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Evaluation of Different Fungicides against *Bipolaris oryzae* in Upland Rice (*Oryza sativa L.*) Under Northern Indian Plains

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ABSTRACT:

In the world, rice (*Oryza sativa* L.) is an essential crop that provides food for more than half of the population. India's Northern Indian Plain is one of the country's principal rice-producing regions. However, brown spot disease, which is brought on by *Bipolaris oryzae*, is one of the most destructive diseases that affect rice farming. By using effective management approaches, including fungicides, resistant cultivars, biological procedures, and cultural strategies, crop losses caused by brown spot disease can be mitigated. This study presents a comprehensive examination of five chemical fungicides and one biocontrol agent to prevent the prevalence of brown spot disease among three rice cultivars i.e. BPT 5204, Swarna mansuri and Kasturi. Results of this study reveals, the disease found most severe in BPT 5204, and other rice varieties like Swarna mansuri and Kasturi displayed less susceptibility towards brown spot disease. To mitigate the impact of brown spot disease foliar application of Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1} at 45 days will become most beneficial and increase rice yield at 53.32, 76.9 and 79.66% increase over control in all tested varieties i.e. V_1, V_2 and V_3 respectively. After that, foliar application of Definiconazole@ 1.0 ml L^{-1} and Propiconazole@ 1.0 ml L^{-1} also displayed a good performance against *Bipolaris oryzae*. It is crucial for farmers to adopt good rice cultivar and better control technique to major diseases. This research will assist farmers in minimizing losses due to brown spot disease and improving rice production levels.

Keywords: Rice, Bipolaris oryzae, Fungicide, Disease incidence, Cultivar

1. Introduction

Rice (*Oryza sativa* L.) is a crucial cereal crop and plays a key role in the global food supply. Current production levels stand at 676 million tonnes, but global demand is expected to increase, reaching 852 million tonnes by 2035. To bridge this gap, an additional 176 million tonnes of rice will need to be produced, necessitating a rise in productivity from 10 to 12.5 tonnes per hectare (Kumar et al., 2017). The introduction of high-yielding rice varieties has unfortunately increased the crop's susceptibility to various diseases. Fungal infections pose a major threat (Rameez et al., 2024) in majority of crops. Among these, brown spot, sheath blight, sheath rot, and blast diseases have emerged as significant problems (Azizi et al., 2022). Specifically, brown spot is particularly damaging, with potential yield losses exceeding 90% in some areas (Ristaino et al., 2021). Beyond affecting plant growth and reducing yields, this disease also causes grain discoloration at maturity, which diminishes the market value of the harvest. Grain production is lost because of the disease in both quantitative and qualitative ways (Savary et al., 2000). As things stand, the illness is pervasive throughout rice-growing regions and is the second largest cause of output losses, behind blast disease (Sharma et al., 2008). When timely control measures are not performed, yield losses ranging from 18.75% to 22.50% are recorded by Kamal and Mia (2009). Moreover, there is a proof that brown spot is getting worse in areas that are vulnerable to drought (Savary et al., 2005). In India, regions like Bihar, Uttar Pradesh, Jharkhand, Madhya Pradesh, Orissa, Chhattisgarh, Assam, and West Bengal where direct-seeded or transplanted both types of rice are cultivated have noticeably increased disease severity (Sunder et al., 2014). Currently, options for controlling brown spot are limited, and there is a shortage of rice cultivars that possess sufficient resistance to this disease (Srinivasachary et al., 2011). Reducing crop losses can be accomplished by the application of appropriate control techniques, such as the use of fungicides, resistant cultivars, biological methods, and cultural strategies. Although, fungicide treatment is available and low cost for the management of brown leaf spot, host plant resistance is most economical. Hence, keeping all the reviewed literature in account this study was setup to evaluate the potential of five fungicides and one biocontrol agent against brown leaf spot (*Bipolaris oryzae*) occurred in upland rice crop in Northern Indian plains.

2. Materials and Methods

Experimental Site

The experiment was conducted at the research farm of Integral Institute of Agricultural Science and Technology (IIAST), Integral University, Dasauli, Lucknow, Uttar Pradesh, India during the year 2021-2022 in Split Plot Design (SPD). The study site is located at 28°42.013′ N latitude and 119°43.932′ E longitude, and at an altitude of 123 m above the mean sea level. Average annual rainfall during experimental year was 827 mm. The growing season is generally short and lasts for 228 days. The mean annual temperature was 25.1 °C and the mean temperatures during crop period (July to October) was 17.08 °C. The site selected was uniform, cultivable with typical sandy loam soil having good drainage.

