Control Effect of Different Chemicals on Rice Panicle Rot Induced by Flowering Promoter

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Abstract. Flowering promoters, as a class of chemical reagents that can improve the flowering rate of plants, are widely used in the process of rice hybrid seed production. Their core purpose is to enhance hybrid success rate by regulating flowering characteristics. However, spraying them can increase humidity and reduce air permeability around rice panicles, thereby significantly raising the risk of panicle rot. In this study, the flowering promoter was compounded with 50% propiconazole, 40% difenoconazole, and 40% fluosilazone, and spraying experiments were conducted at the flowering stage on three rice male sterile lines (Mo 3A, Mo 1A, and Mo 15A) with different flowering habits to explore the control effect of flowering promoter compounded with fungicides on panicle rot. The results showed that, compared to flowering promoter alone, the optimal compounded treatments reduced disease rating by 47.58% in Mo 1A (flowering promoter + difenoconazole), 10.43% in Mo 3A (flowering promoter + fluosilazone), and 46.18% in Mo 15A (flowering promoter + propiconazole + fluosilazone), while simultaneously increasing flowering rate by 37.60%, 8.25%, and 33.63%, respectively. The optimal fungicide combinations for controlling panicle rot varied among male sterile lines with different flowering habits. The optimal fungicide combinations for controlling panicle rot varied among male sterile lines with different flowering habits. In practical application, the compounded reagents should be reasonably selected according to rice varieties.

Keywords: Inhibition effect; Rice production; Pharmaceutical formulation

1 Introduction

Rice panicle rot disease is a fungal disease that primarily affects rice panicles and grains (Wang et al., 2022). In recent years, it has become a widespread post-harvest disease in rice-growing regions across China, with a particularly high incidence under high-temperature and high-humidity climatic conditions (Cao et al., 2025; Gu et al., 2025). This disease not only reduces yield but also causes the pathogenic bacteria to produce

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pigments and toxins, altering the appearance of rice grains and degrading their quality and safety, thereby posing risks to human and livestock health (Deng et al., 2025; Huang et al., 2012; Li et al., 2023).

The occurrence of panicle rot is closely related to environmental humidity. In hybrid rice seed production, the application of flowering promoters is commonly employed as a technical measure to enhance the flowering rate of maternal sterile lines and ensure seed production efficiency (Huang et al., 2023). Flowering promoters, as a class of chemical agents that regulate plant flowering characteristics, can effectively shorten flowering time and enhance cross-pollination seed setting rates (Jiang, 2020). Particularly in hybrid rice seed production, they facilitate concentrated flowering timing, which is beneficial for paternal pollination. However, production practice has revealed that the application of flowering promoters significantly increases panicle moisture content in rice, particularly under small-scale bagging seed production conditions. The moist environment provides a breeding ground for pathogen proliferation in panicles, serving as a critical anthropogenic factor contributing to the onset of panicle rot (Gao et al., 2024).

In view of the above situation, this study intends to control the occurrence of panicle rot by using compound pesticides, clarify the control effect of flowering promoter and different fungicides on rice panicle rot, screen out the best compound combination, and explore its possible control mechanism, so as to provide scientific and effective solutions for rice hybridization.

2 Materials and Methods

2.1 Overview of Test Materials and Site

The flower rate of Mo3A was 27.15%, Mo1A was 14.17%, and Mo15A was 2.28%, which showed that the flower rate of Mo3A was the highest.

The test rice material R727 (father plant) was sown on March 20, while the sterile mother plant was sown from late April to early May according to its growth period. The flowering period was adjusted to mid-July to coincide with the flowering period of the father plant. Field management was carried out normally.

The test strains were collected from rice plants infected with panicle rot in the experimental field. They were brought back to the laboratory for isolation, purification, and cultivation on potato dextrose agar (PDA) medium.

The tested fungicides were 50% propiconazole (Qingdao Gris Pharmaceutical Co., Ltd., Shandong Province, 1.147 mg/L), 40% difenoconazole (Shanghai Hulian Biological Pharmaceutical (Xiayi) Co., Ltd., 1 mg/L), and 40% fluosilazone (Shandong Yetai Biotechnology Co., Ltd., 1.154 mg/L).

