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Ecofriendly Management of Wheat Panicle Blast Caused by *Magnaporthe oryzae triticum*

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Abstract

In this study, three wheat varieties were tested to determine seed germination and the incidence of *Magnaporthe oryzae triticum* (MoT). Among these varieties, BARI Gom 24 (Prodip) wheat seed exhibited the highest seed germination rate (93%) but also had the highest incidence (30%) of MoT. To manage blast disease in an ecofriendly manner, seven treatments were employed: T_1 = Control, T_2 = Garlic clove extracts, T_3 = *Aloe vera* leaf extracts, T_4 = Black cumin seed extracts, T_5 = Neem leaf extracts, T_6 = Nativo 75 WG, and T_7 = Provax 200 WP. The experiment was conducted using a Randomized Complete Block Design (RCBD) layout with three replications using Prodip wheat variety that exhibited highest MoT infection severity based on laboratory analysis among collected varieties. Data were collected on blast disease incidence (%), disease severity, and various growth and yield parameters of wheat. The experiment's results indicated that among all the treatments, T_7 (Seed treatment with Provax 200 WP) and T_5 (Foliar spraying with Neem leaf extract) performed better in controlling blast disease in wheat. The lowest blast disease incidence (%) was observed with T_7 (Provax 200 WP), with values of 7.86, 9.86, and 10.19 recorded during the milking stage, soft dough stage, and hard dough stage of wheat, respectively. T_5 (Neem leaf extract) also demonstrated a statistically equivalent reduction in blast disease incidence (%). In terms of disease severity, T_7 (Seed treatment with Provax 200 WP) showed the lowest values of 1.03, 1.23, and 1.63 during the milking stage, soft dough stage, and hard dough stage of wheat, respectively. Foliar spraying with neem leaf extract also exhibited similar result as of Provax 200 WP regarding panicle blast severity. As a result of these findings, it can be concluded that T_5 (Neem leaf extract) is recommended as an ecofriendly management approach for blast disease in wheat.

Keywords

Wheat, Panicle Blast, *Magnaporthe oryzae triticum*, Botanicals, Management

1. Introduction

Wheat, a cereal grain with its origins in the Levant region of the Near East, is cultivated on a global scale today, with approximately one-third of the world's population relying on it for nourishment [1]. Wheat provides 20% of the protein and calories for most people in developing countries, making it a key player in global food security [2]. However, biotic and abiotic stresses such as fungal diseases and increasing population threaten the productivity of wheat crops [3], which must increase by 70% by 2050 to feed an additional 2.3 billion people [4]. Bangladesh, primarily reliant on agriculture, has approximately 80% of its population either directly or indirectly linked to this sector [5]. Wheat is the second most important cereal after rice, providing 7% of the total output of food cereals [6]. Fungal diseases pose a significant threat to wheat production, causing 10% - 28% of yield losses worldwide [7]. Among these diseases, blast disease is particularly concerning because it has emerged as a global threat to wheat production since its first appearance in Brazil in 1985 [8] [9] [10]. Wheat blast, attributed to the fungal pathogen *Magnaporthe oryzae triticum* (MoT), stands as one of the most destructive afflictions to wheat crops. This devastating disease has been responsible for yield reductions ranging from 40% to a staggering 100% in diverse wheat cultivars across various wheat-growing regions. Gaining insights into pathogenic diversity and the cultural and morphological features of MoT isolates represents a highly effective strategy for disease management [11]. The morphological and cultural variant of *B. sorokiniana* found on wheat exhibited pathogenicity on the same host [12]. The disease can cause losses ranging from very low to 100% of production and affects all above-ground parts of the plant. Wheat blast was first reported outside of South America in Bangladesh in 2016, where it affected approximately 15% of the country's total wheat area [13], resulting in a 1.78% decrease in national yield rate [14]. The molecular characteristics of the wheat blast in Bangladesh were found to be similar to those in Brazil [15]. Plant diseases like wheat blast can adversely affect human well-being by causing economic and agricultural losses, with repercussions for biodiversity conservation [16]. In this chapter, we explore the results of an innovative study that focuses on an ecofriendly solution for wheat foliar diseases. Our analysis covers key parameters, shedding light on the treatment's effectiveness in managing panicle blast across different wheat growth stages: milking, soft dough, and hard dough stages. We also investigate essential agricultural metrics, such as grain weight, weight of thousands of grains, panicle length, spikelet count, and crop yield. Our findings are organized for easy comprehension and meaningful discussions, providing insights into the treatment's implications for both agriculture and the environment.

