Research Article

Tackling The Mungbean Yellow Mosaic Virus Disease Intensity By Opting Multiple Approaches

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Abstract |Mungbean (*Vigna radiata L.*) is a vital source of iron, protein, vitamins and minerals. Its yield and quality are extremely affected by mungbean yellow vein mosaic virus (MYVMV) that is transmitted by whitefly (Bemisia tabaci). The present study was conducted to find resistant source in mungbean germplasm and evaluates the effects of chemicals to manage MYVMV. The screening and management experiments were conducted using an augmented and randomized complete block design (RCBD), respectively. The data of disease incidence, severity, whitefly population, and growth and yield parameters was recorded weekly. In the screening experiment, out of 12 cultivars, no variety showed a resistant response. However, three varieties-Abbas Mung (6%), NM-2011 (9%) and Ramzan Mung (7%) were found to be moderately resistant. The varieties NM-2016 (17%), NM-51 (24%), Azri-2006 (17%), NM-54 (30%), NM 121-25 and NM-28 were moderately susceptible while 3 varieties NM 2021, NM-13-1 and NM-98 were susceptible. Imidacloprid was found most effective for management of whitefly and MYVMV, followed by Thiamethoxam; while significant improvement in growth and yield parameters was recorded in the plants treated with zinc (Zn) and sulphur (S). The findings will be helpful for future studies focused on the development of resistant germplasm against MYVMV and its management through nutrient and chemicals.

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Introduction

Mungbean is a widely cultivated pulse crop in Pakistan. It is also known as green beans, green gram, golden gram, and green soy (Diatta *et al*., 2024). It belongs to the family Fabaceae and has a strong root system with numerous thin lateral roots and well-developed root nodules (Siddiq *et al*., 2022). Mungbean seeds contain calcium, magnesium, potassium, phosphorus, iron, and vitamins such as ascorbic acid, thiamine, riboflavin, vitamin A, thiamine, and pantothenic acid (Uppalwar *et al*., 2021). Proteins make up 26% of mungbean grains while vitamins, carbohydrates, and moisture constitute 3%, 51%, and 10%, respectively (Shrestha *et al*., 2023). As a legume, mungbean can fix atmospheric nitrogen (58-109 kg/ha) due to its symbiotic relationship with Rhizobia. It may supply the soil with significant levels of nitrogen (30-251 kg/ha) and biomass (7.16 t biomass/ha) (Islam *et al*., 2021). Mungbean yellow vein mosaic disease (MYVMD) is a major viral disease of the mungbean caused by mungbean yellow vein mosaic virus (MYVMV) (Akram *et al*., 2024). The affected plants exhibit mosaic pattern on the leaves with green and yellow areas that are uneven, a tiny number of blooms, undersized, deformed pods (Swamy *et al*., 2023). Whitefly (Bemisia tabaci) sucks on the lower side of the leaf in phloem and the process of MYVMV acquisition and transmission is in a persistent and circulative manner (Sivalingam *et al*., 2022). Being deprived from metabolic machinery, viruses depend on the control of insect vectors by using insecticides. Yellow sticky traps and marigolds as a trap crop reported a reduction in MYVMV disease incidence, managed by utilizing different combinations of an insecticide and bioformulation as seed treatment, with or without foliar sprays (Dubey and Singh, 2013). Numerous reports have been made on the discovery of germplasm lines and cultivars with various degrees of resistance to regional strains of the disease causing viruses (Paul *et al*., 2013). In multi-location experiments, a number of germplasm lines resistant to MYMV were found in mungbean and urdbean (Mondol *et al*., 2013). The emphasis is on the improvement of widespread and viable management approaches, that includes finding and incorporation of resistant genes in mungbean germplasm, management of virus through vector control using less harmful insecticides and fulfilling the losses through micronutrients to enhance mungbean productivity in Pakistan. The current study was planned with the objectives of evaluating mungbean germplasm against mungbean yellow mosaic virus and assessing the effectiveness of different nutrient applications and insecticides for the management of the disease and its insect vector. The integrated approaches of resistant cultivars, control of vector and boosting the plant immunity may provide a sustainable management strategy for the management of mungbean yellow mosaic virus.