The test flowering promoter was prepared as a 500 mL mixture using commercially available reagents, which consisted of 1 μg/mL KT(500 μL), 0.1% (V/V) Tween-20 (2.5 mL), 1 μg/mL 6-BA(500 μL), and 1 mmol/L MeJA(125 μL). (prepared from commercial reagents)

The field experiment was conducted at the Bai Xiang Valley Research Base in Shizhong District, Leshan City, Sichuan Province. The experiment was carried out in

July 2024. All experimental plots had identical rice cultivation conditions. During the experiment, the soil temperature ranged between approximately 25°C and 28°C.

2.2 Experimental Design

This study comprised two components: laboratory antimicrobial tests and field trials. Field experiments were conducted first to investigate the synergistic effects of flowering promoters. After the trials, infected rice panicles were collected and returned to the laboratory for pathogen isolation, purification, and culture. Subsequently, antimicrobial tests were performed to further validate the efficacy of the flowering promoter combined with fungicides.

Three fungicides were compounded with a flowering promoter and mixed in a beaker to prepare a 500 mL solution. The seven compound formulations are listed in Table 1.

Table 1. Composition of the seven compound formulations.

Number	Formula	Total fungicide concentration (mg/L)
1	Flowering promoter+ Propiconazole	1.147
2	Flowering promoter+ Difenoconazole	1.000
3	Flowering promoter+ Fluosilazone	1.154
4	Flowering promoter+ Propiconazole + Difenoconazole	2.147
5	Flowering promoter+ Propiconazole + Fluosilazone	2.301
6	Flowering promoter+ Difenoconazole + Fluosilazone	2.154
7	Flowering promoter+ Propiconazole + Difenoconazole + Fluosilazone	3.301

Laboratory Antifungal Test.

The pathogen was isolated from infected rice ears and purified for further experimental use.

In a sterile environment, the pathogens were cultured using PDA solid medium by the streaking method. Subsequently, the inoculated plates were uniformly sprayed twice with a spray bottle containing a flowering promoter or compound solution (Table 1) to ensure thorough contact with the pathogens. The inoculated plates were then inverted and incubated in a 30°C incubator for 3 days. The diameter of the mold colonies was measured using the cross-matching method, and the average value of the measured diameter was taken to represent the antifungal efficacy of the flowering promoter or compound solution. Sterile water spray was used as the control (CK), with each treatment repeated three times.

Field Experiment.

Rice plants with good growth status, moderate morphological size, and no other visible diseases were selected as experimental materials. To enhance the accuracy and reliability of the experimental results and minimize interference from random factors, an additional treatment group receiving only flowering promoter spray and another

group receiving only water spray were established, resulting in a total of 9 treatment groups (Table 2).

Table 2. Treatment groups in the field experiment.

Number	Formula
1	Flowering promoter+ Propiconazole
2	Flowering promoter+ Difenoconazole
3	Flowering promoter+ Fluosilazone
4	Flowering promoter+ Propiconazole + Difenoconazole
5	Flowering promoter+ Propiconazole + Fluosilazone
6	Flowering promoter+ Difenoconazole + Fluosilazone
7	Flowering promoter+ Propiconazole + Difenoconazole + Fluosilazone
8	Flowering promoter
9	Water control

For each variety, 12 panicles of uniform size were selected from the initial panicle stage, and each pair of panicles was placed into a hybridization bag, resulting in 6 bags per treatment. Six bags of rice were divided into two groups. The first group (3 bags) underwent only pesticide spraying followed by plastic bagging, with rice flowering observed 1 hour post-treatment. The flowering rate was calculated as the average of observed flowering numbers. The second group (3 bags) received both pesticide spraying and plastic bagging, supplemented with artificial pollination using R727 rice as the male parent. After pollination, the plastic bags were sealed with paper clips. The mold incidence was observed 20 days post-treatment. The disease index (DI) was calculated as the percentage of infected grains relative to total grains, following the grading criteria by Zhang Jinglong et al (Zhang & Qiao, 2019). (Table 3). Unprocessed rice plants served as the control group (CK).

