



RESEARCH

Effect of Triazole and Strobilurin Fungicide Against *Alternaria* Leaf and Pod Blight (*Alternaria raphani*) in Radish (*Raphanus sativus* var. Mino Early)

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Abstract

A field experiment was conducted to evaluate the effect of Triazole and Strobilurin fungicides on *Alternaria* leaf and pod blight (*Alternaria raphani*) of radish (*Raphanus sativus* var. Mino Early). The experiment lasted from November 2021 to March 2022 following a completely randomized block design (RCBD) with three replications. Seven treatments were evaluated, including T1 (Propiconazole 25% EC), T2 (Tebuconazole 25% WDG), T3 (Azoxystrobin 23% SC), T4 (Propiconazole 13.9% + Difenconazole 13.9% EC), T5 (Azoxystrobin 11% + Tebuconazole 18.3% SC), T6 (Tebuconazole 50% + Trifloxystrobin 25% WP), and T7 (control). Analysis of the data showed that T4 had the lowest disease severity in radish leaves with a mean value of 22.67 ± 1.76 . T1 followed closely with a mean disease severity of 27.11 ± 1.16 , while T3 had a mean severity of 29.67 ± 1.73 . Regarding pod infection, T4 also showed the most effective control with a mean infection level of 17.56 ± 1.76 . This was followed by T1 with a mean infection level of 19.78 ± 1.16 and T3 with a mean infection level of 21.33 ± 1.73 . Overall, the results indicate that the application of T4 (Propiconazole 13.9% + Difenconazole 13.9% EC) significantly reduced disease severity in both radish leaves and pods, demonstrating its efficacy in managing *Alternaria* leaf and pod blight. These results suggest that T4 may be a suitable fungicide treatment option for the control of *Alternaria* blight in radish crops. Further research and field trials are required to validate these results and to investigate the long-term effects of treatments on radish growth, yield, and quality.

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Statement of Sustainability: This research aligns with sustainable development goals by addressing key aspects of sustainability. It contributes to Goal 2 (Zero Hunger) by improving radish crop productivity and food security through effective disease management. Goal 12 (Responsible Consumption and Production) is addressed by promoting the responsible use of fungicides and exploring sustainable alternatives. Goal 15 (Life on Land) is supported through the conservation of ecosystems and biodiversity in agricultural lands. Goal 13 (Climate Action) is advanced by minimizing pesticide use and its associated environmental impacts. Lastly, Goal 9 (Industry, Innovation, and Infrastructure) is promoted through the development of innovative disease management strategies. This research aims to enhance sustainable agricultural practices and contribute to a more resilient and environmentally conscious food production system.

1. Introduction

Radish (*Raphanus sativus* L.), a vital vegetable crop belonging to the Brassicaceae family, is highly sought after due to its fleshy edible root. It is cultivated worldwide in both tropical and temperate regions (Arefin et al., 2019; Gautam et al., 2018). The crop's popularity among farmers stems from its adaptability to various climates and its ease of cultivation (Gautam et al., 2018). However, radish is susceptible to several diseases, including damping off, leaf spot, Fusarium rot, black rot, and *Alternaria* blight. Among these, *Alternaria* blight, caused by various species such as *Alternaria brassicae*, *A. brassicicola*, *A. raphani*, and *A. alternata*, poses the most significant threat, resulting in substantial yield losses (Arefin



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et al., 2019). Notably, *Alternaria* blight caused by *A. brassicae* and *A. brassicicola* is particularly devastating, leading to severe production losses (Rashid et al., 2010).