2. Materials and Methods

2.1. Sample Collection

Wheat seeds exhibiting infection were gathered from blast infected south-western wheat-growing region of Kushtia, Bangladesh. Specifically, seeds from three varieties BARI Gom 24 (Prodip), BARI Gom 26, and BARI Gom 28 were collected because these varieties were available in that region and typical panicle blast symptoms appeared in the field during cultivation of these varieties.

2.2. Isolation and Identification of Causal Organism of Blast Disease of Wheat

Water agar (containing 20 g agar per 1000 ml distilled water) and oat meal agar media (OMA; composition: 40 g of oats, 5 g of sucrose, 20 g of agar, and 1000 ml of distilled water) were employed to isolate the blast pathogen. Using a sterile, moistened needle, individual conidia were carefully picked up from incubated seeds and placed onto the water agar. After a 12-hour incubation period, mycelium became visible in the petri dish, at which point a hyphal tip was transferred to OMA media plates supplemented with Streptomycin (40 $mg \cdot L^{-1}$). This process allowed for the creation of a pure culture of *Magnaporthe oryzae triticum*, which was cultivated at a temperature of 26˚C ± 1˚C. The marginal mycelial growth was aseptically collected for subsequent sub-culturing until a completely pure culture of *Magnaporthe oryzae triticum* was established (**Figure 1**). This pure culture was maintained through regular sub-culturing every 15 days and stored at a low temperature of 4˚C in a refrigerator.

To induce sporulation, oatmeal agar plates were inoculated with mycelial block of *Magnaporthe oryzae triticum* and incubated at a temperature of 26˚C ± 1˚C for approximately 10 to 15 days, subject to a cycle of 12 hours of darkness followed by 12 hours of light to promote sporulation. Once conidia had developed on the Oatmeal Agar (OMA) plates, they were examined under a compound microscope for further analysis. The pathogen was identified based on its cultural and morphological characteristics, following the methods outlined by Agrawal *et al.* (1989) [17] and Mew *et al.* (2002) [18].

2.3. Pathogenicity Test for *M. oryzae triticum* Isolate

Pathogenicity test was conducted to confirm the pathogenic nature of wheat blast pathogen isolates using Koch's postulates and Chevalier *et al.*, 1991 method [19]. The test involved sowing disinfected viable seeds of BARI Gom 24 (Prodip) in previously sterilized field soil in pots, followed by inoculation with a spore suspension of 10^5 $spore \cdot ml^{-1}$ using an atomizer sprayer. After incubation for 7 days at 26˚C ± 1˚C, observations were made for the development of symptoms on the leaves (**Figure 2**), and the fungus was re-isolated from artificially inoculated

