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Efficacy of Some Packages of Fungicide for Seed Treatment and Spraying Corn in the Fields against Downy Mildew

Ichwanul Malik Siregar[1], Salim Widono[1], Mohammed Iqbal Faruk[2], Supyani Supyani[1]*

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Central Java 57126, Indonesia
[2]Plant Pathology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur 1701, Bangladesh

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ABSTRACT

This study aimed to identify the most effective combination of seed treatments and fungicide applications to control downy mildew on corn seeds. It also evaluated the efficacy of various fungicides in suppressing the spread of downy mildew. The research was conducted from October 2021 to January 2022 in Banggle Village, Kanigoro District, Blitar Regency, Central Java Province. The methodology employed a randomized complete block design, with treatment factors including seed treatment and fungicide spraying. Four treatment packages were utilized: one control group with no seed treatment or fungicide application and three others as comparators. Each treatment was replicated four times. The active ingredients used for seed treatment and field spraying included Dimethomorph, Pyraclostrobin, Oxathiapiprolin, and Fenamidone. The results indicated that downy mildew on corn emerged during the fourth week after planting. Corn treated with the fungicide packages exhibited significantly better outcomes compared to the control group. The most effective treatment package involved seed treatment with Dimethomorph and Pyraclostrobin, followed by spraying with Dimethomorph on the seventh day after planting, Oxathiapiprolin on the fourteenth day, and Dimethomorph once again on the twenty-first day after planting. This combination achieved the highest efficacy index of 70.67%.

Keywords: Dimethomorph; Fenamidone; Oxathiapiprolin; Pyraclostrobin; *Zea mays*

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INTRODUCTION

Corn (*Zea mays* L.) is the second most important commodity after rice. Corn is one of the staple foods in various countries, with a total global corn production in 2018 of 1,147 tons (Ranilla 2020). Corn benefits humans and livestock by containing carbohydrates, fats, proteins, minerals, water, and vitamins. Its nutrients provide energy, form tissues, and regulate functions and biochemical reactions. The bioactive compounds contained in corn are phenolic compounds, carotenoids, tocopherols, and phytosterols (Siyuan et al. 2018). All parts of the corn plant can be used, such as stems and leaves, for feed, paper materials, and others (Panikkai et al. 2017). Hybrid corn is corn obtained from the result of crossing several strains. The resistance of the strains used for seed production dramatically determines the success of seed production in the field. Each strain has a different resistance to disease (Didan 2021).

Downy mildew, a major disease affecting corn plants, poses a significant threat due to the fungus *Peronosclerospora* spp. This destructive disease is caused by several fungi, including *P. sorghi*, *P. philippinensis*, *P. sacchari*, and *P. maydis*, and can lead to extensive damage of 80-100%, particularly in susceptible corn varieties (Talanca et al. 2011; Rashid et al. 2013; Ekawati et al. 2018). The pathogen can severely reduce corn yields, especially in favorable conditions such as high temperatures and humidity. Specifically, an air temperature around 30°C combined with high humidity and dew promotes the occurrence of downy mildew in corn. Additionally, wind plays a role in the release and spread of this airborne disease (Rustiani et al. 2015). Currently, controlling downy mildew remains a challenge; without effective measures, the intensity of this disease can reach 100%, leading to complete crop loss (Pakki et al. 2019).

Chemical control with fungicides is still the mainstay of farmers (Suliartini et al. 2022). According to MARI (2021), the accumulated number of pesticide brands has increased from year to year. In 2016 there were 3,930 brands, increasing to 5,284 brands in 2020. Downy mildew control can be done using seed treatment and spraying in the field using fungicides (Tanzil and Purnomo 2021). Examples of fungicides that can be used are fungicides that contain active ingredients metalaxyl and Dimethomorph (Amin et al. 2013). The

****Corresponding Author*:**
E-Mail: supyani.id@gmail.com

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advantages of using chemicals are that they work quickly, practically, efficiently, and effectively, are easy to get, do not need high skills, and control is evaluated rapidly.

