

Harnessing Abiotic Defence Inducers for Effective Management of Pod Rot in Mung Bean

Abstract

Pod rot is a significant issue for mung bean plants, causing substantial reductions in yield and quality. In this study, several defence inducers, including salicylic acid (SA), nicotinic acid (NA), indole butyric acid (IBA), chitosan, and benzothiadiazole (BTH), were applied as foliar sprays to assess their effectiveness in enhancing resistance to pod rot in field conditions. The results indicated that benzothiadiazole BTH-treated plants experienced a marked reduction in disease severity of (18.667%) compared to untreated plants (control) plants with (36.177%). This suggests indicated that benzothiadiazole BTH has antifungal properties, decreases disease severity, and stimulates defence mechanisms in Mung bean against pod rot.

Keywords: Pod rot, mung bean, defence inducers

Introduction

Mung bean (*Vigna radiata* (L.) R. Wilczek var. *radiata*), also known as green gram or moong, is a vital crop in South and Southeast Asia's agricultural systems, with significant cultivation occurring globally. Its popularity among farmers is attributed to its short growth cycle, low input needs, compatibility with cereal crop rotations, and resilience to heat and drought conditions. In countries like India and Pakistan, mung bean is a crucial subsistence crop, supplying essential nutrients such as protein, iron, and zinc to farmer families. Meanwhile, in countries such as Myanmar, China, and Kenya, it serves as a significant income-generating crop. Improving the genetic traits of mung bean is essential for boosting productivity and is mainly conducted by public sector institutions within national agricultural research systems. Mung bean is thought to have originated in the Indo-Burma region, with India identified as its primary centre of domestication (Jain and Mehra, 1980).

India is the top producer of mung bean globally, with Myanmar and China coming next. In India, mung bean is the third most significant pulse crop, following chickpea (*Cicer arietinum* L.) and pigeon pea (*Cajanus cajan* L.), and it covers 3.4 million hectares or 15% of the country's total legume cultivation area (Nair et al., 2012). Mung bean is often cultivated after rice, wheat, and maize, and its demand and production are on the rise. This increasing trend is also seen in Australia, a key exporter of mung bean seeds, where the cultivation area grew from about 1,000 hectares in the 1970s to 125,000 hectares in 2015-2016 (Clarry, 2016).

Despite its advantages, mung bean production is hindered by significant challenges from both abiotic and biotic stresses, with diseases and insect pests being primary causes of reduced yields. Mung bean plants are vulnerable to pathogens and pests at all growth stages, from emergence to reproduction, which can lead to severe damage and even crop failure (Pandey et al., 2018). Common diseases affecting mung bean include powdery mildew, *Cercospora* leaf spot, yellow mosaic virus, anthracnose, *Fusarium* wilt, root rot, charcoal rot/dry root rot, and bacterial leaf blight, with fungal diseases alone responsible for yield losses of up to 40-60% (Pandey et al., 2018). Among these, powdery mildew, *Cercospora* leaf spot, and yellow

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Providing this information is very crucial and it will add value

mosaic virus are the most widespread and economically impactful. Breeding for disease resistance is considered the most effective approach to mitigating yield losses from diseases and pests. Traditional plant breeding has made significant strides in enhancing yield and resistance to diseases and pests in mung bean (**Fernandez and Shanmugasundaram, 1988**), playing a vital role in preserving genetic resources and generating genetic variation through hybridization and induced mutations.

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Pod rot disease has recently become a significant concern for mung bean production (**Buttar et al., 2023**). This disease causes seeds and pods to discolour and rot, with symptoms worsening due to intermittent rainfall during pod formation to crop maturity. Managing pod rot effectively is crucial to avoid substantial yield losses, as the disease results in mung bean seeds that are shrivelled, cracked, and discoloured, thereby reducing both yield quantity and quality. Because the disease can spread through contaminated seeds, using high-quality, disease-free seeds is critical. The use of resistant varieties and fungicide treatments has proven effective in controlling pod rot in mung bean cultivation.

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Unlike conventional chemical fungicides, plant defense elicitors boost a plant's natural immunity by activating systemic acquired resistance, which prepares the plant to combat future pathogen infections (**Bektas and Eulgem, 2015**). Chemical fungicides, on the other hand, can leave residues on crops for long durations (**Ragsdale and Sisler, 1994**). Therefore, plant defence elicitors are regarded as a more environmentally friendly method of disease management than chemical fungicides (**Wang et al., 2015**). Since plant defence elicitors are non-toxic to microorganisms, they are also likely to be less disruptive to the microbiome than chemical fungicides. This study aims to investigate the effect of defence inducers on the severity of pod rot in mungbean.