Experimental Details and Design

The experiment comprised with seven treatments including five chemical fungicides and one biocontrol agent as well as one spray of water was used as control. The treatments are as follows: T_1 - Definiconazole @ 1 ml L^{-1}, T_2 - Propiconazole @ 1 ml L^{-1}, T_3 - Trifloxystrobin 25%+ Tebuconazole @ 0.4 g L^{-1}, T_4 - Azoxystrobin @ 1 ml L^{-1}, T_5 - Hexaconazole @ 2 ml L^{-1}, T_6 – *Trichoderma* spp. @ 4 g L^{-1} as biocontrol agent, T_7 – Spray of water as control. Application water spray in control was performed towards maintain the moisture state in plants.

All the treatments were employed on the crop at 45 days after planting. The experiment was laid down on the principle Split Plot Design (SPD) with three replications.

Crop Raising

Thirty days old healthy nursery of *Oryza sativa* L. cv. BPT-5204, Swarna Mansuri and Kasturi were collected from the research farm of IIAST, Integral University, Lucknow, and were transplanted in the field plots at 15 cm × 20 cm spacing in first week of July 2021 and 2022 in well puddled plots. In all treatments required amount of P and K as per recommended dose were applied through single superphosphate (SSP) and muriate of potash (MOP), respectively, at the time of transplanting. While nitrogen (N) was applied through urea in three equal splits i.e., one third at transplanting and the remaining two-thirds in similar splits at 30 and 45 days after transplanting. Other cultural practices like weeding, irrigation, mixing of fertilizer, foliar applications, etc. had been done according to the requirements or schedule as planned during crop growth.

Identification of Symptoms

During the experiment, observations were made at multiple points, and detailed records were taken of the symptoms appearing on the sheath, stem, and leaf sections of the plants. In addition to these visible symptoms, the presence of disease-related signs on the isolated pathogens was also carefully documented.

Isolation, Purification and Identification Of Pathogen

Leaf samples were collected from experimental fields based on visible symptoms. The leaves were cut into small pieces, approximately 3-5 mm in size, and surface sterilized with a 1% sodium hypochlorite (NaOCl) solution. Afterward, they were thoroughly rinsed with distilled water and placed on blotter paper to dry. Sterilized petri plates were then filled with autoclaved potato dextrose agar (PDA) medium, and the samples were positioned at the center of the plates using sterilized forceps. The plates were sealed and incubated at 28°C. Mycelial growth was regularly monitored, and for pathogen purification, a small portion of the fungal colony was transferred to fresh PDA plates using the single hyphal tip method.

Disease Incidence and Severity

A 1 m^2 disc was positioned at random in the paddy fields at each location to choose four observation points for the purpose of assessing the disease. Disease severity (percent infection) was recorded on the basis of 0 to 9 scale (Anonymous, 2001) as represented in Table 1.

Table 1. Severity percent/score range

Score	Disease Severity %	Level of Resistance/Susceptibility
0	No disease observed	Immune
1	Less than 1%	Resistance
2	1-3%	Resistance
3	4-5%	Moderately Resistance
4	6-10%	Moderately Resistance
5	11-15%	Moderately Susceptible
6	16-25%	Moderately Susceptible
7	26-50%	Susceptible
8	51-75%	Susceptible
9	76-100%	Highly Susceptible

Ten plants were then randomly chosen at each location where the disc had landed, and the total incidence of brown spot-infected leaves was recorded. To calculate disease incidence, the formula proposed by Meya et al. (2015).

$$Disease\ incidence = \frac{n}{N} X100$$

Where, 'n' represents the number of leaves with brown spots, and 'N' signifies the total number of leaves observed. The disease incidence for each location was determined as the average across ten sites, and the average disease incidence for each site was calculated as the average across ten plants.

Assessment of Disease Prevalence

The percentage of disease intensity (PDI) was calculated by using the following formula:

$$PDI\% = \frac{Sum\ of\ all\ disease\ rating}{Total\ no\ of\ leaf\ observed\ X\ Maximum\ rating\ scale} X100$$

Biometric Observations

At the flowering stage of the crop, observations of *Oryza sativa* L. were recorded such as plant height and number of tillers per plant. In the experimental field, representative plants were randomly selected from each treatment, and observation was taken, and average data of all parameters were subjected to statistical analysis. From base to the tip of the plant, plant height was measured, and number of tillers were also counted manually from the same plants.