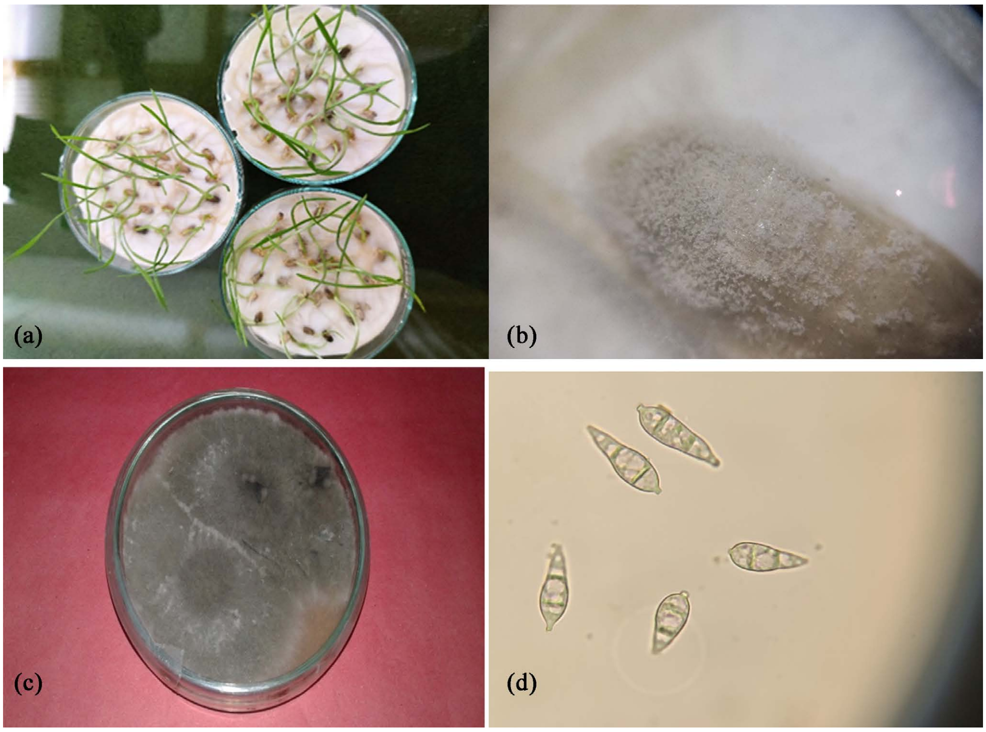

Figure 1. Isolation, identification and culture of *Magnaporthe oryzae triticum* on Oat Meal Agar media. (a) Incubation of infected seed on moist chamber; (b) Habit characteristics of *Magnaporthe oryzae triticum* on seed observed under stereomicroscope (×40); (c) Pure culture of MoT on OMA and (d) Conidia of MoT under compound microscope (×400).

Figure 2. Typical spindle shaped leaf blast symptom on inoculated leaf.

wheat seedling leaves showing blast symptoms. The test was replicated three times, and the pathogenicity of *M. oryzae triticum* isolates was confirmed.

2.4. Maintenance of Isolates *Magnaporthe oryzae triticum*

The fungus was subjected to sub-culturing on OMA (Oatmeal Agar) media and maintained at a temperature of 26˚C ± 1˚C for a duration of 15 days. Following this initial sub-culturing, subsequent re-cultivation of the isolates occurred at 30-day intervals. The isolate was preserved in a refrigerator at −20˚C for further research work.

2.5. Field Experiment: Development of Ecofriendly Management for Panicle Blast of Wheat

The field experiment aims to develop ecofriendly methods to manage wheat blast disease caused by *Magnaporthe oryzae triticum*.

2.6. Treatments

Ecofriendly management components along with control were selected as treatment. Those are; T_1 = Control, T_2 = *Allium sativum* (Garlic clove extracts, 1:5 w/v), T_3 = *Aloe vera* (Allovera leaf extracts, 1:5 w/v), T_4 = *Nigella sativa* (Black cumin seed extracts, 1:5 w/v), T_5 = *Azadirachta indica* (Neem leaf extracts, 1:5 w/v), T_6 = Nativo 75 WG (0.1%), and T_7 = Provax 200 WP (0.3%). Botanical extracts and fungicide (Nativo 75 WG) were sprayed in research plots at 60 days after sowing of the seeds. Seed treatment with Provax 200 WP was done before sowing of seeds.

2.7. Application of Fertilizers and Manures

All fertilizers, except urea, were applied at the BARI recommended rates 150 kg/ha TSP, 50 kg/ha MOP, and 120 kg/ha gypsum. Nitrogen fertilizers were applied according to specific plot treatments. These fertilizers, apart from urea, were uniformly integrated into the soil during land preparation using a spade.

2.8. Intercultural Operation

Seedlings emerged within 10 days of sowing. Thinning occurred twice: first, after 15 days to remove weak seedlings, and second, 15 days later to keep only healthy ones. Three irrigations were applied: at 20 DAS for crown root initiation, at 50 DAS for maximum tillering, and at 72 DAS during grain filling. Drainage was employed as needed. Two hand weeding took place at 30 and 50 days after sowing, and netting protected the seeds from birds.