Downy mildew is both seed-borne and airborne. So, the prevention of transmission through seeds can be done through seed treatment. Meanwhile, to prevent infection through air transmission, spraying can be done in the field. This study aims to evaluate the efficacy of some packages of fungicide for seed treatment and spraying the corn to control downy mildew.

MATERIALS AND METHODS

This research was conducted between October 2021 and January 2022 in Banggle Village, located in the Kanigoro District of Blitar Regency, East Java Province. The study employed a Randomized Complete Block Design (RCBD), utilizing treatment factors related to seed treatment and spraying, consisting of six levels. These levels included: (1) no seed treatment and spraying; (2) Existing Recipe (ER) as the comparator package, which included seed treatment with Dimethomorph and Pyraclostrobin (IM) + B1 (Package A comprising Dimethomorph and Pyraclostrobin (IM) + Dimethomorph (7 DPP), Fenamidone (14 HST), and Dimethomorph (21 DPP)); (3) seed treatment with Dimethomorph and Pyraclostrobin (IM) + B2 (Package B, consisting of Dimethomorph and Pyraclostrobin (IM) + Dimethomorph (7 DPP), Orondis (14 DPP), and Dimethomorph (21 DPP)); (4) Oxathiapiprolin (PLE) + Dimethomorph and Pyraclostrobin (IM) + B1 (Package C, which included Oxathiapiprolin (PLE) + Dimethomorph and Pyraclostrobin (IM) + Dimethomorph (7 DPP), Fenamidone (14 DPP), and Dimethomorph (21 DPP)); and (5) Oxathiapiprolin (PLE) + Dimethomorph and Pyraclostrobin (IM) + B2 (Package D, comprised of Oxathiapiprolin (PLE) + Dimethomorph and Pyraclostrobin (IM) + Dimethomorph (7 HST), Orondis (14 HST), and Dimethomorph (21 HST). Each treatment was replicated three times. The spraying regimen included Dimethomorph at seven Days After Planting (DAP), followed by Fenamidone 14 DAP, Dimethomorph 21 DAP (B1), and ultimately Dimethomorph at seven DAP combined with Orondis 14 DAP, Dimethomorph 21 DAP (B2). This study employed a quantitative methodology, with a sample size of 20 plants per plot, resulting in a total of 360 sampled plants. The research was carried out on corn fields affected by downy mildew, and the observation data was seen directly in the field, according to the change observed. The application of the treatment for seed treatment is carried out by coating the seeds with the active ingredient according to the treatment before planting, and the spraying treatment is carried out directly in the field according to the active ingredient at the specified time. Disease severity score categories according to Matruti et al. (2013) were 1. Normal (0%); 2. Mild attack (> 0− 25%); 3. Moderate attack (> 25−50%); 4. Severe attack (> 50−75%); 5. Very severe attack (> 75−100%). The observation data was statistically analyzed using variance analysis at 5%. Then, further tests were carried out for data that showed a real difference using Duncan's Multiple Range Test (DMRT) at 5%.

RESULTS AND DISCUSSIONS

Disease severity of downy mildew

The results of the observations in Table 1 showed that the best treatment for reducing the severity of the disease was the Comparative Package treatment, with an average severity of 21.95%. The average disease severity was 23.28% to 26.81% due to application of different treatment combination. However, each treatment did not show a significant difference in reducing the severity of downy mildew. Meanwhile, the treatment that showed a high severity was without seed treatment and fungicide spraying (control), with an average disease severity of 62.90%.

The average severity of downy mildew disease in the Java region caused by *P. maydis* is notably high, recorded at 62.90%. This is illustrated in Table 1, which highlights the variations in disease severity across different treatments. The elevated severity of the disease can result in substantial yield losses, ranging from 90% to 100%. Notably, the earlier the plants are infected, the greater the potential for crop loss (Pakki and Jainuddin 2019). It is believed that the severity or virulence of downy mildew caused by *P. maydis* is 25-30% higher than that induced by *P. philippinensis* (Djaenuddin et al. 2018). The discrepancies observed in the severity results across studies may stem from factors such as soil cultivars and the active ingredients in fungicides (Pakki and Jainuddin 2019).