Data Processing

Recorded data on different morphological disease related parameters were analysed statistically using the analysis of variance for Split Plot Design (SPD) of the field experiment. In contrast, average data of two years on all parameters were analysed statistically at critical difference (CD/LSD) values at 5% ($P \leq 0.05$) level of significance were calculated for comparing the treatment means by Duncans Multiple Range Test (DMRT). Statistical analysis performed by using IBM SPSS 20 software package for Windows and subjected to ANOVA (Analysis of variance) were performed.

3. Results

Symptomatology and Pathogen Identification

Typical brown spots with a grey or white core that resemble sesame seeds are one of the leaf symptoms. These spots can be circular to cylindrical in form. Several spots combine, the leaves finally become brown and charred, and eventually they die. Grains produced from infected glumes shrink and change color. Grain discolouration is caused by *Bipolaris oryzae* (Bhat et al., 2009). The disease causes rice plants to become less capable of photosynthesising, which leads to the eventual scorching and death of the leaves. It also causes blighting of coleoptiles and the appearance of oval, dark brown to purplish-brown patches on the leaves and the diseased leaves' early withering (Zadoks, 2023). Some of the observed physical symptoms and microscopic characterization from the experiment are represented below in Figure 1 and 2.

Figure 1: Symptoms (a) and (b) typical brown spot on rice leaf, (c) Discoloured brownish grains of infected glumes.

On synthetic media, *B. oryzae* exhibits a cottony mycelial growth with colours ranging from dark grey to black or greenish. Under the microscope, its spores appear cylindrical to fusiform, light to dark brown in colour, and curved, with septate conidia (Marwein et al., 2022). The pathogen exhibits bipolar germination morphologically, with a single terminal spore and a conidiophore present. The fungus started out as a white mycelium, turned dark brown with septation, and eventually developed conidiophores that were brown in colour, multi septate, and bearing conidia on their tips. Conidia were fusiform, curved, or slightly curved; they were hyaline at first and became brown at maturity, with a hilum at the base.


Figure 2: Microscopic pictures of bipolar germination of spores and fusiform conidia with hilum at base arise from single multi septate conidiophore.

Severity Score

Data related to severity score was recorded till foliar application of treatment was employed. Severity score was determined in the range of 0-9 and recorded data is represented in Table 2. Observations on severity score revealed that the severity of the disease in all the plots was found in the range of 7-8 in V_1, 6-8 in V_2 and 5-7 in V_3. Overall perusal of observation displayed less severity in V_3 in comparison to V_1 and V_2.

Disease Incidence

Statistical results of data recorded on disease incidence was showed a significant difference among the treatments in case of V_1 an V_2 (Table 2). Due to the foliar application in V_3 variety, T_2, T_3, T_4, and T_5 treatments were found to be statistically at par with each other, whereas the remaining treatments were determined to be substantially different from each other. In V_1, lowest disease incidence 31.0 was recorded in T_3 followed by 35.6 in T_2 while the highest disease incidence of 81.1 was recorded in control (T_7). Similarly, in case of V_2 and V_3 also the lowest disease incidence at 31.8 and 14.2 respectively was found in T_3 and highest incidence of 75.5 and 56.0 respectively V_2 and V_3 was recorded in control. Based on mean data highest disease incidence 54.9 was recorded in V_1 followed by V_2 which was recorded at 53.9 and lowest disease incidence of 29.4 was recorded in V_3. Among all the treatments T_3 which was Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1} was d a significant reduction in disease incidence was found after T_3, T_2 was performed well which was the application of Propiconazole @ 1.0 ml L^{-1}.

Percent Disease Index (PDI)

Data calculated on percent disease index was calculated and statistically analyzed and represented in Table 2. Similar trend of the data was recorded in percent disease index (PDI) as disease incidence. Difference among treatment was found statistically significant at $p \geq 0.05\%$ according to DMRT. Lowest PDI at 27.5, 32.5 and 12.6% was recorded in T_3 (Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1}) and the following value of PDI at 39.7 and 16.7% in V_1 and V_3 respectively was recorded in T_2 while in order to V_3, followed by value of PDI at 40.5% was recorded in T_1 (Definiconazole@ 1.0 ml L^{-1}). And the highest percent disease index was recorded at 73.6, 68.2 and 50.3% was recorded in T_7 control. According to mean data highest PDI among the varieties at 50.3% was recorded in V_2 followed by V_1 which was recorded at 48.9% and lowest average PDI at 27.5 was found in V_3.