2.9. Data Collection

Data was recorded on panicle blast incidence (%) at milking stage, soft dough stage and hard dough stage, panicle blast severity at milking stage, soft dough stage and hard dough stage, weight of seeds per plot (g), 1000 seeds weight (g), spike length, Spikelet spike-1 and Yield ($t \cdot ha^{-1}$).

2.10. Harvest and Post-Harvest Operation

Crop maturity was identified when 85% to 90% of the grains turned golden yellow. A 1 m^2 area from the center of each plot was harvested to measure individual treatment yields, which were then converted to tons per hectare ($ton \cdot ha^{-1}$). The harvested crops from each plot were bundled separately, appropriately labeled, and taken to the threshing floor. After drying in the sun, the bundles were threshed, and the grains were thoroughly cleaned. Grain and straw weights for each experimental plot were recorded after proper sun-drying.

2.11. Determination of Panicle Blast Incidence (%) and Severity (%)

Incidence of panicle blast was calculated by following formula:

$$\text{Disease incidence}(\%) = \frac{\text{Numbers of infected plant} \times 100}{\text{Numbers of inspected plant}}$$

Panicle blast severity was determined using the scale proposed by Trindade *et al.* (2006) [20]. It was based according to the point at which the pathogen had penetrated the rachis and affected the length of the spike. The score 0 referred to no visual symptoms, 1 for 25% of the spike showing symptoms; 2 for 50%, 3 for 75% and 4 for 100% length of spike affected.

2.12. Spike Length, Number of Spikelet, Weight of 1000 Grains and Grain Yield

The measurement process involved counting the spike length on five plants, from the basal node of the rachis to the apex of each spike, and then averaging these values. Similarly, the number of spikelet was determined by counting from five spikes and calculating the average per spike-1. For each plot, a random selection of one thousand cleaned, dried grains were weighed using a digital electric balance, with the measurement taken when the grains retained 12% moisture. The mean weight was expressed in grams. Finally, the grain yield was calculated from the randomly selected 1 m^2 area of each plot and expressed as tons per hectare ($t \cdot ha^{-1}$) at 12% moisture content.

2.13. Statistical Analysis of Data

The relevant data were statistically analyzed using analysis of variance to find out the variation of results from experimental treatments by Statistics 10 software. Treatments means were compared by DMRT.

3. Results and Discussion

We isolated five isolates of the blast pathogen using water agar and maintained on Oat Meal Agar (OMA). The pathogen was identified based on cultural and morphological characteristics following methods by Agrawal *et al.* (1989) [17] and Mew *et al.* (2002) [18]. To confirm pathogenicity of five isolates, we followed Koch's postulates following Chevalier *et al.* (1991) [19]. The isolates were cultured on OMA for sufficient sporulation that previously supported by many researchers [21] [22] [23]. We sowed sterilized BARI Gom 24 (Prodip) seeds in pots, inoculated with a spore suspension, and observed symptoms on leaves after 7 days at 26˚C ± 10˚C. The fungus was re-isolated from symptomatic leaves, and this pathogenicity test was repeated three times, confirming the pathogenic nature of *Magnaporthe oryzae triticum* isolates.

3.1. Germination of Wheat Cultivars and Incidence of Seed Borne Fungi of Wheat Cultivars

Different wheat cultivars exhibited varying seed germination and blast disease incidence. BARI Gom 24 (Prodip) had the highest germination and %MoT incidence, while cultivars like BARI Gom 26 and BARI Gom 28 had the lowest %MoT incidence (**Table 1**).

3.2. Effects of Different Control Measures on Incidence (%) and Severity of Panicle Blast of Wheat at Different Growth Stages

Disease incidence (%) indicted the presence of disease in investigated area. Different treatments showed statistically significant variation on blast disease incidence of wheat at milking stage (**Figure 3**). Among different treatments highest blast disease incidence (13.13%) was observed with T_1 (control) treatment which were statistically similar with T_2, T_3, T_4 treatments. Lowest disease incidence (7.86%) was observed with T_7 (Provax 200 WP) treatment which showed statistically identical result with T_5 (Neem leaf extracts) treatment.