Incidence and infection rate of downy mildew

Based on the observation results, each treatment can suppress the incidence of downy mildew. The analysis of the disease incidence of downy mildew in corns in Table 2 shows fundamental differences between treatments. The average disease incidence was 3.86% to 7.71% due to application of different treatment combination. The lowest percentage was obtained in corns that were given package B treatment, which was 3.86%, while in control plants, the disease incidence in corns reached 64%. But all the treatments are statistically identical

The infection rate serves as an indicator of how quickly the pathogen population and the associated disease are progressing. This rate can be calculated based on the severity of the disease. The analysis revealed significant differences in infection rates among various seed treatments and fungicide applications. As shown in Table 3, the highest infection rate was recorded in the control treatment, at 0.012 per unit per day. Generally, a higher infection rate correlates with increased severity and incidence of the disease, while a lower rate indicates reduced severity and incidence. Furthermore, the infection rate in the absence of treatment was significantly different from those in the comparison treatments: packages A, B, C, and D.

According to Pajrin et al. (2013), the higher rate of infection can occur if the host plant is planted in a susceptible variety. Then, the pathogen will infect the plant more quickly and spread wider. According to Jadhav et al. (2018), corn seedlings less than one week old are more susceptible to infection by pathogens, which can accelerate the infection rate by pathogens.

Table 1. Disease Severity of downy mildew for seven weeks after planting as effect of various packages of fungicide for seed treatment and spraying corn in the field

Seed Treatment and Fungicide Spraying Package	Disease Severity (%)
No treatment	62.90 ± 33.24b
Existing recipe as comparator	21.95 ± 2.64a
A. Seed Treatment using Dimethomorph and Pyraclostrobin followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), and Dimethomorph (21 DAP)	26.81 ± 6.82a
B. Seed Treatment using Dimethomorph and Pyraclostrobin (IM) followed by spraying Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	23.95 ± 4.74a
C. Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), Dimethomorph (21 DAP)	24.19 ± 4.35a
D. Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	23.28 ± 3.18a
Significance (*ρ*) of ANOVA	0.000
Coefficient of Variation (%)	17

Remark: Numbers followed by the same letter in the same column show no difference in DMRT of 5%; and DAP= day after planting.

Table 2. Disease Incidence of downy mildew for seven weeks after planting as effect of various packages of fungicide for seed treatment and spraying corn in the field

Seed Treatment and Fungicide Spraying Package	Disease Incidence (%)
No treatment	64.00 ± 5.42b
Existing recipe as comparator	4.43 ± 4.20a
A. Seed Treatment using Dimethomorph and Pyraclostrobin followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), and Dimethomorph (21 DAP)	7.71 ± 7.99a
B. Seed Treatment using Dimethomorph and Pyraclostrobin (IM) followed by spraying Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	3.86 ± 4.52a
C. Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), Dimethomorph (21 DAP)	6.71 ± 7.30a
D. Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	6.71 ± 6.70a
Significance (*ρ*) of ANOVA	0.000
Coefficient of Variation (%)	25

Remark: Numbers followed by the same letter in the same column show no difference in DMRT of 5%; DAP: the day after planting.

Area under the disease progression curve

Downy mildew is an epidemic disease that damages corn almost every season, especially outside the planting season or late planting. The total percentage of diseases depicted with the area under the disease progress curve (AUDPC) shows that control treatment has the highest total severity with a value of 2786, and the lowest was Package B with an AUDPC value of only 161 (Table 4). In the treatment combination package between packages A, B, C, and D, the highest AUDPC value was owned by package A, with a value of 315, followed by package D and package C, which had a value of 276.50 and 273, respectively. The lowest score among Package A, B, C, and D was owned by Package B, with a value of 161.

Fluctuations in the incidence, severity, and rate of disease progression can be influenced by various factors. Internal characteristics of pathogens, such as sporulation, play a significant role. Downy mildew spores that adhere to guttation water can develop and infect corn through the leaf tissue; however, in the absence of guttation water, the spores are unable to grow and progress. Environmental variables impacting downy mildew development include wind speed, humidity, and temperature (Purwanto et al. 2016). This observation aligns with the data presented in Table 4, as each treatment demonstrates varying AUDPC values, particularly those treated with seed treatments and fungicide applications compared to untreated ones.