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Material and methods

In July 2021, field experiment was conducted at the Crop Research Centre, GBPUA&T, Pantnagar (29.0222°N, 79.4908°E), Uttarakhand to evaluate the efficacy of defence inducers against pod rot in mung bean. Six treatments were tested: salicylic acid (SA), indole butyric acid (IBA), chitosan, nicotinic acid (NA), benzothiadiazole (BTH), and a control group. These treatments were arranged in a randomized block design with three replications. The defence inducers were applied as foliar sprays at a concentration of 0.1%, while the control group received nothing except water. Each treatment was applied three times at seven-day intervals, beginning with maturing of pods.

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Disease severity was evaluated using the scale (0-5) defined by **Singh (2021)**. The percent disease index was determined according to the formula established by **Wheeler (1969)**.

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$$\text{PDI (\%)} = \frac{\text{Sum of all ratings}}{\text{Number of ratings} \times \text{Maximum grade}} \times 100$$

Further, the percent efficacy of disease control (PDC) was calculated by using the formula:

$$\text{PDC (\%)} = \frac{\text{Disease severity in control} - \text{Disease severity in treatment}}{\text{Disease severity in control}} \times 100$$

To measure the extent of disease development on the pods, disease severity grades and the area under the disease progress curve (AUDPC) were calculated using the formulas provided by Vanderplank (1963), Wheeler (1969), and Wilcoxon et al. (1975), respectively.

$$\text{PDI}(\%) = \frac{\text{Sum of all ratings}}{\text{Number of ratings} \times \text{Maximum grade}} \times 100$$

Where, r is the apparent infection rate, t_1 is the time of the first measurement, t_2 is the time of the second measurement, x_1 is the proportion of infection measured at time t_1 and x_2 is the proportion of infection measured at time t_2 .

$$\text{AUDPC} = \sum_{i=1}^{N-1} [(y_{i+1} + y_i) / 2] [(x_{i+1} - x_i)]$$

Where y_i = severity at first observation; x_i = time (days) at first observation; N = total number of observations.

Result and Discussion

The results of the experiment evaluating the effectiveness of various treatments on the percent disease index (PDI) in mung bean, using the percent disease control (PDC) and the Area Under Disease Progress Curve (AUDPC). Six treatments were assessed: Salicylic Acid (SA), Indole Butyric Acid (IBA), Chitosan, Nicotinic Acid (NA), Benzothiadiazole (BTH), and a control with water spray. Each treatment's PDI was measured at four stages: before spray, after the first spray, after the second spray, and after the third spray.

The PDI measures the severity of the disease as a percentage, with higher values indicating more severe disease symptoms. Percent disease index was recorded at four different stages: before spraying, after the first spray, after the second spray, and after the third spray. Benzothiadiazole (BTH) demonstrated the lowest initial PDI of 6.177%, increasing to 18.667% after the third spray, and it achieved the highest PDC of 48.40% and the lowest AUDPC of 206.11, indicating it was the most effective treatment for controlling disease progression.

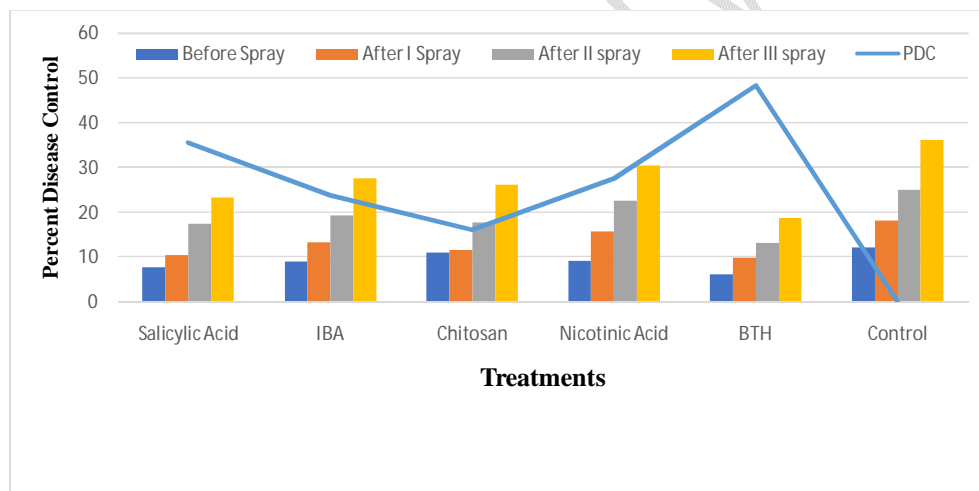
Table 1: Evaluation of defence inducers under field condition to manage pod rot of mung bean

