Plant Archives Vol. 26, Supplement 1, 2026 pp. 1336-1342 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.177

REINFORCING PLANT IMMUNITY: FIELD EVALUATION OF BIOTIC INDUCERS AGAINST YELLOW MOSAIC VIRUS DISEASE IN POLE BEANS

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(Date of Receiving : 10-09-2025; Date of Acceptance : 23-11-2025)

ABSTRACT

The pole bean crop face susceptibility to a wide range of pathogens, with viruses being a major contributor to significant production losses. Among these viruses, yellow mosaic virus caused by a begomovirus, has become increasingly severe in recent years in pole bean growing regions of Karnataka. The present investigation was envisaged to evaluate the efficacy of biotic inducers for defence against yellow mosaic virus disease. Among the eight treatments, including sea weed extract treatment 2 (LBD 46 @ 1.5 ml/L) was found to be significantly superior over the untreated control as it effectively suppressed the pole bean yellow mosaic virus disease by recording the average lowest disease incidence (7.77%) during *Kharif* 2022 and Summer 2023. The Seaweed extract may have role in activation of the plant immune system, thereby having the impact on the vector. Seaweed extracts have been highly reported to enhance plant growth, vigour, and improve resistance to pests and diseases.
Keywords**:** Pole beans, Biotic inducers, yellow mosaic virus, whiteflies, per cent disease incidence.

Introduction

The pole bean (*Phaseolus vulgaris* L.) originates from South America, where it has been cultivated as a primary food source for many centuries. French bean cultivars were selectively developed to grow as climbing vines, utilizing poles or trellises for support, leading to its name ‘pole bean’. It is commonly consumed while its pods are still young and tender, both as green vegetables and when the grains are immature. Furthermore, the dried beans known as Rajmah are also a part of its utilization.

Pole bean are acknowledged for their valuable contributions to human health and nutrition due to their substantial protein content of 22 per cent. Additionally, they contain 62 per cent carbohydrates, 15 per cent soluble fibres, and a range of essential micronutrients such as calcium, iron, magnesium, phosphorus, and potassium, as highlighted by Jeevan *et al.* (2015).

Pole beans are susceptible to a range of fungal, bacterial, and viral diseases, including ascochyta blight, anthracnose, rust, root rot, angular leaf spot, bacterial blight, common bean mosaic, Bean yellow mosaic, Bean golden mosaic, southern bean mosaic, Bean pod mottle, and Bean leaf roll virus. Among these viral diseases, yellow mosaic disease significantly impacts pole bean productivity (Kumar *et al*., 2019).

Bemisia tabaci (Gennadius) (Aleyrodidae: Homoptera) is one of the important sucking pest which inflicts heavy damage to the crop, not only through direct loss of plant vitality by feeding cell sap but also by transmitting the yellow mosaic virus disease (Muniyappa, 1980).

Seaweed extracts contains major and minor nutrients, amino acids, vitamins, cytokinins, auxin and abscisic acid like growth promoting substances (Mooney and Van Staden, 1986) and have been reported to stimulate the growth and yield of plants. Seaweeds have developed efficient defense mechanisms in order to fight their own natural pathogens. Seaweed-based bioactive compounds are known to induce defence responses against pathogens by acting as priming or elicitor molecules (Shukla *et al*., 2016). They have a broad range of biological activities including antibacterial and antiviral properties (Bouhlal *et al*., 2010). The present investigation was carried out to evaluate the biotic inducers for defence against yellow mosaic virus disease under field conditions.

Materials and Methods

In order to evaluate different biomolecules and insecticides for effective management of pole bean yellow mosaic disease, field experiments were conducted at Hadonahalli, Doddaballapura taluk, Bengaluru rural district during the *Kharif* 2022-23 and summer 2023-24. The experiment comprised of 8 different treatments, each replicated three times.

Table 1: Treatment details on management of yellow mosaic virus disease through an integrated approach

Treatments	Treatment details	Dose
T1	LBD 12	1 ml/L
T2	LBD 46	1.5 ml/L
T3	PBD 05	0.3 gm/L
T4	LBD 41.1-I	1 ml/L
	LBD 41.1-II	2 ml/L
T5	PBD 05. K1-I	0.3 gm/L
	PBD 05. K1-II	2 ml/L
T6	Imidacloprid 17.8% SL	0.5 ml/L
T7	Thiamethoxam 25% WG	0.5 g/L
T8	Control	_

Note: LBD: Liquid bio-defence
PBD: Powdered bio-defence

The observation on disease incidence were recorded at fortnightly intervals.