Table 2. Severity score, disease incidence and percent disease index of brown spot in different varieties of Oryza sativa as influenced by the different fungicides.

Treatments	Details	Severity Score			Disease Incidence			Percent Disease Index (%)		
		V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
T_1	Definiconazole @ 1.0 ml L^{-1}	7.0	7.0	6.0	46.0^c	45.4^c	20.4^b	$42.5b^c$	40.5^b	18.6^b
T_2	Propiconazole@ 1.0 ml L^{-1}	7.0	7.0	5.0	39.2^b	35.6^b	14.5^a	39.7^b	42.3^b	16.7^a
T_3	Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1}	7.0	6.0	5.0	31.0^a	31.8^a	14.2^a	27.5^a	32.5^a	12.6^a
T_4	Azoxystrobin@ 1.0 ml L^{-1}	7.0	8.0	6.0	54.2^d	57.2^d	26.5^c	46.4^c	51.5^c	24.3^c
T_5	Hexaconazole@ 2.0 ml L^{-1}	8.0	8.0	7.0	61.3^e	60.9^e	28.7^c	48.0^c	54.5^d	29.3^c
T_6	*Trichoderma* spp.@4.0 g L^{-1}	8.0	8.0	7.0	71.9^f	71.2^f	45.3^d	64.3^d	62.5^e	40.5^d
T_7	Control	8.0	8.0	7.0	81.1^g	75.5^g	56.0^e	73.6^e	68.2^f	50.3^e
Mean		**7.4**	**7.4**	**6.1**	**54.9**	**53.9**	**29.4**	**48.9**	**50.3**	**27.5**

Note: Mean followed by same letter within one column (SS, DI and PDI) do not differ significantly at $p \leq 0.05$ (Duncan's Multiple Range Test); V_1: Variety 1 (BPT 5204); V_2: Variety 2 (Swarna mansuri); V_3: Variety 3 (Kasturi).

Percent Reduction in Disease Prevalence

Percent reduction in disease prevalence was calculated for all the applied treatments against control and findings are represented in Table 2. Calculated showed a highest reduction in T_3 in order to all three varieties i.e. 62.59, 52.05 and 74.88% where the foliar application of Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1} was employed. After that disease prevalence was significantly reduced by T_2 (Propiconazole@ 1.0 ml L^{-1}) and T_1 (Definiconazole@ 1.0 ml L^{-1}), data recorded in T_1 as 46.01, 37.81 and 66.73% while in T_2 the reduction was found at 42.26, 40.41 and 63.09% in V_1, V_2 and V_3 respectively over control. Lowest disease reduction was found in T_6 where a biocontrol agent (*Trichoderma spp.*@4.0 g L^{-1}) was applied and recorded reduction at 12.64, 8.28, 19.47% to V_1, V_2 and V_3 respectively. Among the varieties highest disease prevalence was found reduced by the foliar application of all the treatments in V_3 followed by V_1 and lowest reduction was recorded in case of V_2.