S. No.	Treatment	Percent disease index				PDC	AUDPC
		Before spray	After Ist Spray	After IInd Spray	After IIIrd Spray		
1.	Salicylic Acid (SA)	7.733	10.443	17.467	23.290	35.63	235.36
2.	Nicotinic Acid (NA)	9.157	13.287	19.287	27.553	23.83	284.98

3.	Indole butyric Acid (IBA)	8.980	11.557	17.733	26.223	16.09	336.78
4.	Chitosan	11.023	15.643	22.623	30.357	27.52	254.96
5.	Benzothiadiazole (BTH)	6.177	9.867	13.243	18.667	48.40	206.11
6.	Control	12.220	18.133	25.067	36.177	0.00	384.38
CD @ 5%		1.508	1.31	2.244	3.114	-	-
S-Em±		0.472	0.41	0.703	0.976		

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*PDC: Percent disease control; AUDPC: Area under disease progress curve



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Fig 1. Variation in Disease control percentage with different treatments

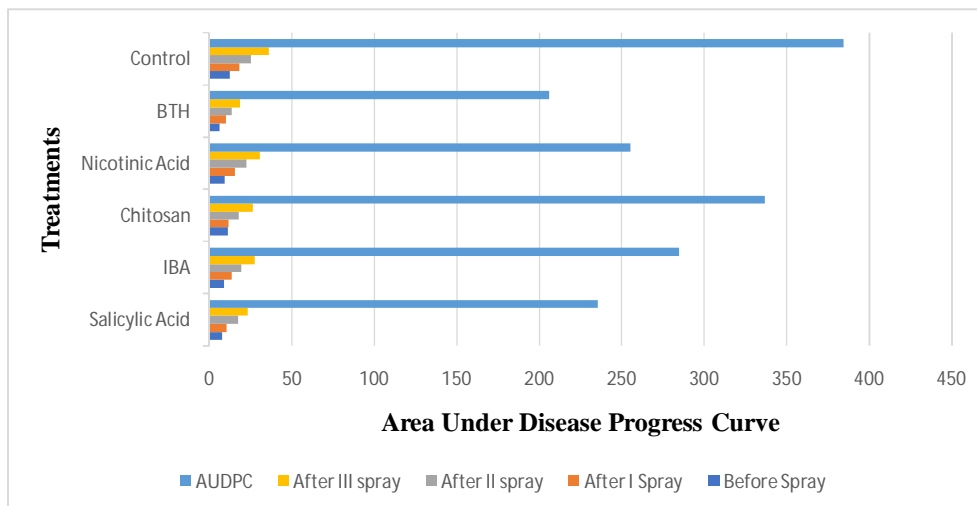


Fig 2. Disease progress curve in different treatments

Salicylic acid showed an increase in PDI from 7.733% before spraying to 23.290% after the third spray, with a PDC of 35.63% and an AUDPC of 235.36, indicating moderate disease control. In comparison, nicotinic acid (NA) exhibited a PDI increase from 9.157% to 27.553% with a PDC of 23.83% and an AUDPC of 284.98, suggesting lower effectiveness than salicylic acid. Indole butyric acid (IBA) showed a PDI increase from 8.980% to 26.223%, with a PDC of 16.09% and an AUDPC of 336.78, making it less effective than salicylic acid (SA) and nicotinic acid (NA).

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Sangpueaket *et al.*, (2021) explored the defence mechanisms in cassava triggered by salicylic acid, finding that SA was able to decrease anthracnose severity in cassava plants by up to 33.3%. Chitosan increased from 11.023% to 30.357% in PDI, achieving a PDC of 27.52% and an AUDPC of 254.96, which was more effective than nicotinic acid (NA) and indole butyric acid (IBA). Jabnoun-Khiareddine *et al.*, (2015) demonstrated that salicylic acid and chitosan could serve as effective inducers of systemic acquired resistance for managing fungal diseases in tomatoes. Additionally, Alnefaie *et al.*, (2023) found a positive correlation between reduced disease severity and the use of salicylic, nicotinic, and oxalic acids in faba bean. In contrast, the untreated control experienced a significant increase in PDI from 12.220% to 36.177%, with no disease control (PDC of 0.00%) and the highest AUDPC of 384.38, reflecting the natural progression of the disease without any treatment. These findings suggest that Benzothiadiazole (BTH) is the most effective defence inducer for managing pod rot in mung bean, significantly reducing disease severity and spread compared to other treatments. Salicylic Acid (SA) and chitosan also demonstrated considerable effectiveness, while indole butyric acid (IBA) and nicotinic Acid (NA) showed moderate results. The study emphasizes the potential of BTH and SA as important elements in managing pod rot in mung bean, offering a promising and effective approach to controlling foliar fungal pathogens.