Different treatments showed statistically significant variation on panicle blast severity of wheat at milking stage (**Figure 3**). Among different treatments highest blast disease severity score (1.97) was observed with T_1 (control) treatment followed by T_4 treatment which showed 1.60 disease severity at milking stage. Lowest disease severity 1.03 was observed with T_7 (Provax 200 WP) treatment which showed statistically identical result with T_5 (Neem leaf extracts) treatment. The treatment T_5 showed 1.13 blast disease severity at milking stage. It has been observed that chemical fungicide showed statistically similar results with ecofriendly botanical treatment. The severity of the disease during the milking stage resulted in poor wheat grain development. Natural compounds that are safe for the environment and have low toxicity to living animals are gaining

Table 1. Germination of wheat cultivars and %incidence of seed borne fungi on wheat seeds.

Variety	%Germination	Incidence of *Magnaporthe oryzae triticum* (%)	Incidence of *Bipolaris sorokiniana* (%)	Incidence of *Alternaria triticina* (%)	Incidence of *Aspergillus niger* (%)
BARI Gom 24 (Prodip)	93	30	12	15	14
BARI Gom 26	90	0.1	13	11	12
BARI Gom 28	92	0.8	13	10	11

interest as important sources for the manufacture of fungicides.

At the soft dough stage, treatments exhibited significant differences in wheat blast disease incidence (**Figure 4**). The control treatment had the highest incidence, while Provax 20WP and Neem leaf extracts showed lower incidences. Chemical fungicides and ecofriendly botanicals showed similar effectiveness. Some fungicides can have harmful effects, while botanical pesticides have proven to be safe and environmentally friendly. The findings align with previous studies recommending neem extract for blast disease management.

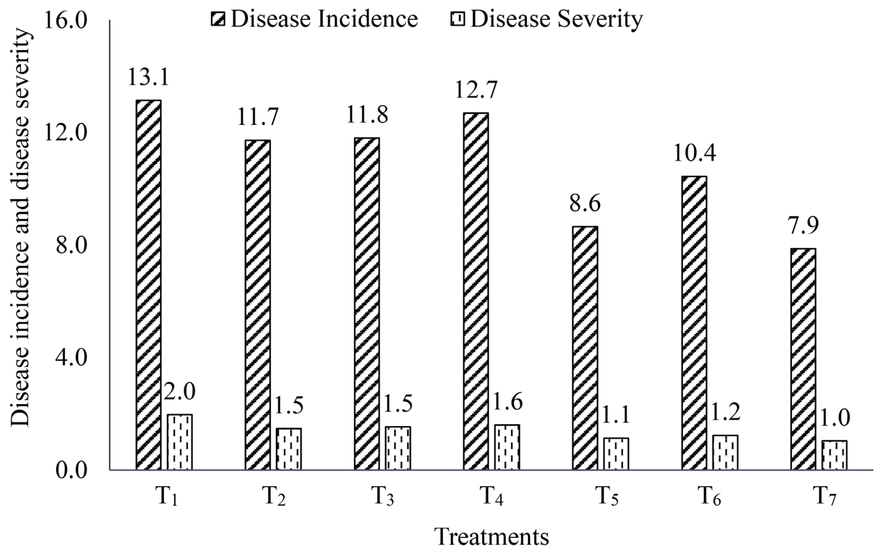

Figure 3. Effects of different control measures on wheat panicle blast incidence (%) and severity at milking stage. Where T_1 = Control, T_2 = Garlic clove extract, T_3 = *Aloe vera* leaf extract, T_4 = Black cumin seed extract, T_5 = Neem leaf extract, T_6 = Nativo 75 WG and T_7 = Provax 200 WP.

