International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(7): 807-810
www.biochemjournal.com
Received: 02-04-2025
Accepted: 06-05-2025

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Comparative efficacy of fungicides and bioagents for the management of powdery mildew in black gram

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i7Sk.4988

Abstract
Powdery mildew caused by *Erysiphe polygoni* is one of the most widely spread and destructive disease of black gram (*Vigna mungo* L. Hepper). The present investigation on ''Epidemiological studies on powdery mildew of black gram caused by *Erysiphe polygoni* DC'' was undertaken during *Kharif* season 2024-2025. In field experiments, among different fungicides Cyflufenamid 5% EW @ 1 mL/L of water, was found significantly most effective followed by Azoxystrobin 5.1% w/w + Tebuconazole 9.1% w/w + Prochloraz 18.2% w/w EC and Penconazole 10% EC, achieving a maximum disease control rate of 80.90 percent over the untreated control. Additionally, among bioagents *Ampelomyces quisqualis* @ 2 mL/L of water, was found most effective followed by *Trichoderma harzianum*, and *Bacillus subtilis*, resulting in a disease control rate of 54.26 percent over the untreated control.

Keywords: Black gram, powdery mildew, *Erysiphe polygoni*, epidemiology, Cyflufenamid

Introduction

Black gram (*Vigna mungo* (L.) Hepper), commonly referred to as 'urd', 'biri', or 'mash' in local vernacular, is a leguminous species that is indigenous to India and classified within the family Fabaceae, possessing a chromosome count of 2n = 22. This pulse is a significant dietary component, constituting approximately 25 percent protein content within its seeds and serving as the most prolific source of phosphoric acid among leguminous crops; when consumed in conjunction with cereals, it effectively satisfies the protein requirements of human diets (Duffus and Slaughter, 1980) [8]. Black gram containing 25.21 percent protein, 2 percent fat, 3.2 percent minerals, 0.9 percent fiber, 58 percent carbohydrates, 138 mg calcium, 379 mg phosphorus, 7.57 mg iron, 0.273 mg vitamin B1, 0.254 mg vitamin B2, 1.447 mg niacin, 347 Kcal calorific value, and 10.9 percent moisture (Anonymous, 2016) [2].
The cultivation of black gram operates as a miniature fertilizer factory, as it enhances soil fertility by the process of atmospheric nitrogen fixation, thereby generating an estimated nitrogen equivalent of around 22 kg per hectare (Rachie and Roberts, 1974) [19]. The immature pods are utilized as a vegetable and are recognized for their high nutritional value (Nilanthi D., 2014) [15]. Furthermore, *Vigna mungo* is cultivated as a forage crop, frequently employed as an intercrop during the dry season alongside rice or wheat, as well as serving the functions of a cover crop and green manure (Korra *et al.*, 2018) [11].
In India, black gram ranks as the third most significant pulse crop, producing approximately 18.4 lakh tonnes annually across 39.6 lakh hectares, with a productivity of 520 kg/ha in the year 2023-24. The principal states for black gram production include Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, Maharashtra, and Tamil Nadu (Anonymous, 2024) [3, 4].
In 2023-24, Maharashtra cultivated black gram on 2.59 lakh hectares, producing 1.02 lakh tonnes with a productivity of 396 kg/ha. Major black gram growing districts include Washim, Buldhana, Akola, Hingoli, Nanded, Beed and Yavatmal (Anonymous, 2024) [3, 4].
Black gram is susceptible to various phytopathogenic diseases, including fungal, bacterial, and viral infections, which significantly contribute to yield losses. Notable fungal pathogens include *Colletotrichum lindemuthianum* (Anthracnose), *Cercospora canescens* (Cercospora leaf spot), *Erysiphe polygoni* (Powdery mildew), *Rhizoctonia solani* (Root rot and leaf blight), *Uromyces phaseoli* (Rust), and *Macrophomina phaseolina* (Macrophomina blight). Among bacterial diseases, *Xanthomonas phaseoli* is responsible for Bacterial leaf blight.

Additionally, viral infections such as Mungbean yellow mosaic virus (causing yellow mosaic disease) and Leaf crinkle virus (inducing leaf crinkle disease) further exacerbate biotic stress in black gram crops.

Powdery mildew is a widespread and economically significant disease affecting crops globally, primarily targeting the aerial parts of plants and posing a major threat to foliar health. The disease is caused by an obligate parasitic fungus from the phylum Ascomycota, specifically the genus Erysiphe, first described by Linnaeus (1767) [13] and further documented by De Candolle (1802) [7]. *Erysiphe polygoni* DC is the main species responsible for powdery mildew in black gram, severely reducing crop yields, particularly in cool, dry climates, leading to significant seed losses. High humidity levels facilitate the infection process, although free water does not promote fungal growth (Pande *et al.*, 2009; Channaveeresh and Kulkarni, 2017) [16, 6].

