 42.98   | 42.98   |
| Carbendazim (Bavistin 50WP)       | 0.1      | 50.94   | 52.80   | 36.70   | 35.80   | 37.40   | 34.76   | 40.46   | 40.46   |
| Copper oxychloride (Blitox-50)    | 0.25     | 58.20   | 63.34   | 26.80   | 23.00   | 36.40   | 33.60   | 40.20   | 40.30   |
| Mancozeb (Indofil M-45)           | 0.25     | 70.54   | 75.80   | 12.20   | 7.80    | 32.80   | 32.20   | 38.50   | 38.50   |
| Check                             |          | 80.30   | 82.20   | -       | -       | 31.70   | 30.80   | 36.80   | 336.79  |
| CD 5%                             |          | 1.77    | 2.36    | 2.46    | 3.09    | 2.56    | 3.27    | 2.26    | 3.38    |
| SE(m)                             |          | 0.61    | 0.78    | 0.85    | 1.04    | 0.86    | 1.10    | 0.77    | 1.14    |

*Average of 4 replications
4. DISCUSSION

4.1 In vitro Screening of Fungicides against Radial Growth of Bipolaris sorokiniana

In the present studies on effect of fungicides on radial growth of *B. sorokiniana*, it was observed that after seven days of incubation, Propiconazole, Hexaconazole and Difenacconazole + Propiconazole completely inhibited the growth of *B. sorokiniana* in vitro at a concentration of 250 ppm or more. Carbendazim produced cent per cent inhibition at a concentration of 500 ppm or more whereas copper oxychloride produced it at 1000 ppm only. Mancozeb even at 1000 ppm concentration could not completely inhibit the growth of *B. sorokiniana* in vitro. Possibilities of using these fungicides in the field for the management of spot blotch of wheat can be explored. Earlier, Singh and Chauhan [17] studied the efficacy of Dithane M-45, Tilt and Topsis-M against *Helminthosporium* leaf blight of wheat in vitro. Tilt (500 ppm) provided significant control of the pathogen in vitro. Narayan [18] has also observed complete inhibition of radial growth of *H. sativum* in vitro by Tilt 25 EC (100 ppm), Blitox-50 (1000 ppm) and Saaf (50 ppm). Meboob et al. [14] found that Score (Difenacconazole) and Topsis-M (Thiophanate methyl) exhibited the best performance in inhibiting the mycelial growth of *D. sorokiniana* followed by Amistar Top (Azoxystrobin + Difenacconazole), while Halonil (Chlorothalonil) and Curzate-M (Cymoxanil + Mancozeb) were least effective. Kavita et al. [16] evaluated efficacy of 15 fungicides at 0.5, 0.1 and 2 per cent for studying their inhibitory effect on the mycelia growth of *Bipolaris sorokiniana* by using food poison technique and recorded, the maximum mycelial growth inhibition (87.77 per cent) with Propiconazole (0.1 per cent) followed by Propiconazole (0.05 per cent) which showed 81.57 per cent inhibition. Hexaconazole (0.2 per cent) and Hexaconazole (0.1 per cent) showed 77.98 per cent and 70.37 per cent mycelial growth inhibition, respectively.

4.2 Effect of Foliar Spraying of Fungicides on Spot Blotch, Yield and 1000-grain Weight of Wheat

Present finding clearly indicated that two sprays of Propiconazole at fifteen days interval @ 0.1 per cent was best for controlling spot blotch of wheat under field condition as it provided minimum PDI of 29.12 and 25.80 per cent and maximum disease control of 63.74 and 68.40 per cent over check during both years i.e. 2018-19 and 2019-20, respectively. Hexaconazole @ 0.1 per cent ranked second best in reducing the PDI and gave 54.20 and 54.25 per cent disease control over check in both years i.e. 2018-19 and 2019-20, respectively. Hence, present finding clearly indicates that both Propiconazole and Hexaconazole are equally effective in reducing disease and increasing yield but on the basis of cost-benefit ratio Hexaconazole has an edge over Propiconazole.