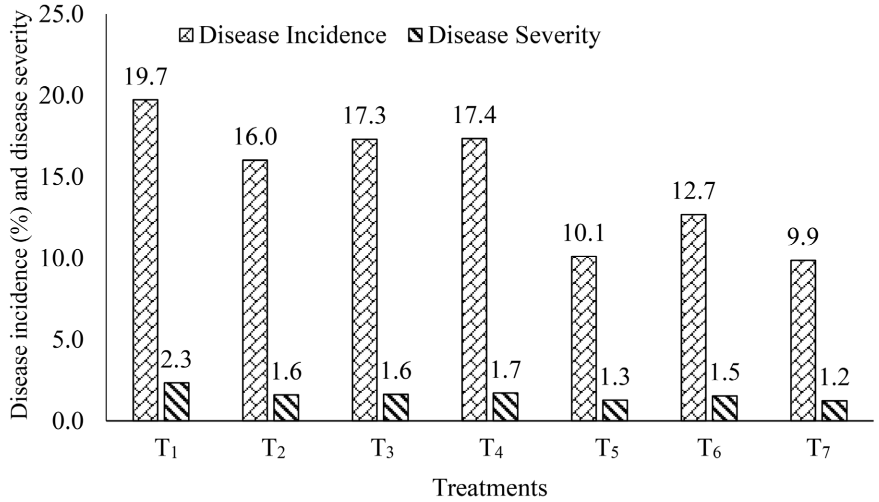

Figure 4. Effects of different control measures on wheat panicle blast incidence (%) and severity at soft dough stage. Where T_1 = Control, T_2 = Garlic clove extract, T_3 = *Aloe vera* leaf extract, T_4 = Black cumin seed extract, T_5 = Neem leaf extract, T_6 = Nativo 75 WG and T_7 = Provax 200 WP.

Treatments showed significant variations in panicle blast severity of wheat at the soft dough stage (**Figure 4**). The control treatment had the highest severity, followed by T_4. The lowest severity was observed with T_7 (Provax 200 WP) and T_5 (Neem leaf extracts) treatments. The treatment T_5 effectively reduced blast disease severity. Chemical fungicides and ecofriendly botanicals had similar effectiveness in reducing wheat blast disease severity.

According to Hajano *et al.* (2012) [24], fungicide overuse can harm humans, plants, and beneficial microbes. In contrast, botanical pesticides have minimal environmental impact. Like our study Agbowuro *et al.* (2020) [25] found the effectiveness of neem extract in reducing wheat blast incidence and severity. The findings of the present study also corroborate with the study of Rijal and Devkota (2020) [26].

Different ecofriendly treatments showed significant variations in wheat blast disease incidence at hard dough stage (**Figure 5**). The control treatment had the highest incidence, while Provax 200 WP and Neem leaf extracts exhibited lower incidences. Chemical fungicides and ecofriendly botanicals had similar effectiveness. Natural compounds with minimal toxicity are gaining interest as fungicide alternatives. Previous studies support the use of ecofriendly botanicals to reduce blast disease incidence in wheat.

At the hard dough stage, treatments showed significant differences in panicle blast severity (**Figure 5**). The control treatment had the highest severity, while Provax 200 WP and Neem leaf extracts showed lower severities. Ecofriendly management achieved similar results to chemical fungicides in controlling wheat blast disease. Botanical metabolites were found to have toxic effects on fungal cells. Previous studies also support the use of ecofriendly botanicals to reduce blast disease severity in wheat [25] [26].