Numerous systemic, non-systemic fungicides and bio-control agents have been documented to control powdery mildew in black gram. However, the data regarding the effectiveness of various new fungicides and bio-control agents against this disease is inadequate; therefore, it is essential to assess new fungicides and bio-control agents targeting *Erysiphe polygoni* DC.

Materials and Methods

Disease rating scale: The level of powdery mildew was rated using a scale from 0 to 9, as described by Mayee and Datar (1986) [14].

Disease rating scale

Disease scale	Description
0	No signs of powdery mildew
1	Small scattered spots on the leaves covering 1 percent or less leaf area
3	Tiny powdery patches between 1-10 percent of leaf surface
5	Larger patches of powdery mold that cover 11-25 percent of leaf area
7	Powdery patches merge into to larger areas covering 26-50 percent of leaf surface
9	Extensive patches covering 51 percent or more of the leaf, and leaves may fall off.

These ratings were then converted into a percentage called the disease index (PDI), using the formula provided by Wheeler (1969) [22].

$$\text{Percent disease index} = \frac{\text{Sum of all numerical ratings}}{\text{No. of plants observed} \times \text{Maximum rating}} \times 100$$

Disease management

Evaluation of fungicides and bioagents

A field trial was carried out to test the effectiveness of different fungicides and bioagents against powdery mildew on black gram variety ‘TAU-1’. The experiment was conducted during the *Kharif* season of 2024-25.

Details of experiment

Statistical Design: RBD (Randomized Block Design)
No. of Treatments: Eight
No. of Replications: Three
Variety: TAU-1
Spacing (cm): 30 x 10
Plot size (m): 3.0 x 2.10
No. of sprays: 2 spray

Observations

The first spraying was taken immediately after the onset of the disease. Subsequent second spraying were taken at fifteen days intervals. Observations regarding the severity of the powdery mildew disease were conducted on ten randomly chosen plants from each treatment group. For each assessed plant, three leaves from the lower, middle, and upper portions were selected for detailed observation. The first observation was taken at first appearance of the disease while the subsequent two observations were conducted prior to each spraying event. The percent disease index (PDI) was calculated as shown in materials and methods. Furthermore, the percent disease control (PDC) for each treatment was calculated utilizing the following formula.

Percent Disease Control (PDC)

$$\text{PDC} = \frac{\text{PDI in control plot} - \text{PDI in treatment plot}}{\text{PDI in control plot}} \times 100$$

Where,
PDC-percent disease control
PDI-percent disease index

Treatment details

Tr. No.	Treatments	Trade Name	Manufacturer	Dose (mL/L of water)
T_1	Cyflufenamid 5% EW	Nissodium	Dhanuka	1 mL
T_2	Penconazole 10% EC	Topas	Syngenta	1 mL
T_3	Azoxystrobin 5.1% w/w + Tebuconazole 9.1% w/w + Prochloraz 18.2% w/w EC	Almagor	Adama	1 mL
T_4	*Ampelomyces quisqualis* (2×10^8 CFU/mL)	Dr. Bacto’s Ampelo	Anand Agro Care	2 mL
T_5	*Trichoderma harzianum* (1×10^9 CFU/mL)	-	VNMKV, Parbhani	5 mL
T_6	*Bacillus subtilis* (2×10^8 CFU/mL)	-	VNMKV, Parbhani	5 mL
T_7	Water spray	-	-	-
T_8	Untreated control	-	-	-

Results and Discussion
Disease management
Effects of fungicides and bioagents against powdery mildew disease intensity of black gram

To investigate the influence of fungicides and bioagents on the intensity of powdery mildew, a field experimental study was conducted, and the results obtained are presented in Table 4. The findings indicated that all fungicides and bioagents employed were effective and significantly diminished the severity of powdery mildew in comparison to the control group.

Table 4: Effects of fungicides and bioagents against powdery mildew disease intensity of black gram

Tr. No.	Treatment details	Dose (mL/L)	Disease intensity (%)			Reduction over control (%)
			Before 1st spray	After 1st spray	After 2nd spray	
T_1	Cyflufenamid 5% EW	1 mL	5.73 (13.84)	9.46 (17.91)	8.60 (17.05)	80.90
T_2	Penconazole 10% EC	1 mL	6.32 (14.56)	15.60 (23.26)	14.03 (21.99)	68.84
T_3	Azoxystrobin 5.1% w/w + Tebuconazole 9.1% w/w + Prochloraz 18.2% w/w EC	1 mL	5.79 (13.92)	12.43 (20.64)	11.44 (19.76)	74.60
T_4	*Ampelomyces quisqualis* (2×10^8 CFU/mL)	2 mL	6.56 (14.84)	23.99 (29.32)	20.60 (26.99)	54.26
T_5	*Trichoderma harzianum* (1×10^9 CFU/mL)	5 mL	6.90 (15.22)	24.77 (29.84)	21.47 (27.60)	52.33
T_6	*Bacillus subtilis* (2×10^8 CFU/mL)	5 mL	6.03 (14.21)	26.07 (30.70)	22.35 (28.21)	50.37
T_7	Water spray	-	6.36 (14.60)	34.47 (35.95)	30.26 (33.37)	32.81
T_8	Untreated control	-	6.71 (15.01)	38.57 (38.39)	45.04 (42.15)	0
SE (m)±			0.258	0.848	0.692	-
CD @ 5%			NS	2.57	2.10	-