Table 3. Disease rating criteria for rice panicle rot.

Grade	Incidence
0	Healthy
1	Fewer than 5 infected grains (infected grains account for less than 6% of the total)
3	6-10 infected grains (infected grains account for 7%-13% of the total number of grains)
5	11-30 infected grains (infected grains account for 14%-38% of the total number of grains)
7	31-50 infected grains (infected grains account for 39%-63% of the total number of grains)
9	51 or more infected grains (with infected grains accounting for 64% or more of the total)

3 Results

3.1 In Vitro Antifungal Activity

The antifungal efficacy of the flowering promoter and compound formulations is shown in Table 4 and figure 1. The flowering promoter exhibited no significant antifungal effect, comparable to water. Among the seven tested compound solutions, all demonstrated certain antifungal effects against *Fusarium* head blight pathogens. The most effective compound solution was the combination of flowering promoter, propiconazole, difenoconazole, and fluosilazone, achieving an average colony diameter

of 1.88 cm, which was 79.11% lower than the water control group. This is likely due to the higher concentration of active ingredients in this compound solution, which inhibited pathogen growth through multiple mechanisms, thereby comprehensively suppressing *Fusarium* head blight pathogen proliferation and significantly reducing colony diameter.

Table 4. Antifungal effects of the flowering promoter and compound formulations.

Number	Formula	Average colony diameter (cm)
1	Flowering promoter+ Propiconazole	$8.25\pm0.75^{a,A}$
2	Flowering promoter+ difenoconazole	$3.96\pm2.04^{ab,A}$
3	Flowering promoter+ Fluosilazone	$5.65\pm1.70^{ab,A}$
4	Flowering promoter+ Propiconazole + Difenoconazole	$6.81\pm1.25^{ab,A}$
5	Flowering promoter+ Propiconazole + Fluosilazone	$7.88\pm0.65^{a,A}$
6	Flowering promoter+ Difenoconazole + Fluosilazone	$5.13\pm1.44^{ab,A}$
7	Flowering promoter+ Propiconazole + Difenoconazole + Fluosilazone	$1.88\pm0.37^{b,A}$
8	Flowering promoter	$8.25\pm0.75^{a,A}$
9	Water control	$9.00\pm0.00^{a,A}$

Note: Lowercase letters indicate statistically significant differences at the 5% level.

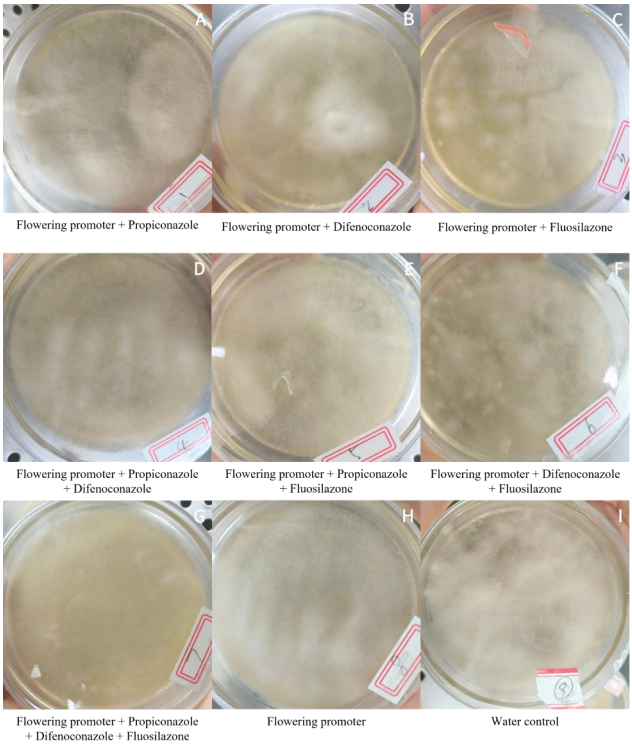


Fig. 1. In vitro antifungal activity of representative treatments.