Alternaria leaf blight fungi, including *Alternaria* spp., survive in diseased plant debris, susceptible weeds, or perennial crops during the winter (Rangel, 1944). They can persist in debris for up to two years and are dispersed by wind, water, and field equipment during the growing season. Infection occurs when there is leaf wetness, allowing spores to enter through leaf pores. Lesions appear 3–5 days after infection and serve as a source of new inoculum. However, the fungi cannot survive in the soil for long after the complete decomposition of plant tissues. The rate of disease spread in the field depends on the initial inoculum level, air temperature, and the presence of moisture in the form of dew, rain, irrigation, or high humidity (Singh, 2015). *Alternaria* blight symptoms are considered the primary disease affecting radishes, both fresh vegetable and seed production (Sapkota et al., 2002). Initial symptoms appear on older leaves as small necrotic spots surrounded by a yellow halo before the flowering stage (Islam et al., 2007; Singh, 2015). As the disease progresses, typical symptoms include dark brown spots on leaves, stems, and siliqua. These spots start as small brown or black lesions and develop into concentric circles in later stages (Rashid et al., 2010). Leaf symptoms of *Alternaria* infection begin as small, circular dark spots that can expand to 1 cm in diameter or larger, often exhibiting grey, grey-tan, or near-black coloration. The spots tend to form in a target pattern of concentric rings due to the uneven growth rate of the pathogen (Nayyar et al., 2014). Circular lesions may also develop on pods and tender twigs, appearing as dark, blackish-colored small spots (Gusain et al., 2020; Singh, 2015). The pathogen can cause pod shriveling or premature death of pod stalks before seed formation (Rashid et al., 2010). If left uncontrolled, the inoculum level increases over time (Islam et al., 2007). To effectively manage *Alternaria* blight in Cole crops such as broccoli, kale, mustard, radish, and cabbage, a well-organized disease management approach includes early sowing of clean, properly stored certified seeds after deep plowing. Clean cultivation practices, suitable weeding, and maintaining an optimum plant population are also crucial (Arefin et al., 2019). Additionally, it is important to avoid irrigation during the flowering and pod formation stages, as excess moisture can promote disease development. This study hypothesizes that the application of triazole and Strobilurin fungicides will effectively control *Alternaria* leaf and pod blight in radish, resulting in a significant reduction in disease severity compared to the control group.

Therefore, the objective of the present study is to identify effective fungicides belonging to the triazole and Strobilurin groups for controlling *Alternaria* leaf and pod blight in radish, using field experiments conducted under natural conditions. The findings from this research will contribute to a better understanding of fungicide efficacy and aid in developing practical disease management strategies for radish cultivation.

2. Material and Methods

2.1. Experimental Site and Design

The field experiment was conducted at the farm of Purbanchal University, G.P. Koirala College of Agriculture and Research Centre (PU, GPCAR) in Gothgaun, Morang, Nepal. The experiment lasted from November 2021 to March 2022, covering the winter cropping season. The experiment followed a Completely Randomized Block Design (RCBD), which is a widely used design for agricultural experiments. This design helps in reducing the effects of variability and provides a robust statistical analysis. The treatments were randomly assigned to the experimental units, which were organized into blocks to account for any spatial variability across the field. The experiment had seven treatments, and each treatment was replicated three times, resulting in a total of 21 experimental plots. The seven treatments used are well documented in Table 1.

Table 1. Configuration of treatments applied in this study

Treatment	Configuration
T1	Propiconazole 25% EC
T2	Tebuconazole 25% WDG
T3	Azoxystrobin 23% SC
T4	Propiconazole 13.9% + Difenoconazole 13.9% EC
T5	Azoxystrobin 11% + Tebuconazole 18.3% SC
T6	Tebuconazole 50% + Trifloxystrobin 25% WP
T7	Control

EC: emulsifiable concentrate; WDG: water dispersible granules; SC: suspension concentrates; WP: wettable powder.

The fungicides were applied as foliar sprays at their recommended doses. Application timings were at 30 days after sowing (DAS) and 45 DAS during the vegetative stage, while 60 and 75 DAS during the reproductive stage. This allowed for appropriate coverage of the critical growth stages of the radish crop.