Materials and Methods

Collection of germplasm

The research material consisted of 16 varieties of mungbean, including four for management (NM-2021, NM-2006, NM-54 and NM-98) and 12 varieties for screening. All varieties were collected from Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad (Pakistan).

Experimental details

The germplasm was sown using a randomized complete block design (RCBD) with three replications. In screening experiment, 12 varieties (NM 2021, Abbas Mung, NM-2016, NM-2011, NM-51, Ramzan Mung, NM 13-1, AZRI 2006, NM-54, NM121-25, NM-98 and NM-28) were sown. After the evaluation of varieties from screening experiment, an experiment for the management was conducted where 4 susceptible and moderately susceptible varieties (NM-2021, AZRI-2006, NM-54 and NM-98) were sown in RCBD.

The 10 cm distance was maintained for plant to plant and 30 cm for row to row distance. Borax, Sulphur (S), Zinc (Zn), combination of Zinc and Sulphur (Zn + S), Imidacloprid, Thiamethoxam and control (water) were applied for management of whitefly and MYVMV. The spray applications of nutrient combinations were started at early growth stage before the onset of disease while insecticides were applied just after the first appearance of whitefly infestation in the field. Details of the treatments are provided below (Table 1).

Data recording

The data was recorded by selecting random 10 plants per replication. The data of disease severity, disease incidence, vector population, no. of pods/plant, no. of grains/plant, 100 grains weight (g), plant height (cm), grain Weight/Plant (g), no. of leaves/plant).

Table 1. *Details of the treatments used for MYVMV and whitefly.*

Serial No.	Treatments	Formulations	Brand name (Company)	Application rates	Method
1	Control	Fresh Water	------------	------------	Foliar spray
2	Borax (B)	20% Powder	Borostar (FMC)	30g/15 liter water	Foliar spray
3	Sulphur (S)	80% WG	Smolder (Al Noor Agro Chemicals)	20g/liter	Foliar spray
4	Zinc (Zn)	10 % W/V	Tara Zinc Liquid (Tara Group)	30 ml/liter	Flooding
5	Zn+S	80%WG+10%W/V	------------	50 ml/liter	Flooding
6	Imidacloprid	20% SL	Imidacloprid (Syngenta)	80 ml/liter	Foliar spray
7	Thiamethoxam	25% WG	Actara (Syngenta)	0.5 g/liter	Foliar spray

Disease incidence and severity were calculated using following formulae:

$$\text{Disease incidence}(\%) = \frac{\text{Number of symptomatic plants}}{\text{Total observed number of plants}} \times 100$$

$$\text{Disease severity } (\%) = \frac{\text{Number of symptomatic leaves/plant}}{\text{Total number of leaves/plant}} \times 100$$

The varieties were evaluated by using following disease rating scale (Table 2) (Suman *et al*., 2015).

Table 2. *Disease rating scale for MYVMV disease severity.*

Rating	Percentage foliage affected	Infection category
0	No. visible symptoms	Immune
1	0.1-5% area covered with minute specks of yellow color	(R) Resistant
2	5.1-15% leaf area covered with mottling of leaves	(MR) Moderately resistant
5	15.1-30% leaf area covered with mottling and yellow discoloration	(MS)Moderately susceptible
7	Leaves discoloration and pronounced yellow mottling, pods reducing in leaf size, stunted plant growth, foliage affected30.1-75%	(S) Susceptible
9	Severe yellow discoloration and mottling of leaves, stunted growth of plants, failure of flowering and fruit setting 75.1-100% foliar affected	(HS) Highly susceptible

Statistical analysis

The collected data was subjected to statistical analysis. The analysis of variance (ANOVA) was calculated for parameters. All pairwise comparisons by using LSD test were made.