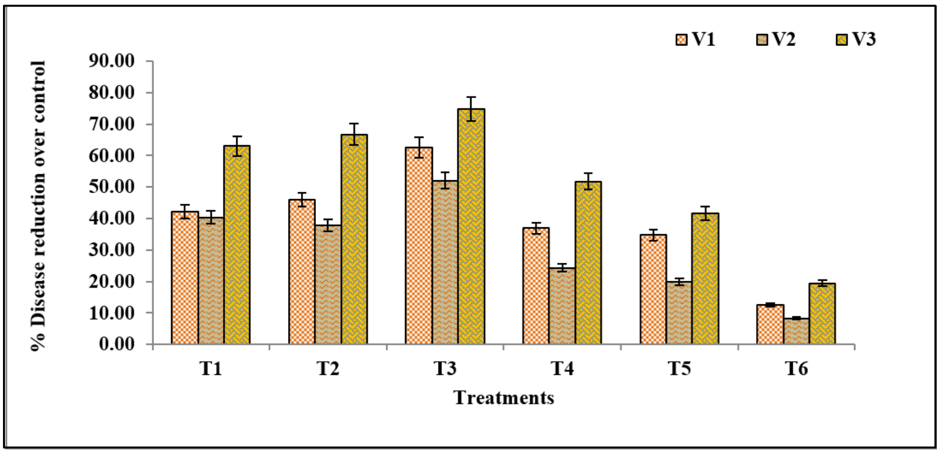

Figure 3. Percent disease reduction over control as influenced by the applied fungicides. Note: T_1: (Definiconazole@ 1.0 ml L^{-1}), T_2: (Propiconazole@ 1.0 ml L^{-1}), T_3: (Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1}), T_4: (Azoxystrobin@ 1.0 ml L^{-1}), T_5 (Hexaconazole@ 2.0 ml L^{-1}), T_6: (*Trichoderma spp.*@4.0 g L^{-1}), T_7: (Control); V_1: Variety 1 (BPT 5204); V_2: Variety 2 (Swarna mansuri); V_3: Variety 3 (Kasturi).

Plant Height and Number of Tillers

Observations on plant height and tiller counting was recorded at flowering stage and analyzed statistically, and results are represented in Figure 4 and 5. According to Duncan's multiple range test (DMRT), difference among the treatments was found statistically significant at $p \geq 0.05\%$ in plant height of V_3 and rest of two varieties viz. V_1 and V_2 displays very complex trend statistically and most of the treatment recorded statistically at par with each other. In order to V_1, highest plant height as 93.2 cm recorded in T_3 followed by 93.0 cm which was recorded in T_2 and they both were statistically at par with each other and lowest height 86.8 cm was recorded in T_7 (control). On the other hand, highest plant in V_2 and V_3 was also recorded in T_3 at 96.6 and 100.4 cm respectively. Based on average plant height of all the varieties highest average height at 96.6 cm was recorded in V_3 followed by V_2 (92.7 cm) and V_1 (90.4 cm) respectively.

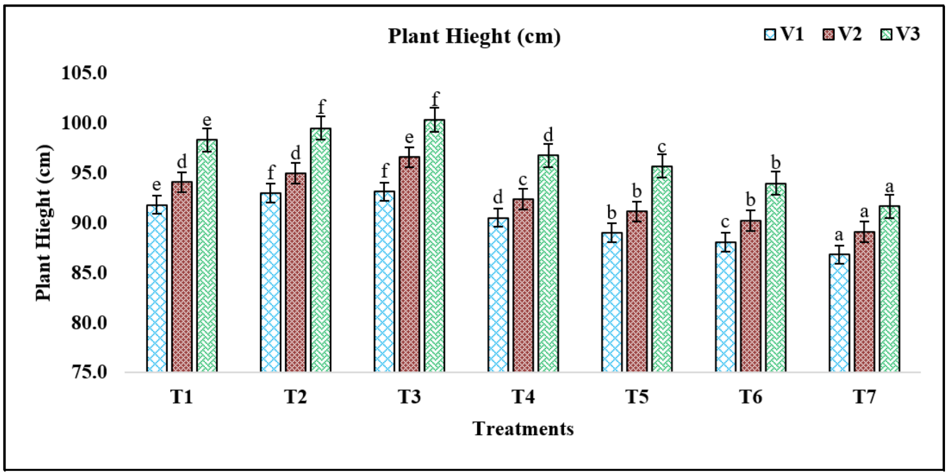

Figure 4: Plant height of *Oryza sativa* as influenced by the foliar application of different fungicides. Note: T_1: (Definiconazole@ 1.0 ml L^{-1}), T_2: (Propiconazole@ 1.0 ml L^{-1}), T_3: (Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1}), T_4: (Azoxystrobin@ 1.0 ml L^{-1}), T_5 (Hexaconazole@ 2.0 ml L^{-1}), T_6: (Trichoderma spp.@4.0 g L^{-1}), T_7: (Control); V_1: Variety 1 (BPT 5204); V_2: Variety 2 (Swarna mansuri); V_3: Variety 3 (Kasturi). Mean followed by same letter within one column (V_1, V_2 and V_3) do not differ significantly at $p \leq 0.05$ (Duncan's Multiple Range Test).