3.2 Field Test of Flowering Promoter

Figure 2 and figure 3 demonstrates the effects of flowering promoters and chemical formulations on rice flowering and mold growth. The nine tested formulations (Table 2) exhibited varying mold-inhibiting effects on Mo1A, Mo3A, and Mo15A. To enhance experimental reliability and minimize random effects, an untreated control group (Formulation 10) was added to the study. In order to explore whether the compound agent can reduce the risk of infection of panicle rot caused by the application of flowering promoter, the flowering promoter treatment group was used as the control in the data analysis.

The Disease Prevention Effect of Flowering Promoter Compound Liquid on Mo 1A.

The control group treated with flowering promoter alone (average flowering rate: 21.57%, average disease rating: 5.67) served as the baseline. The combined formulation of flowering promoter + difenoconazole demonstrated superior performance. While maintaining a high flowering rate (34.57%, a 37.60% increase relative to the control), it achieved an average disease rating of 3.00, corresponding to a disease control efficacy of 47.58% (calculated as (5.67 − 3.00) / 5.67 × 100%). The formulation flowering promoter + propiconazole + difenoconazole + fluosilazone also showed moderate effectiveness, with a flowering rate of 31.13% (30.71% increase) and a disease rating of 3.00 (47.58% control efficacy). No other tested formulations achieved a disease rating below 4.00 on Mo 1A.

Effect of Flowering Promoter Compound Liquid on Disease Resistance of Mo 3A.

The control group treated with flowering promoter alone (average flowering rate: 80.04%, average disease rating: 6.33) served as the baseline. The combined formulation of flowering promoter + fluosilazone achieved an average flowering rate of 87.24% (8.25% increase relative to the control) and an average disease rating of 5.67, corresponding to a disease control efficacy of 10.43% (calculated as (6.33 − 5.67) / 6.33 × 100%). The formulation flowering promoter + difenoconazole + fluosilazone showed similar performance, with a flowering rate of 87.10% (8.11% increase) and the same disease rating of 5.67 (10.43% control efficacy). Other formulations did not achieve disease ratings lower than 6.00 on Mo 3A.

Effect of Flowering Promoter Compound Liquid on Disease Resistance of Mo 15A.

The control group treated with flowering promoter alone showed an average flowering rate of 12.83% and an average disease rating of 4.33. The combined formulation of flowering promoter + propiconazole + fluosilazone achieved the best overall performance, with an average flowering rate of 19.33% (a 33.63% increase relative to the control) and an average disease rating of 2.33, corresponding to a disease control efficacy of 46.18% (calculated as (4.33 − 2.33) / 4.33 × 100%). The formulation flowering promoter + difenoconazole + fluosilazone also showed moderate effectiveness, with a flowering rate of 16.93% (24.23% increase) and a disease rating

of 3.00 (30.72% control efficacy). Other formulations did not achieve disease ratings below 4.00 on Mo 15A.

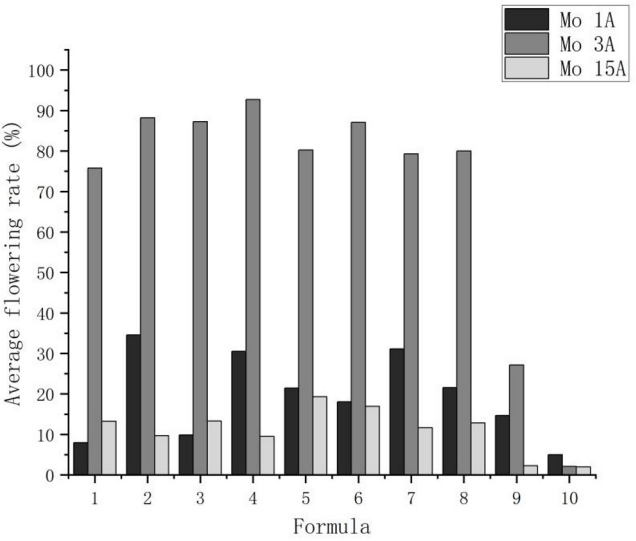


Fig. 2. Average flowering rate of three rice varieties.