Per cent disease incidence

Percent disease incidence was calculated by counting number of plants infected and total number of plants in a plot.

$$\text{Per cent disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants examined}} \times 100$$

Observations were recorded at 15th, 30th, 45th and 60th days after sowing. Subsequently, the gathered data subjected to statistical analysis. The per cent disease inhibition over control was calculated by using the formula given by Vincent (1927).

$$\text{Per cent disease inhibition} = \frac{(C - T)}{C} \times 100$$

Where, C = Per cent disease in control

T = Per cent disease in treatment

Growth and yield parameters

Within each treatment, ten plants were chosen at random to evaluate various growth and yield parameters. The study focused on assessing the impact of the yellow mosaic disease on parameters such as plant height, pods per plant, pod length and yield per hectare in pole beans. The average data from the ten selected plants was subjected to statistical analysis. The analysis was conducted using a Randomized Complete Block Design (RCBD).

Benefit : Cost ratio

Net returns were determined for each treatment, taking into account the yield achieved and the treatment costs on a per hectare basis. Additionally, a Benefit to Cost ratio was computed to assess the economic viability of different treatments in comparison to the yield obtained in the control group.

Result

Incidence of yellow mosaic virus disease of pole bean

A field experiment was conducted at Hadonahalli in Doddaballapura taluk, Bangalore Rural district, during both the *Kharif* 2022 and summer 2023 to determine effective biotic inducers for managing yellow mosaic virus in pole bean. The per cent disease incidence and reduction over control were recorded at 15th, 30th, 45th, and 60th days after sowing (DAS). The experimental result obtained were statistically analysed for two seasons *viz*., *Kharif* 2022-23 and summer 2023-24 (Table 2 and Table 3).

Effect of different biotic inducers for defense against yellow mosaic virus in pole beans during 2022-23

From the data it is evident that, the lowest mean disease incidence of 6.67 per cent was recorded in treatment T2: LBD 46 @ 1.5 ml/L, followed by treatment T4: LBD 41.1-I @ 1ml/L+LBD 41.1-II @ 2ml/L (11.80%) and treatment T5: PBD 05. K1-I @ 0.3 g/L and PBD 05. K1-II @ 2ml/L (12.79%) when compared to untreated control (38.9%).

At 15th DAS the least per cent disease incidence was recorded in treatment T2: LBD 46 @ 1.5 ml/L (5.85%) followed by treatment T4: LBD 41.1-I @ 1ml/L+LBD 41.1-II @ 2ml/L (7.45%) and treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (9.57%) when compared to untreated control (20.56 %) (Table 2).

At 60th DAS the least per cent disease incidence was recorded in Treatment T2: LBD 46 @ 1.5 ml/L (4.88%) followed by Treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (11.80%) and Treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (12.79%) when compared to untreated control (38.9%).

Among the treatments, T2: LBD 46 @ 1.5 ml/L showed highest disease reduction (82.85 %) over control followed by T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (69.66 %) and T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (67.12 %).

Effect of different Biotic inducers for defense against yellow mosaic virus in pole beans during 2023-24

At 15th DAS the least per cent disease incidence was recorded in treatment T2: LBD 46 @ 1.5 ml/L (6.70 %) followed by treatment T4: LBD 41.1-I @ 1ml/L+LBD 41.1-II @ 2ml/L (8.86 %) and treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (11.00 %) when compared to untreated control (22.70%) (Table 3).

At 60th DAS the least per cent disease incidence was recorded in Treatment T2: LBD 46 @ 1.5 ml/L (5.66%) followed by Treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (7.83%) and Treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (9.83 %) when compared to untreated control (51.30%).

Accordingly, the average per cent disease incidence was least in treatment T2: LBD 46 @ 1.5 ml/L (7.70%) followed by treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (13.78%) and treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (14.71 per cent) when compared to control (41.28%).

Among the treatments, T2: LBD 46 @ 1.5 ml/L showed highest disease reduction (82.00%) over control followed by T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (67.00%) and T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (65.00%).