Similarly, data related to number of tillers per plant was also displayed analogous trend to plant height. Recorded data revealed a significant difference among the treatments as well as in varieties too. Higher number of tillers at 10.3, 13.3 and 14.1 were recorded in T_3 in all three varieties i.e. V_1, V_2 and V_3 respectively. After T_3 following number of tillers 9.0 and 8.1 was recorded in T_2 and T_1 respectively regarding V_1. While, in case of V_2 these values were found in T_2 and T_4 at 10.7 and 10.4 tillers per plants respectively. Lowest number of tillers among all three varieties were found in control and recorded as 5.9, 5.6 and 5.9 in V_1, V_2 and V_3 respectively. Average data on number of tillers of varieties highest number at 9.3 was found in V_3 followed by V_2 (8.9) and V_1 (7.8).

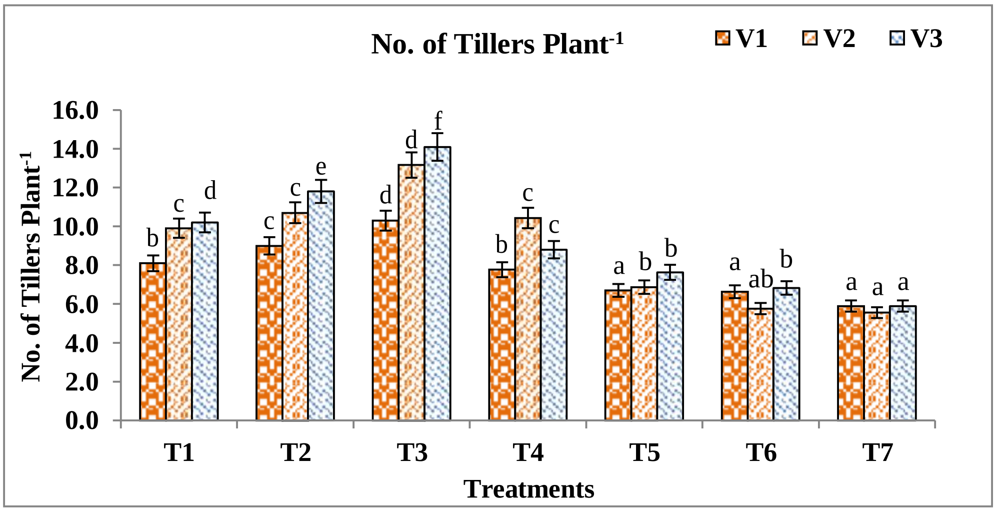

Figure 5: Number of tillers of *Oryza sativa* as influenced by the foliar application of different fungicides. Note: T_1: (Definiconazole@ 1.0 ml L^{-1}), T_2: (Propiconazole@ 1.0 ml L^{-1}), T_3: (Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1}), T_4: (Azoxystrobin@ 1.0 ml L^{-1}), T_5

(Hexaconazole@ 2.0 ml L^{-1}), T_6: (Trichoderma spp.@4.0 g L^{-1}), T_7: (Control); V_1: Variety 1 (BPT 5204); V_2: Variety 2 (Swarna mansuri); V_3: Variety 3 (Kasturi). Mean followed by same letter within one column (V_1, V_2 and V_3) do not differ significantly at $p \leq 0.05$ (Duncan's Multiple Range Test).

Grain Yield

Grain yield was recorded just after harvesting of the crop in triplicates from all the treatment plots and analyzed statistically. Significant influence of all foliar applied fungicides was noted on rice grain yield (Figure 6). Recorded data revealed that the foliar application of Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1} was significantly enhanced the grain yield at 53.32, 76.9 and 79.66% increase over control in all tested varieties i.e. V_1, V_2 and V_3 respectively. In case V_1, highest grain yield (61.5 q h^{-1}) was recorded in T_3 followed by T_6 (56.3) and lowest grain yield at 40.1 q h^{-1} was recorded in T_7 (control). Similarly, in V_2 also highest grain yield 68.3 q h^{-1} was recorded in T_3 followed T_1 (54.0 q h^{-1}) which was statistically ($p \geq 0.05\%$) at par with T_4 (52.7 q h^{-1}) where Azoxystrobin was applied at the rate of1.0 ml L^{-1}. In order to V_3, similar as V_1 and V_2 was noted and highest grain yield of 76.9 q h^{-1} was recorded in T3 followed by T_4 which was recorded at 63.5 q h^{-1} and T_1 (Definiconazole@ 1.0 ml L^{-1}) recorded at 59.9 q h^{-1} and lowest grain yield of 42.8 q h^{-1} was reported in control plot. In all the treatments grain yield was significantly increased due to the foliar application of different fungicides and a graph of percent increase in all the treatments over control is represented in Figure 7.