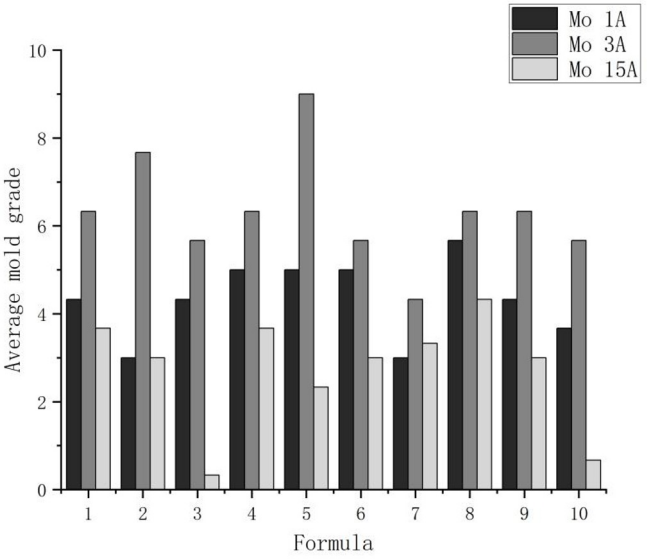


Fig. 3. Average disease rating of the three rice varieties.

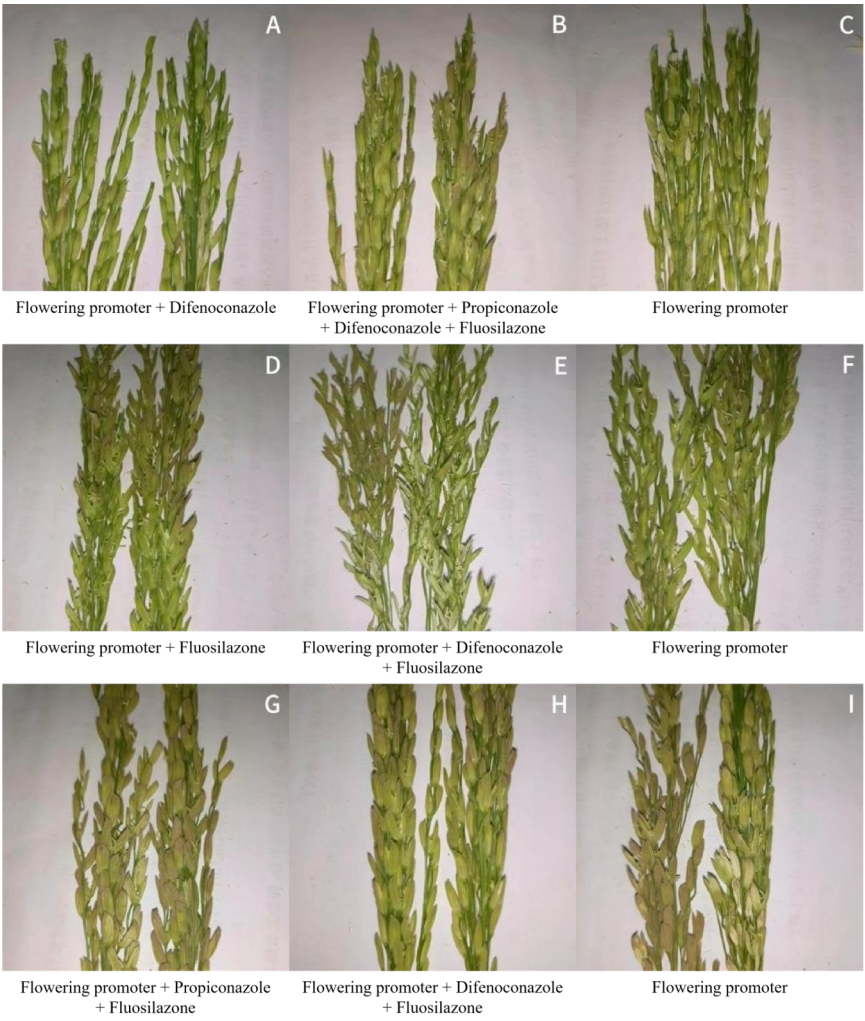


Fig. 4. Representative flowering performance of selected treatments on the three sterile lines. Mo 1A: A, B, C; Mo 3A: D, E, F; Mo 15A: G, H, I