Kavyashri and Nagaraju (2019) showed a significant difference among the defense inducing treatments by reducing the CMV disease with increased growth and yield. A significantly less PDI (35.29%) and AUDPC (1238.33) was observed in plants treated with Chitosan (0.1%) with enhanced plant height (49.19 cm), number of branches (19.52), number of pods per plant (187.87), individual pod weight (2.44 g), green pod yield (483.56 g/plant), green pod weight (4.59 t/ha) and seed weight (1.38 t/ha).

Pole bean growth and yield parameters in different treatments

The effect of various treatments on growth and yield parameters *viz*., pod length, pods per plant and yield per ha were evaluated in both the seasons (Table 4 and Table 5).

Effect of biotic inducers on growth and yield parameters of pole bean during *Kharif* 2022-23

Among the eight treatments, average pod length was higher in treatment T2: LBD 46 @ 1.5 ml/L (30.91cm) followed by treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (26.57cm) and treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (23.90cm) when compared to untreated control (9.82cm) (Table 4).

Average pods per plant /harvest were higher in Treatment T2: LBD 46 @ 1.5 ml/L (21.46) followed by Treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (19.72) and treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (19.22) when compared to untreated control (12.98).

The pole bean yield, was highest in the treatment T2: LBD 46 @ 1.5 ml/L (33.89 t/ha) with the B:C ratio of 7.18 followed by treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (29.34 t/ha) with the B:C ratio of 6.33 and in treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (27.76 t/ha) with the B:C ratio of 5.91when compared to untreated control (12.89 t/ha) with the B:C ratio of 2.96 (Table 4).

The percentage increase in yield over control (treatment 8) was higher in treatment 2 (61.96%) followed by treatment 4 (56.06%) and treatment 5 (53.56%) (Table 4).

Effect of biotic inducers on growth and yield parameters of pole bean during *Kharif* 2023-24

The increased pod length was observed in treatment T2: LBD 46 @ 1.5 ml/L (18.57cm) followed by Treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (17.57cm) and Treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (23.30cm) when compared to untreated control (10.27cm) (Table 5).

Accordingly increased pods per plant/harvest was recorded in Treatment T2: LBD 46 @ 1.5 ml/L (28.20) followed by Treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (24.27) and treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (23.30) when compared to untreated control (7.30).

The pole bean yield, was highest in the treatment T2: LBD 46 @ 1.5 ml/L (30.46 t/ha) with the B:C ratio of 6.76 followed by Treatment T4: LBD 41.1-I @ 1ml/L and LBD 41.1-II @ 2ml/L (26.60 t/ha) with the B:C ratio of 6.08 and in Treatment T5: PBD 05. K1-I @ 0.3 gm/L and PBD 05. K1-II @ 2ml/L (17.53cm) with the B:C ratio of 5.77 when compared to untreated control (9.13 t/ha) with the B:C ratio of 2.22 (Table 5 and Fig. 4).

The pooled data indicates that the lowest disease incidence of yellow mosaic virus disease in pole bean and highest yield was recorded in treatment T2: LBD 46 @ 1.5 ml/L (6.605%, 32.82 t/ha) when compared to untreated control (39.7cm, 9.13 t/ha) (Table 6).

It is clear that the treatment 2 (LBD 46 @ 1.5 ml/L) was found to be significantly superior over the control as it effectively suppressed the pole bean yellow mosaic virus disease by recording lowest disease incidence (7.77 %) during *Kharif* 2022-Summer 2023.

Table 2: Effect of different treatments on per cent disease incidence of yellow mosaic disease of pole bean during *Kharif* 2022

Treatment	Treatment details	Yellow mosaic virus disease incidence (%)				Average per cent disease incidence	Per cent disease reduction over control
		15DAS	30DAS	45DAS	60DAS		
T1	LBD 12 (1.0 ml/L)	9.67	25.87	12.78	7.98	14.08	63.05
T2	LBD46(1.5 ml/L)	4.80	7.98	4.98	4.23	5.50	85.56
T3	PBD 05 (0.3 g/L)	16.56	34.89	18.87	14.87	21.30	44.10
T4	LBD 41.1 (1.0 ml/L+2.0 ml/L)	5.98	18.56	10.87	4.78	10.05	73.62
T5	PBD 05. K1 (0.3 g/L + 2.0 ml/L)	8.29	21.78	12.87	6.45	12.35	67.59
T6	Imidacloprid 17.8% SL (0.5 ml/L)	11.78	27.89	24.89	11.73	19.07	49.96
T7	Thiamethoxam 25% WG (0.3 g/L)	11.78	31.87	27.89	12.87	21.10	44.63
T8	Control	19.67	39.98	44.89	16.87	38.11	-
	S. Em ±	0.38	0.88	0.72	0.34	-	-
	CD (0.05)	1.15	2.68	2.17	1.03	-	-