Many other workers have previously reported that Propiconazole (Tilt 25 EC) was effective against spot blotch of wheat [19,20,21,22,23,24, 25,26,27,28]. Three sprays of Propiconazole, according to Lapis [29], provided the best control of spot blotch and enhanced grain production by 65 percent. Mondol et al. [30] discovered that Tilt 25 EC (0.05%) was the most successful and profitable, effectively controlling the disease and creating a high yield with the highest gross margin. Murray et al., [31] reported that fungicides groups like Mancozeb, Propiconazole and Tebuconazole were effective in controlling the spot blotch disease and reducing inoculum pressure. Singh and Gupta [32] have also reported that Tilt and Folicur were most effective. Malik et al., [10] reported that propiconazole and difenoconazole (0.1 and 0.2 per cent) were most effective and reduced the score of spot blotch up to 12 as compared to 79 score in unsprayed crop. The fungicidal sprays increased grain yield (40.1-46.3 per cent) and 1000-grain weight significantly as compared to unsprayed check. Carbendazim, Propiconazole, and Hexaconazole were nearly equally effective against wheat spot blotch, according to Yadav et al., [13], and might be used as a substitute for one another for disease management.

5. CONCLUSION

Propiconazole, Hexaconazole and Difenaconazole + Propiconazole at 250 ppm completely inhibited the mycelial growth of *B. sorokiniana*. Carbendazim and Copper oxychloride also produced cent per cent inhibition but at 500 and 1000 ppm, respectively. Mancozeb could not produce complete inhibition even at 1000 ppm.

Spot blotch of wheat could be effectively and economically controlled by two foliar sprays of either Propiconazole or Hexaconazole @ 0.1 per
cent at fifteen days interval but on the basis of cost- benefit ratio Hexaconazole has an edge over Propiconazole.

Despite the harmful effects of fungicides to human and environment, there have been proved useful and economical in the control of spot blotch. Non systemic and systemic foliar fungicides belonging to the dithiocarbamate and Triazoles are found to be effective. Foliar applications especially with systemic fungicides are applied between heading and grain filling stages, have been proved to be cost effective.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gupta RK. Quality of Indian wheat and infrastructure for analysis. In: Joshi, A.K., Chand, R., Arun, B., Singh, G. (eds.) A compendium of the training program (26-30 December, 2003) on wheat improvement in eastern and warmer regions of India: Conventional and non-conventional approaches. NATP project, (ICAR), BHU, Varanasi, India; 2004.
2. Joshi AK, Chand R. Variation and inheritance of leaf angle and its association with spot blotch (*Bipolaris sorokiniana*) severity in wheat. Euphytica. 2002;124: 283-191.
3. Singh SP, Khanna BM, Dodan DS, Bagga PS, Kalappanavar IK, Singh A. Losses caused due to leaf blight in wheat in different agro climatic zones of India. Pl. Dis. Res. 2002;17(2):313-317.
4. Shamim I, Shahzad A, Anjum M. Incidence of *Bipolaris sorokiniana* in Punjab and Khyber Pakhtoon Khawa, Pakistan. Pak. J. Phytopathol. 2010;22:95-97.
5. Rattu AR, Asad S, Fayyaz M, Zakria M, Shamim Iftikhar S, Ahmad Y. Status of foliar diseases of wheat in Punjab, Pakistan. Mycopath. 2011;9(1):39-42.
6. Acharya K, Dutta AK, Pradhan P. *Bipolaris sorokiniana* (Sacc.) Shoem.: The most destructive wheat fungal pathogen in the warmer areas. Aust. J. Crop Sci. 2011;5: 1064-1071.
7. Chowdhary AK, Singh G, Tyagi BS, Ojha A, Dhar T, Battacharya MP. Spot blotch disease of wheat-a new thrust area for sustainable productivity. J. Wheat Res. 2013;5:1-11.
8. Iftikhar S, Shahzad A, Munir A, Ahmed I. Characterization of *Bipolaris sorokiniana* isolated from different Agro-Ecological zones of wheat production in Pakistan. Pak. J. Bot. 2009;41(1):301-308.
9. Bahadar K, Munir A, Asad S. Management of *Bipolaris sorokiniana* the causal pathogen of Spot Blotch of Wheat by Eucalyptus Extracts. J. Plant. Pathol. Microbiol. 2016;7:326.
10. Malik VK, Singh DP, Panwar MS. Management of spot blotch of wheat (*Triticum aestivum*) caused by *Bipolaris sorokiniana* using foliar sprays of botanicals and fungicides. Indian J. Agric. Sci. 2008;78(7):646-48.
11. Sarkar A, Rakwal R, Agarwal SB, Shibato J, Ogawa Y. Investigating the impact of elevated levels of ozone on tropical wheat using integrated phenotypical, physiological, biochemical, and proteomics approaches. J. Prot. Res. 2010;9:4565–4584.
12. Kumar A, Solanki S, Kumari S. Management of foliar blight (spot blotch) of wheat the most threatening disease of north eastern plain zone (NEPZ) through chemicals. J. Agroeco. Nat. Res. Manage. 2014;1(1):4-6.
13. Yadav B, Singh R, Kumar A. Management of spot blotch of wheat using fungicides, bio-agents and botanicals. Afr. J. Agric. Res. 2015;10(25):2494-2500.
14. Mehbboob S, Rehman A, Ali S, Idrees M, Zaidi SH. Detection of wheat seed mycoflora with special reference to *Drechslera sorokiniana*. Pak. J. Phytopathol. 2015;27(1):19-25.
15. Pradeep PE, Kalappanavar IK. Efficacy of fungicides against spot blotch of wheat caused by *Bipolaris sorokiniana* Sacc. (Shoem.). Res. Environ. Life Sci. 2016; 9(9):1128-1134.
16. Kavita Pande SK, Yadav JK, Dalbeet. *In vitro* evaluation of fungicides against *Bipolaris sorokiniana* causing spot blotch of barley (*Hordeum vulgare* L.). Int. J. Curr. Microbiol. App. Sci. 2017;6(10):4734-4739.
17. Singh VA, Chauhan SKS. Efficacy of fungicide *in vivo* and *in-vitro* against leaf blight of wheat, Indian J. Myco. Pl. Path. 1995;25(1&2):111
18. Narayan UP. Foliar blight of wheat and its management. Ph.D. Thesis Department of Plant Pathology, RAU, Pusa, Bihar; 2004.
19. Rashid AQMB, Sarker K, Khalequzzaman KM. Control of Bipolaris leaf blight of wheat with foliar spray of Tilt 250 EC. Bangladesh J. Pl. Path. 2001;17(1&2):45-47.

