



# **Field Evaluation of Fungicides for Management of *Alternaria* Blight in Rapeseed (*Brassica rapa* var. toria)**

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## **Authors' contributions**

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

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## **ABSTRACT**

*Alternaria* blight caused by *Alternaria brassica* and, *A. brassicicola* singly or by mixed infection is one of the most widespread and destructive disease of oilseed brassicas globally. In order to identify the effective and economic molecules of fungicides against *Alternaria* blight, a field trial was conducted during Rabi 2021-22 and 2022-23 at Nagaon, Assam in rapeseed (*Brassica rapa* L. var. toria). The trial was conducted with seven fungicides and replicated thrice (RBD) to assess the most effective fungicide in managing the disease. Among the different fungicides tested, the ready-mix formulation of tebuconazole 50% + trifloxystrobin 25% WG resulted in maximum reduction in disease severity both on leaves (54.1 %) and pods (55.7 %). Thus, this combo-formulation led to realization of the highest seed yield (1187 kg ha<sup>-1</sup>) with yield advantage of 78.5 % over check. The highest net monetary return (NR) of Rs. 39001 ha<sup>-1</sup> with benefit-cost ratio (B:C) of 2.02 was

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received in the treatment, followed by azoxystrobin 23 % SC @ 1 ml l<sup>-1</sup> with 46.1 % and 45.8 % reduction in disease incidence respectively on leaves and pods and yield increase of 54.8 %. Interestingly, when B:C ratio was calculated, azoxystrobin 23% SC recorded the highest B:C (2.31) with NR of Rs. 37959 ha<sup>-1</sup>.

**Keywords:** *Alternaria blight; benefit-cost ratio; disease severity; fungicides; net return; rapeseed; yield advantage.*

## 1. INTRODUCTION

"The oilseeds, particularly the Brassicas play a significant role in edible oil production and hence, in Indian economy. India's domestic production of edible oil is not enough to meet the demand. In 2022-23, the country produced 41.35 million tons (mt) of edible oil from nine cultivated species. Mustard oil was the highest produced edible oil, followed by groundnut oil and soya oil. In the same year, India imported 16.5 mt of edible oils. This meant that the domestic production could meet only 40-45 % of the country's requirement" (PIB, 2024). "In Assam, total oilseed crops occupied 3.42 lakh ha of area with a production of 2.66 lakh tons and productivity of 776 kg/ha" (2022-23; Directorate of Agriculture, Govt. of Assam, Khanapara, Guwahati). "Out of this, rapeseed-mustard covered 3.19 lakh ha and produced 2.51 lakh t with a productivity 785 kg/ha. The oilseed requirement of the state is around 6.2 lakh t and the state domestic production can meet only 43 % of it. Low production might be attributed to low level of productivity. Low productivity is a function of lack of quality seeds and irrigation networks, imbalanced use of fertilizers, insect-pest and disease infestation, etc. Besides the aforementioned reasons, poor disease management weighs as one of the major factors responsible for low yield. *Alternaria* blight caused by *Alternaria brassicae* (Berk) Sacc., *A. brassicicola* (Schw) Wiltshire is an important limiting factor, resulting in 42.4 % yield loss in rapeseed" (Chakrabarty et al., 2022). "Symptoms of the disease are characterized by formation of spots on leaves, stem and siliquae. *A. brassicae* and *A. brassicicola* can affect host species at all stages of growth, including seed. On seedlings, symptoms include dark stem lesions immediately after germination that can result in damping-off and stunted seedlings. The disease diminishes the seed oil content both in qualitative and quantitative terms" (Meena et al., 2010). "To minimize the yield loss due to *Alternaria* blight, search for effective and economically viable control measures is of utmost significance. There are many effective fungicides viz., dithane M 45,

blitox 50, ridomil MZ 72, etc. against this disease" (Khan et al., 2007). "But residual toxicity of these chemicals affecting oil quality in Brassicas is a matter of great concern" (McCartney et al., 1999). "Development of resistance against fungicides being under repeated use is also reported" (Rai et al., 2014). Thus, an experiment was planned to study the efficacy of a number of fungicides for management of *Alternaria* blight to give the farmers effective and economically viable options and thereby maximizing the yield of rapeseed and farm income.