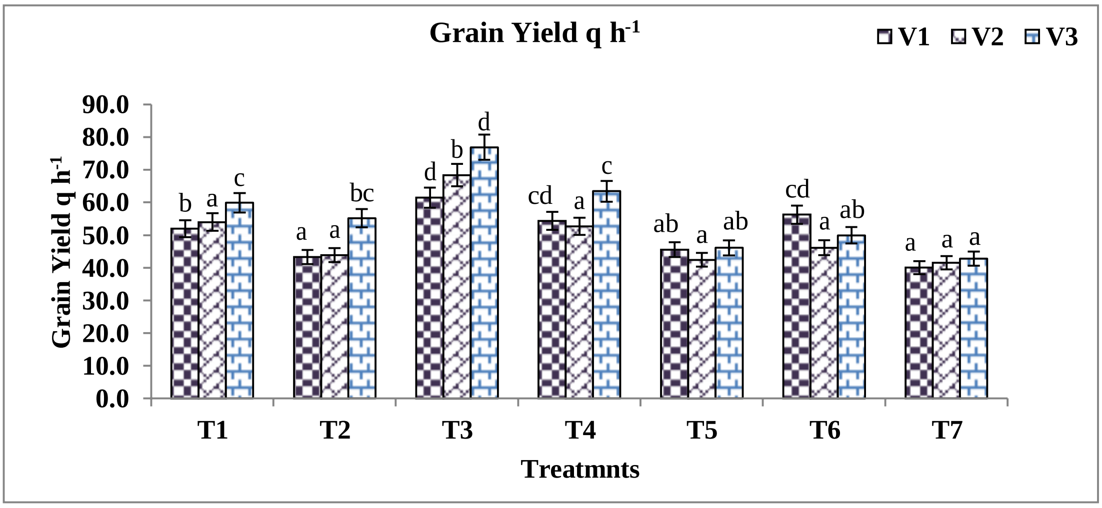

Figure 6. Impact of foliar application of different fungicides on grain yield in *Oryza sativa*. Note: T_1: (Definiconazole@ 1.0 ml L^{-1}), T_2: (Propiconazole@ 1.0 ml L^{-1}), T_3: (Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1}), T_4: (Azoxystrobin@ 1.0 ml L^{-1}), T_5 (Hexaconazole@ 2.0 ml L^{-1}), T_6: (Trichoderma spp.@4.0 g L^{-1}), T_7: (Control); V_1: Variety 1 (BPT 5204); V_2: Variety 2 (Swarna mansuri); V_3: Variety 3 (Kasturi). Mean followed by same letter within one column (V_1, V_2 and V_3) do not differ significantly at $p \leq 0.05$ (Duncan's Multiple Range Test).