* Figures in parenthesis are arcsine transformed values

The findings presented in results (Table 4) indicate that the application of fungicides resulted in a statistically significant reduction of the percentage of powdery mildew intensity in black gram. The preliminary data obtained before to the administration of fungicides demonstrated that the percentage of powdery mildew intensity varied from (5.73%) to (6.90%), with the treatments showing statistically non-significant differences among them.

The percentage of disease intensity observed subsequent to the first application of the fungicides indicated that Cyflufenamid 5% EW @ 1mL/L produced the most favorable outcomes in terms of mitigating disease intensity. Significantly lowest percent disease intensity of powdery mildew 9.46 percent was recorded with application of Cyflufenamid 5% EW. This treatment was followed by combination of Azoxystrobin 5.1% w/w + Tebuconazole 9.1% w/w + Prochloraz 18.2% w/w EC (12.43%) and Penconazole 10% EC (15.60%). However, treatments *Ampelomyces quisqualis* (23.99%), *Trichoderma harzianum* (24.77%) and *Bacillus subtilis* (26.07%) had similar effects. The plot sprayed with water showed the maximum intensity of 34.47 percent over control.

The percent disease intensity noticed after second spray ranged from 8.60 percent in Cyflufenamid 5% EW (T1) to 45.04 percent in untreated control (T8). The lowest level of powdery mildew disease was observed when using Cyflufenamid 5% EW. The disease intensity was only 8.60%, followed by combination of Azoxystrobin 5.1% w/w + Tebuconazole 9.1% w/w + Prochloraz 18.2% w/w EC (11.44%) and Penconazole 10% EC (14.03%). The treatments with *Ampelomyces quisqualis*, *Trichoderma harzianum*, and *Bacillus subtilis* were statistically itself at par with each other. The percentages were 20.60, 21.47, and 22.35 percent, respectively. These results show that all three treatments performed at a comparable level. Among the bioagents *Ampelomyces quisqualis* showed the minimal level of powdery mildew i.e., 20.60 percent. However, the highest severity of powdery mildew was examined in the Water spray treatment of 30.26 percent on untreated control.

The result obtained on percent disease reduction after 2nd spray over untreated control recorded that, among the fungicides tested, highest reduction over control (80.90%) was noticed in the plots sprayed with Cyflufenamid 5% EW @ 1 mL/L of water. This was followed by the plots sprayed with combination of Azoxystrobin 5.1% w/w + Tebuconazole 9.1% w/w + Prochloraz 18.2% w/w EC and Penconazole 10% EC, which reported a percent disease reduction of 74.60 and 68.84 percent, respectively over the untreated control. The pe cent reduction in powdery mildew of bioagents treatment plots i.e., *Ampelomyces quisqualis*, *Trichoderma harzianum* and *Bacillus subtilis* on control plot was 54.26 percent, 52.33 percent and 50.37 percent, respectively. Among bioagents highest reduction over control (54.26%) was examined in the plots sprayed with *Ampelomyces quisqualis* @ 2 mL/L of water. However, lowest reduction in disease intensity over the untreated control was observed in plots sprayed with Water spray (32.81%).

The same results were examined in previous research works by Potdukhe and Gudlekar (2007) [18], Gilardi *et al.* (2008) [9], Sudha and Lakshmanan (2009) [21], Adinarayana *et al.* (2012) [1], Jayasekhar M and Ebenezar EG (2016) [10], Sharma *et al.* (2017) [20], Patel *et al.* (2017) [17], Balol *et al.* (2020) [5] and Lakshmanan (2023) [12].

Conclusions
Consequently, based on the findings derived from different aspects of the current studies on black gram powdery mildew (*Erysiphe polygoni*), the following conclusions can be made: *Erysiphe polygoni* was identified as the causative

agent of powdery mildew in black gram within the Parbhani district of Maharashtra state. The fungicide Cyflufenamid 5% EW @ 1 mL/L of water, was found significantly most effective for management of powdery mildew in black gram followed by Azoxystrobin 5.1% w/w + Tebuconazole 9.1% w/w + Prochloraz 18.2% w/w EC and Penconazole 10% EC. Among bioagents *Ampelomyces quisqualis* @ 2 mL/L of water, was found most effective against powdery mildew of black gram followed by *Trichoderma harzianum* and *Bacillus subtilis*. The fungicide Cyflufenamid (Trade name: Nissodium) was found to be most effective against powdery mildew of black gram. Hence, it can be recommended to farmers for effective management of the disease.

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