## 2. MATERIALS AND METHODS

Two field trials were carried out at Assam Agricultural University-Zonal Research Station, Shillongani, Assam (Latitude: 26.359999°, Longitude: 92.630372°). The locations are areas, where rapeseed is grown extensively in the entire district with heavy incidence of diseases, including damage by *Alternaria* blight. The study was carried out over two years-during *rabi* season of 2021-22 and 2022-23.

The experiment was conducted in a randomized block design to test the efficacy of different fungicides against *Alternaria* blight disease in rapeseed. The trial consisted of eight treatments (Table 1):

1. Tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l<sup>-1</sup>,
2. Propiconazole 25% EC @ 1 ml l<sup>-1</sup>,
3. Metalaxyl 4% + mancozeb 64% (ready mix) @ 0.5 g l<sup>-1</sup>,
4. Hexaconazole 5% SC @ 2 ml l<sup>-1</sup>,
5. Tebuconazole 25.9% @ 1 ml l<sup>-1</sup>
6. Azoxystrobin 23 SC @ 1 ml l<sup>-1</sup>,
7. Trifloxystrobin 50% WG @ 1 g l<sup>-1</sup> and
8. An untreated control.

Each treatment was laid out with three replications. The individual plot size was 4m x 3m with a spacing of 30 cm x 10 cm. The rapeseed variety 'TS 38' was sown on 29 October and 2 November in respective year of

experimentation using a seed rate of 7.5 kg/ha under rainfed conditions. The crop was cultivated using customary cultural practices, such as nutrient and water management, weeding and destruction of crop residue in the field etc. The duration of the crop was recorded during the first and second year of study.

During the crop season, the meteorological parameters viz., mean temperature (maximum and minimum), mean relative humidity (morning and evening) and rainfall was recorded from AAU-Zonal Research Station meteorological department. The fungicides were sprayed twice, first at appearance of the disease and the second at 20 days after the first spray. For all the treatments, the per cent disease severity on leaves and pods were counted from 10 randomly selected plants using revised rating scale 0-9 (Conn *et al.*, 1990). On leaves, the disease severity of *Alternaria* blight was recorded at 70 DAS and on pods at 75 DAS. Yield was recorded at harvest. Data on per cent values was angular transformed before statistically analysis using standard procedure (Panse & Sukhatme, 1985). The year-wise data generated were pooled, and reduction in disease severity and yield increase were calculated from pooled data over the untreated control. The preventable yield loss was calculated against the treatment with the highest seed yield. For drawing economic inference, the market price of Rs. 65 kg<sup>-1</sup> seed was taken into account.

### 3. RESULTS AND DISCUSSION

#### 3.1 Meteorological Record

During the experimental period 2021-22, the maximum and minimum mean temperature was 27.8 °C and 13.2 °C, respectively, while in 2022-23, it was found to be 27.7 °C and 16.0 °C. During 2022-23, the mean relative humidity was 90.0 % (morning) and 62.0 % (evening) in the first year and 90.3 % (morning) And 66.1 % (evening) in the second year of experimentation. The rainfall received was 173.2 mm and 171.3 mm, respectively during 2021-22 and 2022-23. The duration of the crop was 91 And 94 days in the first and second year of study, respectively.

#### 3.2 Disease Severity

*Alternaria* blight disease was significantly reduced on leaves as well as on pods by all the seven fungicides as compared to check (Table 1). The pooled analysis showed that

tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l<sup>-1</sup> of water proved to be significantly superior to all other fungicides except azoxystrobin 23 % SC @ 1 ml l<sup>-1</sup> in controlling *Alternaria* leaf blight (Table 1). The combination of trifloxystrobin and tebuconazole acts as synergist as the individual components have different modes of action. Tebuconazole, a triazole acts as demethylation inhibitor (DMI) that hinders the fungal cell wall synthesis and thereby, acting as an obstacle for the fungal growth and reproduction. On the other hand, the Trifloxystrobin, a Quinone outside Inhibitor (QoI) interferes in the fungal respiration. The combination of the two fungicides with two different modes of action, therefore, helps in regulating the risk of cross resistance (Hegde & Nagaraj, 2020). *Alternaria* leaf blight severity (%) under tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l<sup>-1</sup> and azoxystrobin 23 % SC @ 1 ml l<sup>-1</sup> was 16.18 and 19.0, respectively. The disease severity reduction percentage on leaves was the highest (54.1 %) under the former fungicide closely followed by the latter one (46.1 %). The lowest disease severity on pods (9.82 %) was achieved with spraying of tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l<sup>-1</sup> at appearance of symptoms and 20 days after first spray. The other fungicides barring azoxystrobin 23 % SC @ 1 ml l<sup>-1</sup> were significantly inferior to the best performing above mentioned ready-mix formulation. Per cent disease reduction on pods under tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l<sup>-1</sup> and Azoxystrobin 23 SC @ 1 ml l<sup>-1</sup> were 55.7 % and 45.8 %, respectively. Hexaconazole 5% SC @ 2 ml l<sup>-1</sup>, Tebuconazole 25.9% @ 1 ml l<sup>-1</sup>, and propiconazole 25% EC @ 1 ml l<sup>-1</sup> reduced the disease severity on leaves by 41.1 and 42.5 % and on pods, by 34.9 and 33.9 %, respectively. Ansari *et al.* (1990) reported that Dithane M-45 (0.2%) followed by Dithane Z-78 as foliar spray was most effective for controlling the blight of rapeseed caused by *Alternaria brassicae* and increasing the yield in field trials. Rakesh *et al.* (2018) found that 0.05 % propiconazole spray at 60 DAS was effective in managing diseases of mustard with 62.8 % reduction on leaves and 35.4 % on pods. Metalaxyl 4% + mancozeb 64% (ready mix) @ 0.5 g/l also controlled the disease on leaves registering 38.2 % disease reduction. Jha *et al.* (2013) and Meena *et al.* (2014) reported that mancozeb was found to be the best fungicides against the disease. The disease severity of *Alternaria* leaf spot were reduced in cabbage treated with Tebuconazole (4.62%),