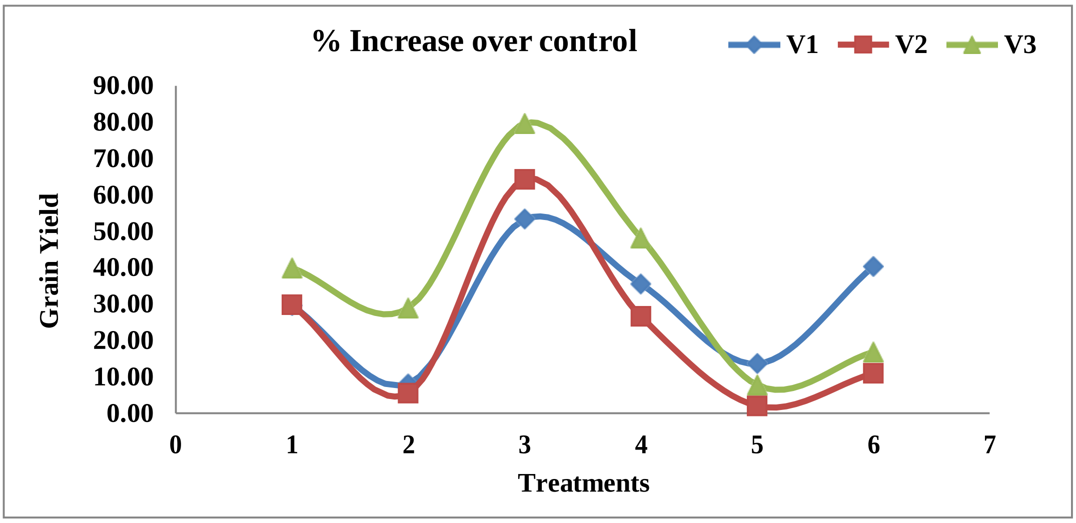

Figure 7. Percent increase in grain yield in *Oryza sativa* over control due to the foliar application of different fungicides. Note: T_1: (Definiconazole@ 1.0 ml L^{-1}), T_2: (Propiconazole@ 1.0 ml L^{-1}), T_3: (Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1}), T_4: (Azoxystrobin@ 1.0 ml L^{-1}), T_5 (Hexaconazole@ 2.0 ml L^{-1}), T_6: (Trichoderma spp.@4.0 g L^{-1}), T_7: (Control); V_1: Variety 1 (BPT 5204); V_2: Variety 2 (Swarna mansuri); V_3: Variety 3 (Kasturi). Mean followed by same letter within one column (V_1, V_2 and V_3) do not differ significantly at $p \leq 0.05$ (Duncan's Multiple Range Test).

4. Discussion

Brown spot disease, remains an enduring global concern with detrimental effects on rice cultivation. It results in substantial losses in terms of both acreage and yield. Previous research has suggested that the disease can lead to a reduction in rice yield ranging from 26% to 52% (Sreenivasaprasad et al., 2001). In our study, a comprehensive examination of different fungicides against brown spot disease was conducted across three varieties of rice such as BPT 5204, Swarna mansuri and Kasturi. The highest disease incidence was observed in BPT 5204, reaching up to, 54.9, while the lowest incidence was found in Kasturi variety at 29.40. Notably, the maximum Plant disease index was recorded in Swarna Mansuri variety, at 50.3%, while the lowest PDI was observed in Kasturi, at 27.5%. Severe infections had a significant impact on the number of grains and tillers, as well as the weight and quality of individual grains, resulting in the losses ranging from 30% to 43%. In contrast, moderately infected crops experienced a lower loss of 12%, while lower disease grades showed non-significant losses (Kumar and Kumar, 2022). After the foliar application of different fungicides among all three varieties a significant reduction in disease prevalence was noted in all the treatments. Due to this reduction a consequence enhancement in grain yield was recorded. The overall increment in yield fluctuated between 8.0 to 22.50% in V_1; 2.04 to 64.28% in V_2 and 7.75 to 79.66% in V_3. Similar findings were previously reported by (Kamal and Mia, 2009). Various studies, including those by Singh et al. (1979) and Mia et al. (2001) had been reported disease prevalence reductions rice brown spot due to the foliar application of different classes of fungicides, in diverse geographical regions. It is noteworthy that the impact of brown spot disease appears to be more devastating in fields where farmers have limited access to nitrogen-based fertilizers and adequate water supply (Bhumarkar et al., 2021). Rain, overcast weather, and high relative humidity provide a favourable set of environmental conditions for disease development (Magar, 2015). Climate change and initial conducive environmental conditions significantly contribute to the spread of the disease. Variations in disease distribution among different varieties of rice can be attributed to the changes in pathogenic variability, favourability in host variety, inoculum quantity, aggressiveness, the failure of vertical resistance, and traditional cultural practices (Gopi et al., 2016). Factors such as the number of inoculums, infection during the growth stage, climatic conditions, and resistance all play a role major in disease incidence and intensity (Groth and Bond, 2007).

5. Conclusion

Brown spot disease is a consequence threat to rice cultivation in the Northern Indian plains, where rice is major crop. The disease is most severe in BPT 5204 variety of rice while other rice varieties like Swarna mansuri and Kasturi displayed less susceptibility towards brown spot disease. To mitigate the impact of brown spot disease, foliar application of Trifloxystrobin 25% + Tebuconazole@ 0.4 g L^{-1} at 45 days had been the most beneficial treatment increase which the rice yield at 53.32, 76.9 and 79.66% over the control in all tested varieties by respectively. Foliar application of Definiconazole@ 1.0 ml L^{-1} and Propiconazole@ 1.0 ml L^{-1} also displayed a good performance against *Bipolaris oryzae*. It is crucial for the farmers to adopt good rice cultivar and better management technique in order to control the diseases in the treated varieties. This study provides the knowledge about best management practices against brown spot disease. Further research is needed to understand the various factor affecting disease incidence and intensity in different agro-climatic zones. Which will assist farmers in minimizing their losses due to brown spot disease and improving rice production levels.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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