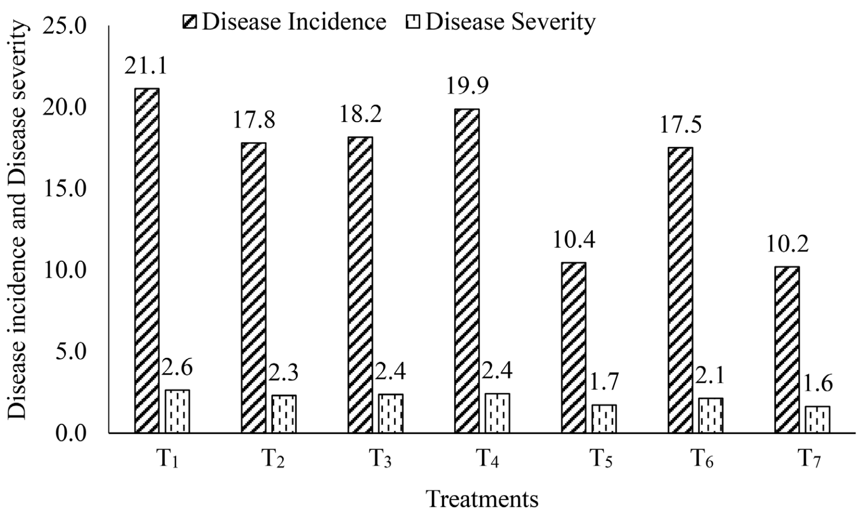

Figure 5. Effects of different control measures on panicle blast incidence (%) and severity of wheat at hard dough stage where T_1 = Control, T_2 = Garlic clove extract, T_3 = *Aloe vera* leaf extract, T_4 = Black cumin seed extract, T_5 = Neem leaf extract, T_6 = Nativo 75 WG and T_7 = Provax 200 WP.

3.3. Effects of Different Control Measures on Growth and Yield of Wheat

Treatments showed significant differences in wheat spike length (**Table 2**). The highest spike length was observed with Provax 200 WP treatment (T_7), while the control treatment (T_1) had the lowest spike length. Botanical metabolites have toxic effects on fungal cells, inhibiting their growth. Ecofriendly botanicals reduced disease infestation and promoted crop growth. The findings are supported by previous studies.

Treatments had significant effects on wheat spikelets per spike (**Table 2**). The highest spikelets per spike were observed with Provax 200 WP and Neem leaf extracts treatments. The control treatment had the lowest spikelets per spike. Ecofriendly botanicals reduce disease severity and promote wheat growth. Previous studies support the findings, emphasizing the effectiveness of botanicals in disease management and crop improvement.

Grain weight per plot of wheat varied significantly with different botanical treatments for blast disease management (**Table 2**). Provax 200 WP and Neem leaf extract treatments resulted in the highest grain weight per plot. The control treatment had the lowest grain weight per plot. Ecofriendly botanicals reduce disease severity and enhance wheat productivity. Previous studies support the use of botanicals for disease control and improved crop yield.

Various control measures had a positive impact on the weight of wheat grains in thousands (**Table 2**). Notably, the Provax 200 WP treatment demonstrated the highest grain weight, on par with the other treatments, while the control treatment yielded the lowest weight. Both ecofriendly botanicals and chemical

Table 2. Effects of different control measures on growth and yield of wheat.

Treatments	Panicle length (cm)	Spikelets per panicle	Grain weight per plot (g)	Weight of thousands grain (g)	Yield ($t \cdot ha^{-1}$)	Yield increased over control (%)
T_1	16.2^{c}	17.1^{d}	1056.0^{d}	48.2^{b}	2.05^{c}	--
T_2	16.9^{bc}	18.3^{bc}	1182.7^{cd}	50.6^{ab}	2.36^{b}	15.5
T_3	16.9^{bc}	18.2^{bc}	1182.0^{cd}	50.1^{ab}	2.31^{b}	13.0
T_4	16.5^{bc}	18.0^{c}	1106.0^{cd}	50.1^{ab}	2.25^{bc}	9.8
T_5	17.1^{b}	20.9^{a}	1352.0^{ab}	52.9^{ab}	2.63^{a}	28.4
T_6	17.0^{bc}	19.1^{b}	1222.3^{bc}	51.0^{ab}	2.37^{b}	15.6
T_7	17.9^{a}	21.1^{a}	1379.3^{a}	53.4^{a}	2.64^{a}	28.9
$LSD_{(0.05)}$	0.83	1.02	152.15	4.71	0.22	--
C.V. (%)	3.75	3.94	7.06	5.21	5.13	--

T_1: Control, T_2: Garlic clove extracts, T_3: *Aloe vera* leaf extracts, T_4: Black cumin seed extracts, T_5: Neem leaf extracts, T_6: Nativo 75 WG T_7: Provax 200 WP. Different letters (a, b, c, d) within the same column indicate statistically significant differences among treatments for that particular parameter.

fungicides yielded similar wheat yields, aligning with previous research advocating the utilization of organic resources in fungicide development.