Results

Evaluation of mungbean germplasm for source of resistance against MYVMV

None of the 12 varieties screened showed resistance against MYVMV. A moderately resistant response was depicted by Abbas Mung, NM-2011 and Ramzan Mung with 6, 9 and 7%, disease severity, respectively. The varieties NM-2016 (17%), NM-51 (24%), Azri-2006 (17%), NM-54 (30%), NM 121-25 and NM-28 were moderately susceptible whereas NM 20-21, NM-13-1 and NM-98 gave susceptible response (Table 3).

Table 3. *Screening of mungbean germplasm against MYVMV.*

Sr. No.	Varieties	Disease severity	Category
1	NM 20-21	35%	S
2	Abbas Mung	6%	MR
3	NM-2016	17%	MS
4	NM-2011	9%	MR
5	NM-51	24%	MS
6	Ramzan Mung	7%	MR
7	NM 13-1	33%	S
8	AZRI 2006	17%	MS
9	NM-54	30%	MS
10	NM121-25	30%	MS
11	NM-98	40%	S
12	NM-28	20%	MS

Vector population was inversely related to insecticide application, decreasing after treatment. "Imidacloprid" gave the lowest population on all varieties followed by "Thiamethoxam" while the highest population was recorded in control followed by "Boron" (Fig. 1).

As whitefly transmits MYVMV; the decrease in whitefly population because of treatment application, disease incidence was also decreased in a similar manner (Fig. 2).

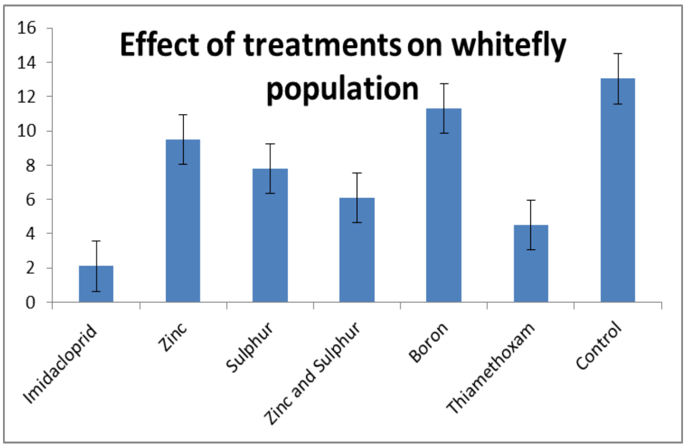

Figure 1. *Effect of treatments on whitefly population*

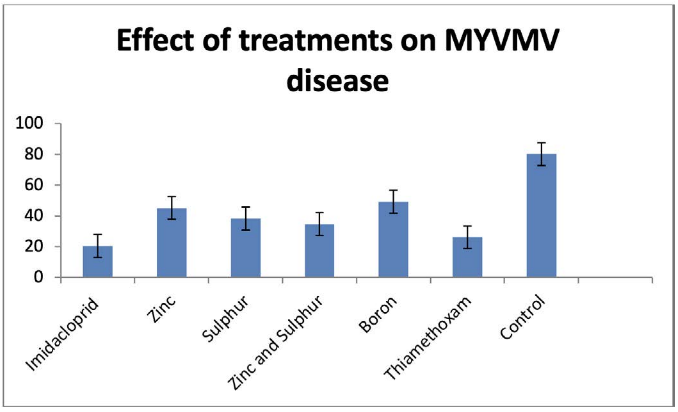

Figure 2. *Effect of treatments on MYVMV disease incidence*

The minimum disease incidence (19%) was depicted by imidacloprid while maximum (80%) was in control.

The interactive effect of treatments and varieties revealed that the insecticide "Imidacloprid" exhibited the minimum disease severity (18.95%) on variety "NM-2021" followed by variety "NM-98" which showed 22.33% disease severity. The maximum disease severity (48.90%) was observed in the plant of variety "Azri-2006" in "Control", followed by Azri-2006 treated with Sulphur (45.33%) (Table 4).