2.2. Planting and Cultural Practices

The Mino Early variety of radish was sown on November 26th, 2021, with a spacing of 20 × 20 cm. The seeds used in the experiment were obtained from Koshi Agroviet, located in Morang, Nepal. The seeds were procured from the Pokhara Seed Company Pvt. Ltd., located in Malepatan, Pokhara-5, Nepal. The recommended cultural practices for radish cultivation were followed throughout the experiment. These practices included soil preparation, sowing method, irrigation management, fertilizer application, and weed control, among others. By adhering to the recommended cultural practices, potential confounding factors that could affect the results were minimized.

2.3. Disease Assessment

Disease assessment was a crucial component of the experiment. Ten plants were randomly selected from each experimental plot, excluding the border plants, and these selected plants were tagged for disease assessment. Disease assessment was conducted three times during the experiment. The first assessment started at 42 DAS, during the vegetative stage, and subsequent assessments were done at 7-day intervals. The second and third assessments were carried out at 77 DAS during the reproductive stage. Leaf and pod infection levels were assessed using a rating scale ranging from 0 to 5, where: 0 = no infection, 1 = 1-5% infection, 2 = 6-10% infection, 3 = 11-20% infection, 4 = 21-30% infection, and 5 = 31-100% infection. Disease severity was calculated based on the assessed infection levels using formulae provided by previous studies (Shrestha et al., 2005; Gautam et al., 2018). This allowed for quantitative evaluation and comparison of disease severity among the different treatments.

$$\text{Disease Severity Index (\%)} = \frac{\text{Sum of Ratings}}{\text{Total Number of Plants Observed} \times \text{Maximum Disease Rating Scale}} \times 100$$

2.3. Statistical Analysis

The collected data, including disease severity ratings, were subjected to analysis of variance (ANOVA) using appropriate statistical software (R Studio, V-4.2.2, Boston Massachusetts, USA) (RCT, 2023). Prior to analysis, disease severity data were transformed using the arcsine transformation to meet the assumptions of ANOVA. Mean comparisons among significant variables were performed using the DMRT (Duncan's Multiple Range Test) at a 5% level of significance. This helped in identifying statistically significant differences between treatments and assessing the efficacy of the fungicide treatments in managing the diseases affecting radish.

3. Results and Discussion

The study observed significant variations in the disease severity of leaf spots caused by *Alternaria* among the different treatments during the vegetative stage at 42, 49, and 56 days after sowing (DAS) (Table 2). At 42 DAS, the plot treated with Propiconazole 13.9% + Difenconazole 13.9% EC exhibited the lowest leaf infection (18.00±2.00), which was statistically similar to the treatments with Azoxystrobin 11% + Tebuconazole 18.3% SC (22.00±1.16) and Propiconazole 25% EC (22.67±1.33). At 49 DAS and 56 DAS, the treatment with Propiconazole 13.9% + Difenconazole 13.9% EC effectively controlled leaf infection, with severity scores of 23.33±2.40 and 26.66±2.91, respectively. These scores did not differ significantly from the treatments with Propiconazole 25% EC (28.00±1.15 and 30.66±2.91), Azoxystrobin 23% SC (31.33±1.76 and 34.33±5.78), and Azoxystrobin 11% + Tebuconazole 18.3% SC (31.33±0.67 and 38.00±2.31). Overall, the mean disease severity of leaf spots significantly varied among the treatments across the three observations. The lowest leaf infection was observed in the plot treated with Propiconazole 13.9% + Difenconazole 13.9% EC (22.67±1.76), which differed significantly from the treatments with Propiconazole 25% EC (27.11±1.16) and Azoxystrobin 23% SC (29.67±1.73).

These results indicate that the application of Propiconazole 13.9% + Difenconazole 13.9% EC showed the most effective control of leaf spots caused by *Alternaria* in radish. However, other treatments, including Propiconazole 25% EC and Azoxystrobin 23% SC, also demonstrated some level of effectiveness in reducing leaf infection. Further analysis and interpretation of the data provide valuable insights into the efficacy of different fungicide treatments against *Alternaria* leaf spots, supporting the development of effective disease management strategies for radish crops.

