G-Tech : Jurnal Teknologi Terapan
Vol. 10, No. 3, July 2026, p. 1350-1358
E-ISSN: 2623-064X | P-ISSN: 2580-8737

Application of *Bacillus* spp. and Potassium Fertilizer Against Corn Downy Mildew Disease

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Article Information

Article History

Received : June 20, 2026
Revised : July 12, 2026
Published : July 24, 2026

***Keywords*:**

Bacillus subtilis;
Biological agent;
Corn;
Peronosclerospora;
Potassium.

ABSTRACT

Downy mildew is an important disease in corn cultivation caused by *Peronosclerospora* spp. There are many different pathogen species such as *P. maydis, P. sorghi*. Losses reach 50-80% in corn fields. The use of synthetic fungicides has a negative impact because it destroys natural enemies, resulting in pathogen resistance and plant residues. Balanced biological agents and fertilization are solutions to replace chemical fungicides. The aim of this study was to obtain the best dosage of *Bacillus* sp. and potassium fertilizer to suppress downy mildew and corn growth. The research method used a factorial Randomized Block Design (RBD). The dosage of *Bacillus* sp. was B0 (0 g), B1 (15 ml), B2 (20 ml). The dosage of potassium fertilizer (KCl) was 3 K0 (0 g/plant), K1 (6 g/plant), K2 (9 g/plant). There were 9 treatment combinations, 3 replications, so there were 27 treatment units. Plant height, number of leaves, temperature, humidity, disease incidence and disease intensity were observed. The treatment of the biological agent *Bacillus* spp. and the best potassium fertilizers are B1K0, B2K0 and B2K2 which are able to suppress the incidence of corn downy mildew disease, but are not yet able to produce plant height and number of corn leaves.

INTRODUCTION

Downy mildew is a significant disease frequently encountered in corn cultivation. This disease is caused by the fungal pathogen *Peronosclerospora* spp., as there are many different pathogen species, such as *P. maydis, P. sorghi,* and *P. phillipinensis* ((Wahyudi *et al.,* 2025). Losses from this pathogen can reach 50-80% (Wulandari *et al.,* 2020). According to Mirsam *et al.* (2023), the pathogen Peronosclerospora phillipinensis can cause yield reductions of more than 50%.

Bacillus subtilis is a bacterium that has biocontrol properties against downy mildew. *B. subtilis* can suppress downy mildew by up to 63.1% (Djaenuddin *et al.*, 2018). Khoiri *et al.* (2021), tested several types of *Bacillus* in suppressing downy mildew and showed that *B. polymyxa* strain BP18, *Bacillus subtilis* strain BS41, *Bacillus* sp. strain BT1, BT2 can suppress downy mildew. *Bacillus* sp. Strain BT1 can protect plants by up to 82.71%. Previous research also showed that the application of *B. subtilis* and *B. polymixa* can suppress the incidence of downy mildew and increase the viability of corn seeds (Windriyati *et al.*, 2023).

Balanced fertilization can improve plant health. Potassium is essential for plant health and suppressing pathogens. Potassium strengthens plant cell walls. Stronger cell walls increase plant resistance to downy mildew-causing pathogens. Potassium plays a role in building plant structural resilience by regulating the speed at which stomata close (Firmansyah *et al.*, 2021). This is

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reinforced by Usmadi *et al.* (2023), who found that potassium is used to enhance carbohydrate synthesis and translocation and can increase the strength of corn stalks. Furthermore, potassium fertilizer can increase the length, diameter, and weight of corn cobs. Syaiful *et al*. (2024) added that adequate plant nutrition makes plants more resistant to pathogen attacks because plant tissue is more difficult for pathogens to penetrate.

The simultaneous use of biological agents such as antagonistic bacteria and potassium fertilizer may be an alternative to synthetic fungicides. Based on this, this study aims to determine the best treatment with *Bacillus* sp. and potassium fertilizer for downy mildew and corn growth. The research will replace the use of synthetic fungicides with the use of a biological agent (biofungicide) *Bacillus* sp. and the addition of potassium fertilizer to corn plants. It is hoped that this research will provide new scientific knowledge and technology, especially for farmers, to reduce the use of synthetic fungicides.