Table 3: Effect of different treatments on per cent disease incidence of yellow mosaic disease of pole bean during *Kharif* 2022

Treatment	Treatment details	Yellow mosaic virus disease incidence (%)				Average per cent disease incidence	Per cent disease reduction over control
		15DAS	30DAS	45DAS	60DAS		
T1	LBD 12 (1.0 ml/L)	14.33	30.82	17.87	13.00	19.00	54.00
T2	LBD46(1.5 ml/L)	6.70	10.93	7.53	5.66	7.70	82.00
T3	PBD 05 (0.3 g/L)	20.66	38.52	21.49	17.96	24.65	41.00
T4	LBD 41.1 (1.0 ml/L+2.0 ml/L)	8.86	22.59	15.84	7.83	13.78	67.00
T5	PBD 05. K1 (0.3 g/L + 2.0 ml/L)	11.00	24.51	13.50	9.83	14.71	65.00
T6	Imidacloprid 17.8% SL (0.5 ml/L)	14.50	31.01	27.62	14.26	21.84	47.00
T7	Thiamethoxam 25% WG (0.3 g/L)	15.50	35.38	30.49	20.56	25.48	39.00
T8	Control	22.73	43.34	47.78	51.30	41.28	–
	S. Em ±	0.81	1.06	0.96	0.77	–	–
	CD (0.05)	1.64	3.19	2.88	2.31	–	–

Table 4: Effect of different treatments on growth and yield parameters of pole bean during *Kharif* 2022

Treatment	Treatment details	Pods per plant/harvest	Pod length (cm)	Yield (t/ ha)	Per cent yield increase over control (%)	B:C
T1	LBD 12 (1.0 ml/L)	27.08	19.88	25.67	49.78	5.64
T2	LBD46(1.5 ml/L)	30.91	21.46	33.89	61.96	7.18
T3	PBD 05 (0.3 g/L)	15.03	17.30	15.89	18.87	3.52
T4	LBD 41.1 (1.0 ml/L+2.0 ml/L)	26.57	19.72	29.34	56.06	6.33
T5	PBD 05. K1 (0.3 g/L + 2.0 ml/L)	23.90	19.22	27.76	53.56	5.91
T6	Imidacloprid 17.8% SL (0.5 ml/L)	20.47	18.28	21.86	41.03	4.94
T7	Thiamethoxam 25% WG (0.3 g/L)	12.35	16.38	14.76	12.66	3.31
T8	Control	9.82	12.98	12.89	-	2.96
	S. Em ±	0.68	0.59	0.77	-	-
	CD (0.05)	2.08	1.79	2.34	-	-

Table 5: Effect of different treatments on growth and yield parameters of pole bean during summer 2023

Treatment	Treatment details	Pods per plant/harvest	Pod length (cm)	Yield (t/ ha)	Per cent yield in crease over control (%)	B:C
T1	LBD 12 (1.0 ml/L)	21.23	16.60	23.2	60.64	5.40
T2	LBD46(1.5 ml/L)	28.20	18.57	30.12	67.62	6.76
T3	PBD 05 (0.3 g/L)	11.97	14.57	13.17	37.33	3.09
T4	LBD 41.1 (1.0 ml/L+2.0 ml/L)	24.27	17.57	26.60	65.67	6.08
T5	PBD 05. K1 (0.3 g/L + 2.0 ml/L)	23.30	17.53	25.57	64.29	5.77
T6	Imidacloprid 17.8% SL (0.5 ml/L)	17.27	15.60	18.27	50.02	4.37
T7	Thiamethoxam 25% WG (0.3 g/L)	9.90	13.57	11.27	18.99	2.68
T8	Control	7.30	10.27	9.13	_	2.22
	S. Em ±	0.90	0.76	1.18	_	_
	CD (0.05)	2.70	2.29	3.53	_	_