Efficacy of control packages

The level of efficacy of the fungicide treatment package against downy mildew in corn plants are presented in Table 5. The observation results showed that the entire treatment package effectively reduced the intensity of downy mildew attack on corn plants, or there was a significant difference between seed treatment and fungicide spraying with efficacy, with the efficacy rate ranging from 0-75%. The comparison package was the most effective in suppressing downy mildew, with an efficacy value of 74%.

Based on the 2013 fungicide efficacy testing standard method, fungicide formulations are said to be effective when the efficacy level (EL) value is at least 50%, provided that the intensity of the treatment attack was significantly different from the control. Among the treatment packages, packages B and C had the highest efficacy rate at 70.67%, followed by package D with an efficacy rate of 68.67%. The lowest efficacy rate of each treatment package was owned by package A, with an efficacy level of 0.00%, so it was ineffective because the treatment has an efficacy rate of 0.00%.

The results of this study indicate that Dimethomorph is an effective fungicide for controlling downy mildew through corn seed treatment. This is in accordance with the results of other researchers. Puspita et al. (2023) reported that seed treatment of corn using Dimethomorph was able to reduce disease incidence of downy mildew, reaching 20.38% at 28 days after planting. More effective results were reported by Tanzil and Purnomo (2021) that seed treatment with Dimethomorph could reduce disease intensity by 71.86% compared to control.

Table 3. Infection rate of downy mildew for seven weeks after planting as effect of various packages of fungicide for seed treatment and spraying corn in the field

Seed Treatment and Fungicide Spraying Package	Infection Rate (unit.day^{-1})
No treatment	0.012 ± 0.001b
Existing recipe as comparator	0.000 ± 0.000a
A. Seed Treatment using Dimethomorph and Pyraclostrobin followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), and Dimethomorph (21 DAP)	0.001 ± 0.000a
B. Seed Treatment using Dimethomorph and Pyraclostrobin (IM) followed by spraying Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	0.000 ± 0.000a
C. Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), Dimethomorph (21 DAP)	0.003 ± 0.003a
D. Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	0.001 ± 0.001a
Significance (*ρ*) of ANOVA	0.000
Coefficient of Variation (%)	33

Remark: Numbers followed by the same letter in the same column show no real difference in terms of DMRT of 5%; DAP= day after planting

Table 4. Area under the disease progress curve of downy mildew for seven weeks after planting as effect of various packages of fungicide for seed treatment and spraying corn in the field

Seed Treatment and Fungicide Spraying Package	AUDPC
No treatment	2786.00 ± 70.32b
Existing recipe as comparator	180.83 ± 62.25a
Seed Treatment using Dimethomorph and Pyraclostrobin followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), and Dimethomorph (21 DAP)	315.00 ± 88.34a
Seed Treatment using Dimethomorph and Pyraclostrobin (IM) followed by spraying Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	161.00 ± 71.04a
Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Fenamidone (14 DAP), Dimethomorph (21 DAP)	273.00 ± 81.90a
Seed Treatment using Oxathiapiprolin (PLE), Dimethomorph, and Pyraclostrobin (IM) followed by spraying using Dimethomorph (7 DAP), Oxathiapiprolin (14 DAP), Dimethomorph (21 DAP)	276.50 ± 61.47a
Significance (*ρ*) of ANOVA	0.000
Coefficient of Variation (%)	24

Remark: Numbers followed by the same letter in the same column show no real difference in terms of DMRT of 5%; AUDPC= area under the disease progress curve; DAP= the day after planting.