Table 2. Effect of Triazole and Strobilurin fungicides on *Alternaria* leaf blight of radish.

Treatment	Disease Severity (%)			
	42 DAS	49 DAS	56 DAS	Mean
T1	18.00e ± 2.00 (25.04)	23.33c ± 2.40 (28.83)	26.66c ± 2.91 (31.03)	22.67e ± 1.76 (38.43)
T2	22.67de ± 1.33 (28.41)	28.00c ± 1.15 (31.94)	30.66c ± 2.91 (33.58)	27.11d ± 1.16 (31.38)
T3	23.33d ± 1.33 (28.87)	31.33c ± 1.76 (34.02)	34.33c ± 5.78 (35.72)	29.67c ± 1.73 (32.99)
T4	22.00de ± 1.16 (27.96)	31.33c ± 0.67 (34.04)	38.00bc ± 2.31 (38.04)	30.44c ± 0.80 (33.48)
T5	30.67c ± 1.76 (33.61)	44.67b ± 4.67 (41.91)	52.00ab ± 1.15 (46.15)	42.44b ± 1.24 (40.65)
T6	37.67b ± 1.45 (37.85)	44.67b ± 3.53 (41.92)	50.00b ± 5.03 (45.01)	44.11b ± 2.25 (41.62)
T7	49.33a ± 1.76 (44.62)	57.33a ± 6.96 (49.31)	66.00a ± 6.71 (54.75)	57.56a ± 4.64 (49.35)
Mean	29.06	37.24	42.52	36.29
F-test	**	**	**	**
CV (%)	10.08	13.25	19.05	9.65

DAS: Day after sowing; CV: Coefficient of variation; **: Significant at 0.01 level of significance: Values with the same letters in a column are not significantly different at a 5% level of significance by DMRT test. Figures after ± indicate the standard error of mean and figures in parentheses indicate arcsine transformation.

Regarding pod infection, there was a significant difference in disease severity at all three observation dates (Table 3). The mean pod infection across the three observations also showed significant variation. The lowest pod infection was observed in the plot treated with Propiconazole 13.9% + Difenconazole 13.9% EC (17.56±1.76), which was statistically similar to the treatments with Propiconazole 25% EC (19.78±1.16) and Azoxystrobin 23% SC (21.33±1.73). These findings demonstrate the efficacy of Propiconazole 13.9% + Difenconazole 13.9% EC in reducing disease severity both in radish leaves and pods. Other treatments, such as Propiconazole 25% EC and Azoxystrobin 23% SC, also showed some level of effectiveness in controlling *Alternaria* leaf and pod blight.

Table 3. Effect of Triazole and Strobilurin fungicides on *Alternaria* pod blight of radish.

Treatment	Pod Infection (%)			
	77 DAS	84 DAS	91 DAS	Mean
T1	12.67d ± 1.15 (20.66)	17.33d ± 3.53 (24.39)	22.67c ± 1.76 (28.40)	17.56e ± 1.76 (24.75)
T2	15.33d ± 2.91 (22.86)	19.33cd ± 2.40 (26.01)	24.67c ± 2.91 (29.70)	19.78de ± 1.16 (26.38)
T3	16.67cd ± 0.67 (24.09)	22.00cd ± 2.00 (27.92)	25.33c ± 2.91 (30.14)	21.33de ± 1.73 (27.47)
T4	18.67cd ± 1.76 (25.55)	22.67cd ± 2.67 (28.36)	26.67c ± 2.40 (31.04)	22.67d ± 0.80 (28.41)
T5	22.66bc ± 0.67 (28.43)	30.00bc ± 1.15 (33.19)	43.33b ± 3.33 (41.15)	32.00c ± 2.25 (34.44)
T6	29.33ab ± 2.31 (32.76)	38.00ab ± 3.06 (38.03)	45.33b ± 1.33 (42.32)	37.56b ± 1.24 (37.79)
T7	34.67a ± 2.40 (36.05)	47.33a ± 5.81 (43.46)	59.33a ± 6.96 (50.50)	47.11a ± 4.64 (43.34)
Mean	21.43	28.10	35.33	28.29
F-test	**	**	*	**
CV (%)	17.83	21.30	17.92	8.94