Table 6: Pooled data of per cent disease incidence and yield of pole bean

Treatment	Treatment details	Average per cent disease incidence (%)		Yield (t/ha)		Pooled PDI (%)	Pooled Yield (t/ha)
		2023	2024	2023	2024		
T1	LBD 12 (1.0 ml/L)	14.08	19.01	25.67	23.2	16.54	24.2
T2	LBD46(1.5 ml/L)	5.50	7.71	33.89	30.12	6.60	32.82
T3	PBD 05 (0.3 g/L)	21.30	24.66	15.89	13.17	22.98	14.17
T4	LBD 41.1 (1.0 ml/L+2.0 ml/L)	10.05	13.78	29.34	26.6	11.91	27.6
T5	PBD 05. K1 (0.3 g/L + 2.0 ml/L)	12.35	14.71	27.76	25.57	13.53	26.57
T6	Imidacloprid 17.8% SL (0.5 ml/L)	19.07	21.85	21.86	18.27	20.46	19.27
T7	Thiamethoxam 25% WG (0.3 g/L)	21.10	25.49	14.76	11.27	23.29	12.27
T8	Control	38.11	41.29	12.89	9.13	39.7	9.13

Discussion

Sugandhika *et al.* (2021) reported that foliar spray of seaweed extract along with insecticide spray reduced the leaf curl disease incidence in chilli by promoting the natural plant immunity. Foliar application of *Kappaphycus alvarezii* extract on tomato induced the defence hormones (SA, IAA, ABA) and pathogenesis related proteins (PR-1, PR-3 and PR-5) which provide innate defence against plant pathogens (Agarwal *et al.*, 2021).

In summary, the treatment-2 *viz.*, LBD 46 successfully suppressed the virus multiplication and seaweed defence molecules (LBD) promoted the plant immunity therefore altogether responsible for lower incidence of Yellow mosaic virus in pole bean. These results clearly suggested that treatment 2 can be effectively used for the management of pole bean yellow mosaic virus under open field conditions during *Kharif* and summer seasons.

The seaweed extracts made from different raw materials, and procedures are attributed to several beneficial effects such as biotic and abiotic stress tolerance, increased nutrient uptake and improve quality of products (Raj *et al.*, 2018). Moreover, the biologically active compounds like polysaccharides, proteins, polyunsaturated fatty acids, pigments, polyphenols, minerals, plant growth hormones and other in the algal extracts mainly boost the antibacterial activity, scavenging of free radicals, host defense activity etc. Therefore, the yield of the plants increased and it highly recommended to use as liquid fertilizer even in poor quality soil (Narayasamy *et al*., 2020; Chojnacka e*t al*., 2012). Abetz (1980) reviewed that cytokinins are a major active constituent of seaweed extracts and may be extracts may increase frost resistance, increase nutrient uptake and changes in plant chemical composition, increase disease and pest resistance, increase yields and improve seed germination.

Venkatesh (2016) stated that the red seaweed extracts of *Kappaphycus alvarezii*-1 (0.4%) reduced the percentage of disease index (PDI) of Cucumber mosaic virus (CMV) in gherkins in the field experiments. Pushpa *et al*., (2018) reported the delay in appearance of Papaya ring spot virus (PRSV) symptoms in papaya plants treated with *K. alvarezii* (0.4%). Kavyashri and Nagaraju (2019) recorded that there was a significant reduction in the severity of CMV disease in chilli treated with *K. alvarezii* as a biotic inducer. Seaweed extracts have been highly reported to enhance plant growth, vigour, and productivity and improve resistance to pests and diseases (Raj *et al*., 2018). The current findings are in agreement with the previous findings.

Devi and Mani (2015) reported that the application of *K. alvarezii* sap with 100 per cent recommended dosage of fertilizer to rice plants increased in growth, yield attributes, quality and chlorophyll content. Application of *K. alvarezii* (0.4%) and *P. fluorescens* (0.6%) significantly improved plant yield under field condition (Kavyashri and Nagaraju, 2019). Arthur (2003) reported that capsicum yield could be increased by using a different concentrated mixer of SWE. These evidences tally with the current findings.

The present study evidenced that there is no vector controlling effect of SWE. But the vector's effect has been reduced by the activation of the plant immune system. The tolerance level could be further maintained by the combined application SWE with recommended insecticides.

Conclusion

Based on the results the conclusions are drawn from the present investigation. The Seaweed extract have role in activation of the plant immune system, thereby having the impact on the vector. Seaweed extracts have been highly reported to enhance plant growth, vigour, and improve resistance to pests and diseases.

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