RESEARCH METHODS

The research method used a factorial Randomized Block Design (RAK). The dosage of *Bacillus* sp. consisted of 3 levels, namely B0 (0 ml), B1 (15 ml), B2 (20 ml). The dosage of potassium fertilizer (KCl) consisted of 3 levels, namely K0 (0 g/plant), K1 (6 g/plant), K2 (9 g/plant). There were 9 treatments, 3 replications, a total of 27 treatment units. Applications are as follows:

1. Control (K); seeds are soaked in distilled water for 30 minutes before planting.
2. *Bacillus*; seeds are soaked in a biological agent containing *B. subtilis* and *Bacillus* sp. for 30 minutes before planting. Water the roots at 10, 15, 20, 25, 50, 55, and 60 days after planting. Spray the leaves at 30, 35, and 40 days after planting. *Bacillus* spp. isolates were cultured on NA slants and propagated in 100 ml of NB (Nutrient Broth) medium. The bacteria were further propagated using a formulated solution consisting of 750 ml of potato extract and 250 ml of coconut water. The mixture was agitated, incubated for one week, and applied (Idah, 2024).
3. *Potassium*; sprinkle around the plant roots and cover with soil. First fertilization (1/3 of the dosage) was applied at 8 days after planting, and second fertilization (2/3 of the dosage) at 24 days after planting.

The observed variables are plant height (cm), number of leaves, temperature, humidity, disease incidence, and disease intensity. The formula for calculating disease and disease intensity Khoiri *et al.* (2021) is as follows:

$$\text{Disease Incidence} = \frac{\text{n}}{\text{N}}\ x\ 100\%$$

N : Number of infected plants
N : Number of plants observed

$$\text{Disease Intensity} = \frac{\sum(\text{n x v})}{(\text{Z x N})}\ \text{x}\ 100\%$$

n : Number of plants in each attack category
v : Attack scale value
N : Total number of plants observed
Z : Highest attack scale value

Tabel 1. Scale of damage from downy mildew disease (Khoiri *et al*., 2021)

Scale	Information
0	No symptom
1	Symptom areas on leaves 1-25%
2	Symptom areas on leaves 26-50%
3	Symptom areas on leaves 51-75%
4	Symptom areas on leaves 76-10%

Data were analyzed using analysis of variance. If the test results showed significant differences between treatments, it was continued with Duncan's Multiple Range Test (DMRT) at the 5% level.

RESULTS AND DISCUSSION

Symptoms of Downy Mildew

Based on the research results, maize plants were found downy mildew symptoms. Symptoms of downy mildew on maize plants began to appear at 20 days after planting. The initial and more advanced symptoms of maize downy mildew can be seen in the image below. The symptoms begin with yellow streaks on the leaves; these streaks run parallel to the leaf veins and start from the upper leaves or the growing point. Subsequently, the yellow streaks spread to the lower leaves. White powder is usually clearly visible in the morning on both the upper and lower surfaces of the leaves. This is consistent with the statement of Sulfitri *et al.* (2024), which states that downy mildew symptoms appear as elongated chlorotic spots that run parallel to the leaf veins. Ukhtani *et al.* (2025) added that downy mildew symptoms are characterized by white lines or leaf chlorosis parallel to the veins. In addition, there is a powdery layer on the upper and lower leaf surfaces. The environmental conditions during the study had an average temperature of 30.41°C and a humidity of 96.14%. According to Nirwanto & Sutikno,(2024), the conidia of Peronosclerospora, the cause of downy mildew, require a minimum of more than four hours at a temperature of 10–33°C. The temperature and environmental conditions during the study are in accordance with this. When environmental conditions are favorable, the symptoms become more severe and the entire leaf of the maize plant turns completely yellow. This can be seen in Figure 1, with symptoms progressing from left to right.

Figure 1. Symptom of downy mildew

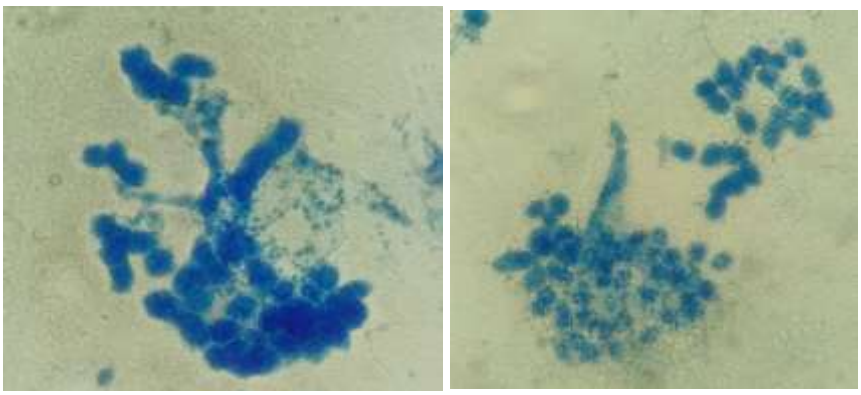

Figure 2. Morphology of *Peronosclerospora maydis* at 40 × 10 magnification

The morphology of the pathogen was observed in Figure 5.2. Methylene blue staining colored the conidiophores and conidia of *Peronosclerospora* sp. Based on the shape of the conidia,