DAS: Day after sowing; CV: Coefficient of variation; *: Significant at 0.05 level of significance **: Significant at 0.01 level of significance: Values with the same letters in a column are not significantly different at 5% level of significance by DMRT test. Figures after ± indicate the standard error of mean and figures in parentheses indicate arcsine transformation.

The findings of the present study demonstrate the effectiveness of Triazole and Strobilurin fungicides in reducing the severity of *Alternaria* leaf and pod blight in radish. Specifically, the mixed formulation of Propiconazole and Difenconazole was found to be highly effective in reducing leaf and pod spot infections, followed by the single formulation of Propiconazole and Azoxystrobin. These results are consistent with the findings of Dinh et al. (2015), who conducted research on *Alternaria* leaf blight in cabbage using new fungicide molecules. They reported that Propiconazole at a concentration of 0.1% and Difenconazole at a concentration of 0.05% showed minimal disease severity of 4.87 and 9.09%, respectively, in field conditions. Similarly, Mahapatra and Das (2016) revealed the efficacy of Propiconazole in reducing leaf and siliqua infections caused by *Alternaria* in mustard. Furthermore, Hossain, Akter, and Anwar (2018) conducted a study on *Alternaria* blight in mustard, evaluating various concentrations of Azoxystrobin. They found that Azoxystrobin at a concentration of 0.1% significantly reduced the incidence of *Alternaria* blight, as well as the percentage of leaf infection and siliqua infection compared to the control group. The consistent findings across these studies highlight the effectiveness of specific fungicides, such as Propiconazole, Difenconazole, and Azoxystrobin, in controlling *Alternaria* blight in various crops. The results of the present study contribute to the growing body of evidence supporting the use of these fungicides as effective tools in the management of *Alternaria* leaf and pod blight in radish. However, it is important to consider that the efficacy of fungicides can be influenced by several factors, including application method, dosage, timing, and environmental conditions. Therefore, further research is recommended to optimize the application parameters of these fungicides and to assess their long-term effects on radish

growth, yield, and quality. Overall, the findings of this study provide valuable insights into the management of *Alternaria* blight in radish and contribute to the development of practical disease management strategies. Further field trials and research are warranted to validate these results and explore additional fungicide options for effective control of *Alternaria* blight in radish crops.

4. Conclusion

The findings of this study demonstrate the effectiveness of triazole and Strobilurin fungicides in controlling *Alternaria* blight of radish compared to the control group. The combination of Propiconazole and Difenoconazole, as well as the individual use of Propiconazole and Azoxystrobin, showed the highest efficacy in reducing leaf and pod spots in radish. However, other tested fungicides also exhibited varying levels of effectiveness. Overall, the study suggests that incorporating these fungicides into disease management strategies can significantly mitigate the impact of *Alternaria* blight in radish crops. It is recommended to use mixed formulations of Propiconazole and Difenoconazole or single formulations of Propiconazole and Azoxystrobin for optimal disease control. It is important to note that this study has certain limitations. The research was conducted under specific field conditions and focused on a limited set of fungicides. Future studies should explore the long-term effects of these fungicides on radish growth, yield, and quality. Additionally, investigations into the potential development of fungicide resistance and the environmental impact of these fungicides should be conducted. By addressing these areas, researchers can further enhance disease management strategies and contribute to sustainable radish cultivation practices.

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