Table 5. Efficacy Index of various packages of fungicide for seed treatment and spraying corn in the field to downy mildew at seven weeks after planting

Seed Treatment and Fungicide Spraying Package	Efficacy Index (%)
No treatment	-
Existing recipe as comparator	74.00 ± 5.29b
A. Dimethomorph and Pyraclostrobin (IM) + Dimethomorph (7 DAP), Fenamidone (14 DAP), Dimethomorph (21 DAP)	64.33 ± 13.87b
B. Dimethomorph and Pyraclostrobin (IM) + Dimethomorph (7 DAP), Orondis (14 DAP), Dimethomorph (21 DAP)	70.67 ± 9.24b
C. Oxathiapiprolin (PLE) + Dimethomorph and Pyraclostrobin (IM) + Dimeomorph (7 DAP), Fenamidone (14 DAP), Dimethomorph (21 DAP)	70.67 ± 12.86b
D. Oxathiapiprolin (PLE) + Dimethomorph and Pyraclostrobin (IM) + Dimeomorph (7 DAP), Orondis (14 DAP), Dimethomorph (21 DAP)	68.67 ± 12.06b
Significance (*ρ*) of ANOVA	0.000
Coefficient of Variation (%)	17

Remark: Numbers followed by the same letter in the same column show no real difference in terms of DMRT of 5%; DAP: the day after planting

Dimethomorph has been shown to effectively inhibit conidia germination of Peronosclerospora species, according to Widiantini et al. (2017). This fungicide penetrates well and disrupts cell wall formation, serving as both a protectant and an antisporulant against oomycete diseases. Anugrah and Widiantini (2018) further demonstrated that a 10,000 ppm concentration of Dimethomorph effectively reduces downy mildew development, resulting in a 37.9% impairment of conidial integrity. FAO (2008) also emphasized that Dimethomorph's mode of action includes inhibiting cell wall formation, leading to the failure of germ tube synthesis.

According to Luz et al. (2018), Pyraclostrobin works by reducing steady-state ATP, mitochondrial membrane potential, mitochondrial basal respiration, ATP-related respiration, and reserve respiratory capacity, indicating mitochondrial dysfunction, while reducing the expression of genes involved in glucose transport (Glut-4), glycolysis (Pkm, Pfkl, Pfkm), fatty acid oxidation (Cpt-1b), and lipogenesis (Fasn, *Acacα, Acacβ*) further indicate a metabolic disorder. Field evolution done by Fan et al. (2019) showed that Pyraclostrobin at 200 and 250 g a.i. per ha provided more than 80% control efficacy against apple ring rot when applied as a therapeutic or preventive fungicide. As for the efficacy when combined, Jiang et al. (2021) reported that the spray application strategy of Pyraclostrobin combined with Bordeaux mixture could effectively control leaf spots caused by *Colletotrichum fructicola*.

Spraying corn with Fenamidone also contributes to the effectiveness of the downy mildew control package with this fungicide. According to Fernández-ortuño et al. (2010), Fenamidone can be used as an alternative to control downy mildew, with active mechanisms that inhibit mitochondrial performance and carry out cellular respiration. Based on the results of the spore germination test conducted by Anugrah and Widiantini (2018) show that Fenamidone can cause spore germination to only reach 0.34, while the control reaches 31.62%. Anugrah and Widiantini (2018) reported that the use of Fenamidone at a concentration of 8.000 ppm can inhibit conidia germination of *Peronosclerospora* spp. By 0.34%, the highest level of conidia damage was detected low, namely 8.54%. Adhi et al. (2024) reported that Oxathiapiprolin was the most effective fungicide than Metalaxyl, Dimethomorph, and Fenamidone in damaging *P. maydis* conidia in all locations in Java.

CONCLUSIONS AND SUGGESTIONS

Conclusions

All disease management packages that included seed treatment and fungicide spraying demonstrated a significant reduction in the severity of downy mildew in corn, highlighting a high efficacy index. In terms of preventing downy mildew and promoting corn growth, all management packages effectively controlled the disease in the field.

Suggestions

The recommended package for fungicide control is particularly beneficial for farmers, emphasizing the use of seed treatment with Dimethomorph and Pyraclostrobin. This should be followed by a spraying schedule: Dimethomorph on the 7th day after planting, Oxathiapiprolin on the 14th day, and another application of Dimethomorph on the 21st day after planting. This approach is considered the most effective due to its high efficacy index and the straightforward nature of the fungicides used.

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