which are round to somewhat round, it is suspected to be the species *Peronosclerospora maydis*. According to Widiantini *et al*. (2017), the conidia are spherical (round) to subspherical (somewhat round) with a size of 7.62–25.10 × 5.431–19.31 µm. The conidiophores are dichotomously branched two to three times, with a length of 78.2–228.0 µm. Sitanggang *et al.* (2025) stated that *P. maydis* has conidiophores that branch in two and then branch again into three. The conidiophores are 254.07 µm long, with spherical conidia measuring 28.79 µm × 25.59 µm and thick cell walls. Ukhtani *et al*. (2025) added that *P. maydis* has branched conidiophores, with conidial cells that are somewhat round, hyaline, and have thin cell walls. The conidia found in the field have thin cell walls, consistent with the statement of Ukhtani *et al.* (2023).

Disease Intensity and Disease Incidence

Based on Table 2, it was found that the intensity of downy mildew disease increased with each observation. The symptoms of downy mildew began to appear at 20 days after planting, namely in the control, B1K2, and B2K0 treatments. This indicates that the control plants, as well as the B1K2 and B2K0 treatments, had the fastest incubation period compared to other treatments. Downy mildew appeared earlier in the control plants, B1K2, and B2K0 compared to the other treatments. This shows that the application of *Bacillus* spp. and potassium fertilizer can shorten the incubation period of the other treatments.

Table 1. The effect of *Bacillus* spp. treatment and potassium fertilizer on the intensity of corn downy mildew disease

Treatment	Disease Intensity (%)						
	20 days NS	25 days NS	30 days NS	35 days NS	40 days NS	45 days NS	50 days NS
B0K0	5,56	13,89	19,44	33,33	38,89	41,67	52,78
B0K1	0,00	5,56	19,44	27,78	25,00	44,44	41,67
B0K2	0,00	5,56	22,22	11,11	25,00	25,00	38,89
B1K0	0,00	0,00	16,67	22,22	22,22	22,22	8,33
B1K1	0,00	8,33	11,11	11,11	11,11	22,22	41,67
B1K2	2,78	5,56	8,33	13,89	11,11	22,22	41,67
B2K0	2,78	8,33	19,44	13,89	11,11	25,00	22,22
B2K1	0,00	0,00	8,33	25,00	25,00	30,56	47,22
B2K2	0,00	5,56	11,11	19,44	22,22	36,11	33,33

NS: Nonsignificant

The analysis of variance showed that the intensity of downy mildew disease observed from 25 to 50 days after planting had no significant effect. However, Table 2 shows a tendency for the B0K0 (control) treatment to have the highest disease intensity compared to other treatments, except at 30 and 45 days after planting. The application of *Bacillus* spp. and potassium fertilizer in all treatments was still the same as the control. Disease intensity reflects the severity of disease in plants and is influenced by the plant's internal conditions after pathogen infection. Disease intensity is calculated from the symptoms observed on sample plants. Downy mildew symptoms tend to be systemic, so the infected part includes the entire plant from the growing point of the canopy downward. This is suspected to cause similar disease intensity among treatments. In addition, this study used the same corn variety, namely Bonanza MB, which is known to be susceptible to downy mildew disease (Ulhaq & Masnilah, 2019). Asri *et al.* (2024) and dSyaiful *et al*. (2024) stated that plant resistance is also influenced by the genetic factors of the plant and the plant variety. Mugiastuti *et al.* (2023) added that if the pathogen successfully infects, the defense mechanism is thought to require a stronger relationship with nutrients such as potassium to limit symptom severity. However, in this study, the potassium fertilizer applied did not have an effect on the disease because it is suspected that the fertilizer was washed away by rainwater. During the study, after the application of potassium fertilizer, there was heavy rainfall for several days and no re-fertilization was carried out.