**Table 1. Disease severity (%) and seed yield (kg ha<sup>-1</sup>)**

| Treatments                                                                                   | Alternaria blight severity (%) at 70 DAS on leaves |                  |                  |                                         | Alternaria blight severity (%) at 75 DAS on pods |                  |                  |                                         | Per cent yield increase |         |         |                         |
|----------------------------------------------------------------------------------------------|----------------------------------------------------|------------------|------------------|-----------------------------------------|--------------------------------------------------|------------------|------------------|-----------------------------------------|-------------------------|---------|---------|-------------------------|
|                                                                                              | 2020-21                                            | 2021-22          | Pooled           | Per cent disease reduction over control | 2020-21                                          | 2021-22          | Pooled           | Per cent disease reduction over control | 2020-21                 | 2021-22 | Pooled  | Per cent yield increase |
| T <sub>1</sub> : Tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l <sup>-1</sup> | 16.83<br>(24.20)                                   | 15.53<br>(23.19) | 16.18<br>(23.71) | 54.1                                    | 10.40<br>(18.79)                                 | 9.23<br>(17.67)  | 9.82<br>(18.24)  | 55.7                                    | 1,272.14                | 1101.86 | 1187.00 | 78.5                    |
| T <sub>2</sub> : Propiconazole 25% EC @ 1 ml l <sup>-1</sup>                                 | 23.70<br>(29.12)                                   | 16.80<br>(24.07) | 20.25<br>(26.65) | 42.5                                    | 13.90<br>(21.87)                                 | 15.40<br>(23.08) | 14.65<br>(22.49) | 33.9                                    | 951.11                  | 965.67  | 958.39  | 44.1                    |
| T <sub>3</sub> : Metalaxyl 4% + mancozeb 64% (ready mix) @ 0.5 g l <sup>-1</sup>             | 23.77<br>(29.14)                                   | 19.73<br>(26.29) | 21.75<br>(27.76) | 38.24                                   | 16.27<br>(23.77)                                 | 15.33<br>(23.02) | 15.80<br>(23.41) | 28.8                                    | 844.45                  | 848.50  | 846.47  | 27.3                    |
| T <sub>4</sub> : Hexaconazole 5% SC @ 2 ml l <sup>-1</sup>                                   | 22.63<br>(28.40)                                   | 18.87<br>(25.43) | 20.75<br>(27.07) | 41.1                                    | 15.20<br>(22.92)                                 | 13.67<br>(21.66) | 14.43<br>(22.31) | 34.9                                    | 922.22                  | 911.83  | 917.03  | 37.9                    |
| T <sub>5</sub> : Tebuconazole 25.9% @ 1 ml l <sup>-1</sup>                                   | 23.37<br>(28.89)                                   | 24.03<br>(29.34) | 23.70<br>(29.12) | 32.7                                    | 13.63<br>(21.65)                                 | 14.87<br>(22.65) | 14.25<br>(22.17) | 35.8                                    | 993.33                  | 993.33  | 993.33  | 49.4                    |
| T <sub>6</sub> : Azoxystrobin 23 SC @ 1 ml l <sup>-1</sup>                                   | 19.60<br>(26.25)                                   | 18.40<br>(25.36) | 19.00<br>(25.83) | 46.1                                    | 12.90<br>(21.03)                                 | 11.13<br>(19.48) | 12.02<br>(20.26) | 45.8                                    | 1,013.33                | 1046.50 | 1029.92 | 54.8                    |
| T <sub>7</sub> : Trifloxytrobin 50% WG @ 1 g l <sup>-1</sup>                                 | 23.53<br>(29.00)                                   | 23.10<br>(28.71) | 23.32<br>(28.86) | 33.8                                    | 15.87<br>(23.45)                                 | 15.67<br>(23.30) | 15.77<br>(23.39) | 28.9                                    | 891.11                  | 893.50  | 892.31  | 34.2                    |
| T <sub>8</sub> : Check                                                                       | 36.60<br>(37.21)                                   | 33.83<br>(35.55) | 35.22<br>(36.38) | -                                       | 23.43<br>(28.92)                                 | 20.93<br>(27.20) | 22.18<br>(28.08) | -                                       | 660.00                  | 670.00  | 665.00  | -                       |
| CD (5 %)                                                                                     | 2.07                                               | 4.43             | 2.90             |                                         | 2.09                                             | 2.20             | 1.92             |                                         | 150.78                  | 152.41  | 24.98   |                         |
| CV %                                                                                         | 4.03                                               | 9.20             | 4.28             |                                         | 5.17                                             | 5.59             | 3.55             |                                         | 9.28                    | 9.28    | 1.12    |                         |

**Table 2. Economics of different treatments**

| Treatments                                                                                   | CoC (Rs ha <sup>-1</sup> ) | GR (Rs ha <sup>-1</sup> ) | NR (ha) | B:C  |
|----------------------------------------------------------------------------------------------|----------------------------|---------------------------|---------|------|
| T <sub>1</sub> : Tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l <sup>-1</sup> | 38154                      | 77155                     | 39001   | 2.02 |
| T <sub>2</sub> : Propiconazole 25% EC @ 1 ml l <sup>-1</sup>                                 | 29718                      | 62295                     | 32577   | 2.10 |
| T <sub>3</sub> : Metalaxyl 4% + mancozeb 64% (redy mix) @ 0.5 g l <sup>-1</sup>              | 30042                      | 55021                     | 24979   | 1.83 |
| T <sub>4</sub> : Hexaconazole 5% SC @ 2 ml l <sup>-1</sup>                                   | 32046                      | 59607                     | 27561   | 1.86 |
| T <sub>5</sub> : Tebuconazole 25.9% @ 1 ml l <sup>-1</sup>                                   | 28999                      | 64566                     | 35567   | 2.23 |
| T <sub>6</sub> : Azoxystrobin 23 SC @ 1 ml l <sup>-1</sup>                                   | 28986                      | 66945                     | 37959   | 2.31 |
| T <sub>7</sub> : Trifloxystrobin 50% WG @ 1 g l <sup>-1</sup>                                | 33894                      | 58000                     | 24106   | 1.71 |
| T <sub>8</sub> : Check                                                                       | 25629                      | 43225                     | 17596   | 1.69 |