Different control approaches significantly impacted wheat yield ($t \cdot ha^{-1}$) for blast disease management (**Table 2**). Provax 200 WP and Neem leaf extract treatments showed the highest yields, while the control had the lowest yield. Ecofriendly botanicals offer a safe and effective alternative to synthetic fungicides. Previous studies support the use of botanicals for blast disease control and maintaining wheat production.

3.4. Effect of Different Control Measures on Association of MoT Isolates on Panicle and Harvested Seeds

The MoT isolate (conidia) was detected on infected glumes but was not present on harvested seeds following incubation (**Figure 6**). Environmental factors may have hindered seed infection. Further evaluation is required to understand the seed transmission nature of the MoT isolate under controlled conditions.

The application of Provax 200 WP proved to be highly effective in controlling blast disease of wheat, resulting in the longest wheat spikes recorded at 17.9 cm. Among all the botanical treatments tested, spike length was statistically similar, but significantly different from the outcomes of Provax 200 WP. The control group exhibited the shortest spike length of 16.2 cm. When Provax 200 WP was applied in the field to manage wheat blast disease, it led to the highest number of spikelets per panicle (21.1), which was statistically comparable to the results obtained with neem leaf extract treatment. The control group had the lowest spikelets per spike, totaling 17.1.

Regarding grain weight per plot, both Provax 200 WP and neem leaf extract applications were successful in controlling blast disease, yielding 1379.3 g and 1352 g, respectively. In contrast, the control treatment had the lowest grain weight per plot, totaling 1056.0 g. Provax 200 WP application also demonstrated superiority in terms of thousands grain weight, with wheat grains weighing 53.4 g, which was statistically equivalent to the results achieved with botanical applications. The control group had the lowest thousands grain weight of 48.2 g. As for overall yield, Provax 200 WP treatment led to the highest yield of 2.64 $t \cdot ha^{-1}$, statistically equivalent to the yield of 2.63 $t \cdot ha^{-1}$ obtained with neem leaf extract application. The lowest yield of 2.05 $t \cdot ha^{-1}$ was recorded in the absence of any chemical or ecofriendly management for wheat blast disease. In a study, *Aloe vera* (*Aloe vera* leaf) extracts and *Nigella sativa* (Black cumin seeds) extracts, both at a concentration of 0.4% (1:1 w/v), showed the highest radial mycelial growth inhibition of the pathogen at 7 days after inoculation. The inhibition measured 3.00 mm and 3.33 mm, respectively. On the other hand, the lowest inhibition was observed using *Allium cepa* (onion) extracts at a concentration of 0.1% (1:0.25 w/v), which resulted in 38.33 mm of growth inhibition of the pathogen under in-vitro conditions [27]. For ethanol extracts of botanical, neem exhibited the highest growth inhibition of *Magnaporthe oryzae oryzae* (MoO) at

Figure 6. Experimental activities and field view. (a) Collected seed sample; (b) Seed sowing in the field; (c) Field visit in seedling stage; (d) Experimental wheat field during panicle initiation stage; (e) and (f). Infected field; (g) Bleached spike and (h) MoT sporulation on infected glume under stereomicroscope after harvest (×40).

all tested concentrations, with inhibition percentages of 92.62%, 90.52%, and 88.42%, respectively [28] that support our study.

4. Conclusion

In Bangladesh, wheat blast disease has caused significant yield losses in a country where 80% of the population relies on agriculture. Traditional fungicides pose risks to humans and the environment, highlighting the need for ecofriendly management strategies. An experiment directed at Sher-e-Bangla Agricultural University found that neem leaf extract showed promising results in decreasing blast disease incidence and severity in wheat, comparable to the chemical fungicide Provax 200 WP. The use of neem leaf extract and Provax 200 WP resulted in higher spike length, spikelets per panicle, grain weight per plot, and wheat yield compared to the control. However, neem leaf extract offers an environmentally safe alternative to Provax 200 WP. Therefore, Neem leaf extract is suggested for further assessment and possible adoption as an environmentally-friendly strategy for managing wheat blast disease across diverse agricultural regions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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