Potassium deficiency leads to reduced enzyme activity and an inability to produce organic compounds, thereby diminishing the plant's disease resistance. Potassium promotes the development of thicker outer epidermal cell walls, which helps prevent pathogen attacks. Potassium deficiency can also disrupt protein synthesis and lead to the accumulation of simple nitrogen compounds (amides). Tissue hardening and stomatal opening are closely linked to potassium levels (Bayindir & Kucukyumuk, 2025). Potassium ions play a role in regulating guard cell turgor pressure, thereby determining stomatal pore opening and access to internal leaf structures. When potassium ions accumulate in the vacuole, guard cells absorb water from surrounding cells, swell, and open, facilitating gas exchange—which also increases the potential for pathogen infection. Conversely, when potassium ions move from the vacuole to epidermal cells, guard cells lose turgor, causing the stomata to close. Potassium deficiency can disrupt plant physiology and increase susceptibility to damage. Potassium fertilization can elicit varying responses depending on the specific disease and pathogen involved; these differences may stem from distinct pathogen infection methods, specific host-pathogen interactions, and the soil conditions used in the study (Ortel *et al.,* 2024). In this study, the spread of the downy mildew pathogen—facilitated by wind and rain splashes—resulted in a random and indistinct disease distribution pattern. Nutrient levels should be analyzed both before and after potassium application to clarify the status of available potassium and its specific impact on plant resistance.

Environmental conditions such as temperature and humidity will affect disease development and are reflected in disease intensity (Sulfitri *et al.*, 2024). Sukorini & Doeswitawati (2023) stated that the pathogen causing downy mildew requires a temperature of 20–32 °C and humidity above 90%. The temperature and humidity during the study were 30.41 °C and 96.14% (Table 3), thus suitable for the development of the pathogen *Peronosclerospora* spp. In addition, downy mildew disease also requires wet leaf conditions for spore germination. Observations during the study were conducted at 06:00–10:00 WIB, and at that time, the condition of the maize leaves was still wet due to morning dew.

Table 3. Environmental conditions during the research

Environmental condition	Time (days)							Average
	20	25	30	35	40	45	50	
Temperature (^{0}c)	29,9	32,9	28,3	31,6	32,3	29,4	28,5	30,41
Humidity (%)	100	97	100	89	90	99	98	96,14

Table 4. The effect of *Bacillus* spp. treatment and potassium fertilizer on the incidence of corn downy mildew disease

Treatment	Disease Incidence (%)						
	20 days NS	25 days NS	30 days NS	35 days NS	40 days NS	45 days NS	50 days *
B0K0	2,08	2,08	4,17	9,38	18,84	18,84	18,84 c
B0K1	2,08	3,13	8,33	9,38	14,49	18,84	14,49 bc
B0K2	0,00	2,08	4,17	5,21	11,59	14,49	15,94 bc
B1K0	0,00	3,13	8,33	7,29	10,14	11,59	4,35 a
B1K1	0,00	6,25	7,29	6,25	10,14	15,94	21,74 c
B1K2	1,04	2,08	8,33	10,42	13,04	26,09	17,39 c
B2K0	1,04	3,13	5,21	4,17	7,25	8,70	7,25 ab
B2K1	0,00	0,00	2,08	8,33	14,49	17,39	18,84 c
B2K2	2,08	4,17	8,33	11,46	14,49	21,74	13,04 abc

NS: Nonsignificant
*: Significant

Table 4 shows that disease incidence at 20 to 45 days was not significantly different, but it was significantly different at 50 days. At 20 to 45 days, all treatments had no effect on disease incidence, meaning that the treatments applied were the same as the control. This is thought to be due to the uniform spread of downy mildew disease in the experimental field at 20 to 45 days. In addition, plants showing downy mildew symptoms in the field were not eradicated, so the spread and transmission of the disease continued until 50 days. The inoculum source (plants showing downy mildew symptoms) present in the field caused downy mildew incidence to continue increasing at each observation. Observation of disease incidence at 50 days showed that the highest disease incidence was found in the control (B0K0), B1K1, B2K1, and B1K2. This is thought to be because in these treatments, the number of surviving plants in the experimental plots was higher than in other plots. This is believed to have resulted in higher humidity and greater plant-to-plant interaction, thereby increasing disease transmission. The lowest disease incidence was found in B1K0, B2K0, and B2K2, namely 4.35%, 7.25%, and 13.04%, respectively. According to Rashwan & Shaheen (2021) and Muis (2026), *Bacillus* can help mobilize potassium in the soil so that it is more easily absorbed by plants and improves plant resistance against pathogens. Mugiastuti *et al.* (2023) added that the combination of *Bacillus subtilis* and B. *amyloliquefaciens* treatments can reduce disease intensity and also AUDPC (area under disease progress curve), as well as produce protease and lipase enzymes that can degrade cell walls and phenolic compounds with antifungal properties, thereby inhibiting the germination of *Peronosclerospora* sp. spores. Djaenuddin *et al*. (2020) and Djaenuddin *et al.* (2021) also stated that *Bacillus* sp. can also stimulate plants to produce phenolic compounds and lignification in the mycelium, thereby inhibiting colonization within plant tissues. Windriyati *et al.* (2023) stated that *Bacillus* sp. acts as a barrier in the prevention process. Early application of *Bacillus*, either through seeds or spraying, can prevent the initial penetration of spores into plant tissues. If pathogen spores fail to infect, then maize plants will remain healthy, resulting in low disease incidence.