\*Rate of rapeseed - Rs. 65 kg<sup>-1</sup>

Trifloxystrobin +Tebuconazole (6.01%) and Propiconazole (9.45%), which were found best among the other fungicides, followed by Mancozeb (11.4%) Difenconazole (10.49%), Pyraclostrobin+Hydrocarbons (10.08%) (Tu et al., 2015). Among Contaf 5EC and Rovral 50WP, double spray of Contaf 5EC @ 0.1% concentration at 45 and 55 DAS showed better results in minimizing disease occurrence and frequency of *Alternaria* leaf blight disease as well as a significant positive impact on the yield parameters of mustard variety BARI Sharisha 14 in the field (Rahman et al., 2020). Al-Lami et al. (2023) studied the screening of 150 diverse Brassicaceae varieties under glasshouse conditions, highlighted important novel resistances and found that particular, *Camelina sativa* '4076' and *Diplotaxis erucoides* 'Wasabi Rocket' had complete resistance across disease assessment parameters (leaf incidence [%LDI]; severity [%LAD]; consequent defoliation [%LCI]). Loona et al. (2025) found that foliar spray of Tebuconazole at 1 ml l<sup>-1</sup> significantly outperformed other treatments in controlling *Alternaria* leaf blight of radish, resulting in the lowest PDI (7.67%) and highest radish root yield (13.62 tons ha<sup>-1</sup>).

### 3.3 Seed Yield

Significant effect on yield was recorded by different treatments during both the years of study (Table 1). The maximum seed yield was the resultant of the highest reduction in disease severity both on leaves and pods under two sprays of tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g/l (1272.14 kg ha<sup>-1</sup>) in 2021-22, 1101.86 kg ha<sup>-1</sup> in 2022-23. This was pooled at 1187 kg ha<sup>-1</sup> with an increase in yield of

78.5 % over check (665 kg ha<sup>-1</sup>). Similar were the findings of Tu et al., 2015. This fungicide was found to be significantly superior to all other fungicides in enhancing crop yield. Azoxystrobin 23 % SC @ 1 ml l<sup>-1</sup> controlled the disease effectively and consequently out yielded the remaining fungicides (1013.33 kg ha<sup>-1</sup> in 2021-22, 1046 kg ha<sup>-1</sup> in 2022-23 and 1029.92 kg ha<sup>-1</sup> of pooled seed yield) showing a yield increase of 54.8 %. This fungicide recorded the least avoidable yield loss of 13.2 %. Tebuconazole 25.9 % @ 1 ml l<sup>-1</sup> and propiconazole 25 % EC @ 1 ml l<sup>-1</sup> led to yield advantage of 49.4 and 44.1 %, respectively over check. Rakesh et al. (2018) also reported likewise in support of propiconazole.

### 3.4 Economics

Tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l<sup>-1</sup> though accrued in the highest seed yield and NR (Rs. 39001 ha<sup>-1</sup>) yet emerged to be the fourth with respect to benefit-cost ratio (2.02) (Table 2). This could be attributed to the maximum cost of cultivation (Rs. 38154 ha<sup>-1</sup>) under this treatment. Azoxystrobin 23 % SC @ 1 ml l<sup>-1</sup> recorded the second highest NR (Rs. 37959 ha<sup>-1</sup>) and the highest benefit-cost ratio (2.31) owing to much lower cost of cultivation (Rs. 28986 ha<sup>-1</sup>) as compared the former fungicide. Tebuconazole 25.9 % @ 1 ml l<sup>-1</sup> and propiconazole 25 % EC @ 1 ml l<sup>-1</sup> gave NR of Rs. 35567 ha<sup>-1</sup> and Rs. 32577 ha<sup>-1</sup> and B:C of 2.23 and 2.10, respectively.

### 4. CONCLUSION

Tebuconazole 50% + trifloxystrobin 25% WG (ready mix) @ 1 g l<sup>-1</sup> of water is one of the most

effective treatments for management of *Alternaria* blight disease at appearance of disease symptoms and 20 days after first spray, without any compromise in the yield may be recommended in Assam. However, for small and marginal farmers' friendly, economically viable rapeseed production system viz., azoxystrobin 23 % SC @ 1 ml l<sup>-1</sup> at appearance of disease and 20 days later is the better option.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I, Ranjana Chakrabarty, hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTEREST

Authors have declared that no competing interests exist.

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