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Conclusion

This research investigates how defence inducers can effectively manage pod rot disease in mung bean, potentially improving the performance and productivity of mung bean plants. Among the abiotic inducers tested, Benzothiadiazole and salicylic acid showed the greatest reduction in pod rot. ~~The study aims to help researchers identifying crucial aspects of plant defense mechanisms against biotic stress.~~ The results suggest that using these resistance inducers to activate the natural defence of plants could be incorporated into plant disease management strategies, alongside other environmentally friendly control methods.

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References

1. **Alnefaie, R. M., EL-Sayed, S. A., Ramadan, A. A., Elmezien, A. I., El-Taher, A. M., Randhir, T. O. and Bondok, A. (2023).** Physiological and Anatomical Responses of Faba Bean Plants Infected with Chocolate Spot Disease to Chemical Inducers. *Life*, 13: 392.
2. **Bektas, Y., and Eulgem, T. (2015).** Synthetic plant defense elicitors. *Front. Plant Sci.* 5:804
3. **Buttar, H. S., Singh, A., Sirari, A. and Sharma, S. (2023).** Pod rot of mungbean in Punjab, India: First record of association of *Fusarium equiseti* and *Fusarium chlamydosporum*. *Crop Prot.*, 168: 106230.
4. **Clarry S (2016)**The rise and rise of mungbeans. In Ground cover supplement issue 125 November– December. Australia: Grains Research and Development Corporation, 15.
5. **Fernandez, G. C. J. and Shanmugasundaram, S. (1988).** The AVRDC mungbean improvement program. The past, present and future. In: Fernandez J, Shanmugasundaram S (eds) Mungbean. Asian Vegetable Research and Development Center, Manila, Philippines, pp 1-10.
6. **Jain, H. K. and Mehra, K. L. (1980).** Evaluation, adaptation, relationship and cases of the species of *Vigna* cultivation in Asia. In: Summerfield RJ, Butting AH (eds) Advances in legume science. Royal Botanical Garden, Kew, London, vol 273, pp 459–468
7. **Nair, R. M., Schafleitner, R., Kenyon, L., Srinivasan, R., Easdown, W., Ebert, A. W. and Hanson, P. (2012).** Genetic improvement of mung bean. *Sabrao J. Breed. Genet.*, 44: 177–190.
8. **Pandey, A. K., Burlakoti, R. R., Kenyon, L. and Nair, R. M. (2018).** Perspectives and challenges for sustainable management of fungal diseases of mungbean [*Vignaradiata* (L.) R. Wilczek var. *radiata*]: a review. *Front Environ Sci.*, 6: 53.
9. **Ragsdale, N. N., and Sisler, H. D. (1994).** Social and political implications of managing plant diseases with decreased availability of fungicides in the United States. *Annu. Rev. Phytopathol.* 32, 545–557.
10. **Sangpueak, R., Phansak, P., Thumanu, K., Siriwong, S., Wongkaew, S. and Buensanteai, N. (2021).** Effect of Salicylic Acid Formulations on Induced Plant Defense against Cassava Anthracnose Disease. *Plant Pathol. J.* 37(4): 356-364.
11. **Singh, H. (2021).** Etiology and management of pod rot of mungbean [*Vignaradiata*]

- L.) wilczek] (Ludhiana: Dissertation, Punjab Agricultural University).
12. **Vanderplank, J. E. (1963).** Plant Disease: epidemics and control. Academic Press, New York. 349 p.
 13. **Wang, Z., Jia, C., Li, J., Huang, S., Xu, B., and Jin, Z. (2015).** Activation of salicylic acid metabolism and signal transduction can enhance resistance to fusarium wilt in banana (*Musa acuminata* L. AAA group, cv. Cavendish). *Funct. Integr. Genomics* 15, 47–62.
 14. **Wheeler, B. E. J. (1969).** An introduction to plant diseases. The English Language Book Society and John Wiley and Sons Limited, London. 386 p.
 15. **Wilcoxson, R. D., Skovmand, B. and Atif, A. H. (1975).** Evaluation of wheat cultivars for ability to retard development of stem rust. *Ann. Appl. Biol.*, 80: 275-281.

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