4 Discussion

This study investigated the control effect of a flowering promoter combined with different fungicides on rice panicle rot. The best combination of flowering promoter and fungicides was screened according to the characteristics of different rice sterile lines. The results showed that the different compound combinations showed significant differences on different rice sterile lines, which might be related to the genetic background and physiological characteristics of the sterile lines (Zhang et al., 2014). The three sterile lines (Mo1A, Mo3A, and Mo15A) used in this study exhibited

differences in flowering level and susceptibility to panicle rot, resulting in distinct responses to the compound fungicide (Chen et al., 2024; Zhou, 2020). As shown in Figure 4, sterile lines with denser panicles exhibited higher disease severity, likely due to reduced air circulation and increased humidity under bagged conditions. This phenomenon may occur because dense panicles create restricted bagging hybridization conditions, reducing internal ventilation and light penetration. Such environments promote moisture accumulation, creating ideal conditions for mold growth. Conversely, sparse panicles maintain better air circulation and lower humidity, which inhibits mold development. Therefore, when formulating fungicide–flowering promoter mixtures, it is essential to comprehensively evaluate rice varieties for disease severity, flowering rate, and grain density per panicle. For low-flowering varieties prone to mold, prioritizing fungicide-flowering promoter combinations can improve flowering efficiency and reduce mold incidence. However, caution should be exercised with high-grain varieties to avoid exacerbating economic losses.

The occurrence of panicle rot not only reduces rice yield but also increases the cost of control, posing a serious threat to food security and sustainable agricultural development (Zhu et al., 2023). The study demonstrates that combining flowering promoters with fungicides effectively controls panicle rot in bagged hybrid rice. Different rice varieties respond differently to the mixed formulations: Mo 1A shows better disease control with a combination of flowering promoters and difenoconazole, Mo 3A responds well to a blend of flowering promoters and fluosilazone, while Mo 15A shows optimal results with a combination of propiconazole and fluosilazone. This indicates that selecting appropriate mixed formulations should be tailored to specific rice varieties, though their long-term effects and mechanisms require further investigation.

Quantitatively, the optimal compounded treatments achieved disease control efficacies of 47.58% (Mo 1A with difenoconazole), 10.43% (Mo 3A with fluosilazone), and 46.18% (Mo 15A with propiconazole + fluosilazone), while simultaneously increasing flowering rates by 37.60%, 8.25%, and 33.63%, respectively. These data confirm that the appropriate fungicide–flowering promoter combination can substantially reduce panicle rot risk without compromising, and in some cases even enhancing, flowering performance.

5 Conclusion

In this study, we demonstrated that compounding a flowering promoter with appropriate fungicides can effectively reduce the risk of rice panicle rot under bagged hybrid seed production conditions, while simultaneously maintaining or even improving flowering rates. The optimal fungicide combination varied among rice male sterile lines with different flowering characteristics: Mo 1A responded best to flowering promoter combined with difenoconazole (47.58% disease control efficacy, 37.60% flowering rate increase); Mo 3A to flowering promoter combined with fluosilazone (10.43% control efficacy, 8.25% flowering rate increase); and Mo 15A to flowering promoter combined with propiconazole and fluosilazone (46.18% control efficacy,

33.63% flowering rate increase). These quantitative results provide clear guidance for precision disease management in hybrid rice seed production.

In addition, laboratory antifungal tests confirmed that the four-component mixture (flowering promoter + propiconazole + difenoconazole + fluosilazone) exhibited the strongest in vitro inhibitory effect against Fusarium pathogens, reducing colony diameter by 79.11% compared to the water control, though its field performance was variety-dependent.

In conclusion, tailoring fungicide–flowering promoter combinations to specific sterile lines is a promising strategy to mitigate the unintended disease risk associated with flowering promoter application. Future research should investigate the long-term effects of these compounds on seed quality, their potential impact on non-target microorganisms, and the underlying mechanisms of variety-specific responses.

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Data availability

Not applicable. The data generated during this study are included within the article and its supplementary information files.

Ethics declaration

Not applicable.

Conflict of interest

The authors declare that they have no known cometing financial or personal interests that could have influenced the work reported in this study.

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