20. Hossain I, Rahman MH, Aminuzzaman FM, Ahmed F. Efficacy of fungicides and botanicals in controlling leaf blight of wheat and its Cost benefit analysis. Pak. J. Bio. Sci. 2001;4(2):178-180.

21. Patil VS, Kulkarni S, Kalapannavar IK. Assessment of losses in wheat cultivars due to leaf blight. J. Maharastra Agric. Uni. 2002;26:263-265.

22. Singh DP, Kumar P, Singh SK. Resistance in wheat genotypes against leaf blight caused by Bipolaris sorokiniana at seedling along with adult plant stage. Indian Phytopathol. 2005;58:344.

23. Sharma RL, Singh BP, Thakur MP, Thapak SK. Effect of media, temperature, pH and light on the growth and sporulation of Fusarium oxysporum f. sp. Lini (Bolley) Snyder and Hensan. Ann. Pl. Protec. Sci. 2005;13:172-174.

24. Shahidullah MS. Avoidable yield loss due to Bipolaris leaf blight of wheat and its management. M.Sc. Thesis. Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh; 2006.

25. Ahmed F. Reaction of wheat genotypes to leaf blight caused by Bipolaris sorokiniana. Bangladesh J. Pl. Path. 2007;23(1&2):75-78.

26. Zamal MS, Aminuzzaman FM, Sultana N, Islam MA. Efficacy of fungicides in controlling leaf blight of wheat caused by Bipolaris sorokiniana of wheat. Interl. J. Sustain. Agril. Tech. 2007;3(2):1-6.

27. Malaker PK, Saha NK, Rahman MM, Hussain ABS, Haque M, Kabir KH. Yield loss assessment of wheat due to Helminthosporium blight at farmer's field. Bangladesh. J. Sci. Res. 2009;29:49-57.

28. Rahman MM, Ali MS, Nahar A, Karim MM, Begum K. Efficacy of fungicides in controlling leaf blight of wheat. Int. J. Expt. Agric. 2013;3(1):1-3.

29. Lapis DB. Insect pests and diseases of wheat in the Philippines. In: Wheat for More Tropical Environments. (Eds. Villareal. R.L. and Klatt A.R.). pp. d152-153. A proceedings of the International Symposium CIMMYT. Mexico. 1985;354.

30. Mondol NA, Assaduzzaman SM, Malaker PK, Rouf MA, Haque MI. Evaluation of fungicides against Bipolaris sorokiniana leaf blight of wheat (Triticum aestivum). Ann. Bangladesh Agric. 1994;4(1):37-40.

31. Murray TD, Parry DW, Cattlin ND. A Color Handbook of Diseases of Small Grain Cereal Crops. Iowa State University Press, Ames. Iowa; 1998.

32. Singh SN, Gupta AK. Bioassay and fungicides against Drechslera sativum causing foliar blight of wheat. National Symposium on Role of Resistance in Intensive Agriculture. 52nd Annual Meeting, Indian Phytopathological Society, IARI, New Delhi (Abstr.); 2000.

© 2022 Tiwari et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here: https://www.sdiarticle5.com/review-history/84553