According to HSD Tukey test, treatments and varieties showed strong effect on minimizing disease incidence. Although imidacloprid was the most effective but its effectiveness varied among varieties according to their resistance potential.

Treatments had a significant effect on mungbean growth and yield. Imidacloprid was the most effective, resulting in the highest number of pods per plant (47), grains per pod (13), 1000-grain weight (51.2 g), plant height (69.3 cm), and number of leaves (75). Thiamethoxam was the second most effective treatment for growth and yield of mungbean followed by Sulfur, Zinc + Sulfur, Boron and Zinc. The lowest growth and yield were recorded that necessitated the use of treatments for disease control and enhancement of productivity (Table 5).

Table 4. *Tukey HSD All-Pairwise comparisons test of disease severity (%) for Varieties x Treatments.*

Varieties × Treatments	Mean disease severity (%)	
AZRI-2006×Borax	43.83	cd
AZRI-2006×Control	48.9	a
AZRI-2006×Imidacloprid	32.21	kl
AZRI-2006×Sulphur	45.53	b
AZRI-2006×Thiamethoxam	38.48	g
AZRI-2006×Zinc	45.08	b
AZRI-2006×Zn + S	40.12	ef
NM-2021×Borax	34.06	ijk
NM-2021×Control	44.68	bc
NM-2021×Imidacloprid	18.95	o
NM-2021×Sulphur	35.25	ij
NM-2021×Thiamethoxam	30.5	m
NM-2021×Zinc	36.38	ghi
NM-2021×Zn + S	30.42	m
NM-54×Borax	37.4	ghi
NM-54×Control	44.5	bc
NM-54×Imidacloprid	33.78	jk
NM-54×Sulphur	40.78	e
NM-54×Thiamethoxam	38.36	gh
NM-54×Zinc	38.06	gh
NM-54×Zn + S	32.93	jkl
NM-98×Borax	40.07	ef
NM-98×Control	45.29	b
NM-98×Imidacloprid	22.33	n
NM-98×Sulphur	40.07	ef
NM-98×Thiamethoxam	32.9	jkl
NM-98×Zinc	34.9	ijk
NM-98×Zn + S	35.75	ij

Discussion

Managing viral diseases is challenging due to the absence of antiviral chemicals (Huang *et al*., 2023). The best strategy for managing the viral diseases is the resistant germplasm and indirectly through vector controls (Anikini *et al*., 2023). In the current study, no cultivar showed resistance to MYMV, and

Table 5. *Effect of treatments on growth and yield parameters of mungbean.*

Treatments	No. of pods	Grains/Pod	1000 Grain weight (g)	Plant Height (cm)	No. of leaves/plant
Imidacloprid	47 a	13 a	51.2 a	69.3 a	75 a
Thiamethoxam	42 b	11 b	49.03 a	63.83 b	72 b
Sulphur	39 c	10 ab	47.6 b	57.12 c	69 c
Zn+S	31 d	9 ab	43.19 c	54.03 d	67 d
B	29 e	8 bc	41.23 c	48.22 e	61 e
Zinc	27 f	8 bc	38.26 d	43.29 f	58 f
Control	21 g	6 bc	29.71 e	26.93 g	49 g