The application of a combination of *Bacillus* sp. and potassium B1K0, B2K0, and B2K2 was the best combination in suppressing the occurrence of downy mildew disease. Potassium physiologically plays a role in structural resistance, namely by thickening cell walls through the synthesis of cellulose and lignin, thereby making it more difficult for the pathogen haustorium that causes downy mildew (Rahim *et al*., 2024; Rashwan & Shaheen, 2021). Firmansyah *et al*. (2021) added that the higher the dose of potassium applied and the older the plant, the greater the plant's resistance. This statement is in accordance with the research of Habibi *et al.* (2017), which states that disease incidence is influenced by plant varieties as well as the dose of potassium fertilizer applied. Higher doses of potassium lead to increased plant resistance.

Corn Growth

Table 5 shows that the application of *Bacillus* spp. and potassium fertilizer had no effect on plant height and number of leaves at 42 days after planting. However, based on the description of the Bonanza MB maize variety used, its height is within the expected range, namely 175–200 cm. The Bacillus spp. treatment and potassium fertilizer applied were unable to increase plant height and number of leaves, presumably because the applied *Bacillus* spp. is more focused on competing with the pathogens causing downy mildew. Research by Bahena *et al*. (2025) also shows that the application of several microorganisms such as Bacillus and Trichoderma sp. as well as chemical fertilizers cannot increase the number of leaves of plants. Genetic interaction is a more important determining factor in growth improvement compared to the application of certain external fertilizers. This is supported by the statements of Reina-hernández *et al.* (2026) and Salama *et al.* (2026) that the morphological response of maize plants such as plant height and number of leaves is specific to the plant's genotype characteristics. Research by Reina-hernández *et al.* (2026) using growth-promoting microorganisms showed that increases in plant height depend on the plant genotype used.

Table 5. Effect of *Bacillus* spp. treatment and potassium fertilizer on plant height and number of leaves at 42 days after planting

Treatment	Plant height (cm) NS	Number of leaves (strands) NS
B0K0	191,00	9,78
B0K1	181,89	10,44
B0K2	192,00	10,44
B1K0	181,00	9,78
B1K1	181,33	10,11
B1K2	187,11	10,33
B2K0	184,00	10,11
B2K1	179,89	9,89
B2K2	183,56	10,00

NS: Nonsignificant

This study was conducted during the rainy season, and heavy rain occurred at the beginning of fertilization. This caused potassium fertilizer to be leached or dissolved, so that it entered deeper soil layers or was lost carried away by water. The study by Salama *et al.* (2026) using nano potassium ferrite fertilizer showed that vegetative traits of plants such as plant height and number of leaves are influenced by the plant's genetic characteristics. Solihin *et al.* (2019) added that potassium plays a greater role in the plant maturation process, especially in chlorophyll formation, seed filling, and is essential in carbohydrate formation.

CONCLUSION

The best treatment of the biological agent *Bacillus* spp. and potassium fertilizer was B1K0, B2K0, and B2K2, which were able to suppress the incidence of maize downy mildew disease at 50 days after planting. The combination treatment of *Bacillus* spp. and potassium fertilizer has not been able to increase plant height and the number of maize leaves. Recommendations for the study include the need for further research on plant defense mechanisms using *Bacillus* sp. and potassium. In addition, further research is needed using these best doses on several different maize varieties.

ACKNOWLEDGEMENTS

Thank you to the Institute for Research and Community Service (LPPM) of Nahdlatul Ulama University, Purwokerto, for funding this research under the 2025 Research and Community Service Grant for the Advanced Research scheme.

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