Lsd = 0.69

Different letters in a column are indicating significantly different values

their resistance potential ranged from moderately susceptible to moderately resistant. The outcomes of the present experiment are in line with prior investigations that focus the lack of MYMV-resistant mungbean germplasm reinforcing the urgent necessity for substitute management approaches (Mishra *et al*., 2020; Singh *et al*., 2020). Gokidi *et al*. (2021) found resistance in tested cultivars while in our study moderately resistant germplasm was identified that needs to be managed with appropriate management tactics. Due to unavailability of complete resistance in the mungbean germplasm; the study was aimed at incorporation of disease management with insecticides and nutrients to boost plant health. Choudhary *et al*. (2023) analyzed the mungbean germplasm with different genetic potential against yellow mosaic virus and concluded that resistance varieties have lost less chlorophyll due to viral attack. Prathyusha *et al*. (2023) inoculated more than 900 cultivars of urdbean with MYMV through agro-inoculation and found only 10 resistant lines. Agro-inoculation is the most authentic way for assessment of resistance potential than natural field screening (Madhumitha *et al*., 2022). Kumari *et al*. (2024) developed infectious clones of the MYMV for breeding of resistant cultivars by locating resistant genes in the varied germplasm.

It is evident from the discussion that there is scarcity of resistance in mungbean germplasm against MYMV which necessitates other management strategies like repelling the insect vectors (Younas *et al*., 2021). Resistant germplasm should be developed by incorporating resistance genes from wild sources, while MYMV management should simultaneously be achieved through sustainable methods (Jha *et al*., 2023). After resistant germplasm; the second most effective way to manage the MYMV disease is by using insecticides against insect vector and use of nutrients to improve plant health to tackle the disease losses (Nawaz *et al*., 2023).

The efficacy of imidacloprid in decreasing whitefly infestation is supported by the research of Reddy *et al*. (2024) who recorded significant mortality in imidacloprid treated fields, but present research also depicted the repair potential of sulfur and zinc in the plants against virus as was discussed by (Mukhtar and Mohamad, 2022). The application of nutrients enhanced the production of antioxidants and plant physiology by improving photosynthesis, respiration and growth (Al-Khayri *et al*., 2023; Noreen *et al*., 2021), whereas the impact of boron to cell wall strengthening and nutrients increase extra coating to the defense system of the plant (Weisany *et al*., 2024). The combination of these management options not only confirmed the previous studies but also focused on the importance of integrated disease management that is a sustainable approach.

The efficacy of different nutrients and insecticides was also evaluated by several researchers (Islam *et al*., 2018). The effects of two pesticides, 'Imidacloprid' and 'Thiamethoxam,' as well as two plant extracts, neem (Azadirachta indica) and Eucalyptus (Eucalyptus camaldulensis), on whitefly suppression were significant (Hussain *et al*., 2024). Imidicloprid is absorbed the plant vascular system durig foliar spray and it disrupts the signals of whitefly in CNS that deter it from feeding and ultimately death; massive death rate of whitefly results in low transmission of MYMV (Shareefdeen and Elkamel, 2024). In treated plants, the significant mean values for growth and yield parameters among varieties, were obtained. The highest yield was obtained from the plants treated with insecticides; it is due to the utilization of plant's potential in obtaining nutrients and water from the soil as there was no engagement in fighting with insects (Li *et al*., 2023). Total number of leaves significance results for size and yield of grain, Prakash *et al*. (2019) had similar results for number of leaves.

Conclusions and Recommendations

Future studies should focus on the molecular characterization of resistance genes and their potential exploration for developing resistant germplasm. This milestone can be achieved through the combination of conventional breeding, molecular techniques and integrated disease management.

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Novelty statement

The research explores the synergistic effect of resistant sources and synthetic insecticides and nutrients in reducing MYMV intensity and improving growth and yield as a sustainable disease management option. It decreases the reliance on chemicals and explores the role of nutrients in boosting the plant defense.

Authors Contributions:

Muhammad Saqlain Naseer: Conducted research & wrote manuscript
Safdar Ali: Conceptualization, Supervised research
Amer Habib: Formal analysis, Investigation and layout of the experiment
Muhammad Usman Ghani: Review and Editing
Yasir Iftikhar: Helped in improving discussion
Muhammad Ahmad Zeshan: Acquisition of germplasm
Muhammad Asif Shabbir: Statistical analysis
Suleman Saleem: Data recording

Conflict of interest
The authors have no conflict of interest.

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