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RESEARCH ARTICLE

BOTANICAL AND ORGANIC APPROACHES FOR IMPROVING SEED QUALITY OF MUNGBEAN UNDER YELLOW MOSAIC DISEASE PRESSURE

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Abstract: Mungbean (*Vigna radiata* (L.) Wilczek) is a nutritionally important pulse crop, but its productivity is severely constrained by Yellow Mosaic Disease (YMD), a whitefly-transmitted viral disease-causing substantial yield and seed quality losses. The present study evaluated eco-friendly management options for YMD through field experiments conducted at Kanpur, during crop seasons (summer and Kharif) for two consecutive years (2024-2025). Fifteen treatments comprising botanical extracts, organic formulations, micronutrients, a chemical insecticide, and an untreated control were tested on two cultivars namely DGGV2 and Soorya, using a randomized block design. Botanical extracts (5% v/v) were applied as uniform foliar sprays. In the cultivar DGGV2, severe YMD incidence resulted in uniform infection across treatments, precluding treatment-wise differentiation. In Soorya, numerical reductions in disease severity and unhealthy seed parameters were observed with *Calotropis procera* leaf and flower extracts; however, these differences were statistically non-significant in summer but were found significant in the Kharif season. Notably, seed weight was significantly influenced by treatments in both seasons and years. Application of *C. procera* leaf extract consistently recorded the highest average seed weight per plant weight (3.51-3.57 g in summer and 3.54-3.56 g in Kharif) indicating improved seed filling and grain development. Overall, the study demonstrates that while *C. procera* extracts may not substantially reduce visible YMD severity under moderate disease pressure, they can significantly enhance seed weight and quality. These findings highlight the potential of Calotropis-based botanicals as components of integrated, environmentally sustainable YMD management strategies in mungbean.

Keywords: YMD, Mungbean, Botanicals, Management, Seed weight

INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is a short-duration grain legume with a typical crop cycle of 60–70 days and a strong capacity to perform across a wide spectrum of agro-climatic environments. These attributes have contributed to a steady expansion of its cultivation, particularly throughout South and Southeast Asia (Huang *et al.*, 2024). Global production of mungbean exceeded 6.5 million tonnes in 2022, with India, Myanmar, and China together accounting for more than 70% of total output (Dikr, 2023). During the last decade, the cultivated area under mungbean in Southeast Asia increased by nearly 23%, a trend largely driven by its low input requirements and suitability for resource-efficient farming systems (Sehrawat *et al.*, 2024). As a result, mungbean has become a key component of food and nutritional security strategies in developing regions of Asia, Africa, and Latin America (Dai *et al.*, 2024). The crop is believed to have originated in India, and its genome size, estimated to range between 494 and 579 megabases (Mb), indicates substantial genetic diversity that offers significant scope for crop improvement and breeding programs (Yin *et al.*, 2024). Mungbean establishes an efficient symbiotic association with Rhizobium species, enabling biological nitrogen fixation and reducing reliance on synthetic nitrogen fertilizers (Huppertz *et al.*, 2023). From a nutritional perspective, mungbean seeds exhibit high digestibility (approximately 85-90%) and are rich in essential nutrients, including B-complex vitamins such as folate and thiamine, high-quality protein (about 20-24%), and antioxidant flavonoids such as vitexin and isovitexin (Yin *et al.*, 2024). Compared with several other widely consumed legumes, including soybean and lentil, mungbean contains relatively lower levels of anti-nutritional factors such as phytic acid and lectins, thereby enhancing its nutritional value and consumer acceptability (Chen *et al.*, 2024).

In recent years, the frequency and intensity of plant disease outbreaks have increased markedly under shifting climatic conditions, posing a serious

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challenge to global food security. In mungbean, several viral diseases including Yellow Mosaic Disease (YMD) recognized as the most devastating across South Asia (Singh *et al.*, 2018). The occurrence of YMD on mungbean was first documented at the Indian Agricultural Research Institute (IARI), New Delhi(Nariani, 1960). YMD in pulse crops is associated with four principal begomoviruses, namely mungbean yellow mosaic virus (MYMV), dolichos yellow mosaic virus (DoYMV), mungbean yellow mosaic India virus (MYMIV), and horsegram yellow mosaic virus (HgYMV), which are collectively referred to as legumoviruses (LYMVs) (Qazi *et al.*, 2007; Naimuddin *et al.*, 2016). Transmission of these viruses occurs exclusively through the whitefly *Bemisia tabaci* in a circulative, non-propagative mode, with no evidence of spread via seed, soil, or mechanical means. Under severe epidemic conditions, YMD can result in yield losses of up to 85% in mungbean, and its incidence continues to extend into previously unaffected geographic regions (Karthikeyan *et al.*, 2014; Deepa *et al.*, 2019).

Infection by YMD initially manifests as small chlorotic specks on newly emerged leaves. These lesions gradually enlarge and merge, giving rise to the characteristic yellow mosaic pattern with irregular green and yellow patches, often accompanied by leaf deformation (Nene, 1973; Dhingra and Chenulu, 1985; Deepa *et al.*, 2019). With disease progression, leaves may become completely yellow, followed by drying, wilting, and premature leaf drop under severe infection. Affected plants show a pronounced decline in flowering and pod set, and the pods that develop frequently contain fewer seeds that are poorly filled, shrivelled, or malformed(Nene, 1973; Dhingra and Chenulu, 1985). Collectively, these symptoms result in substantial reductions in both seed quality and overall yield.

Effective management of YMD relies on an integrated disease management strategy that combines suppression of the whitefly vector through chemical and biological interventions with the use of host plant resistance. Recent studies have drawn attention to plant-derived products, particularly neem (*Azadirachta indica*), which possess bioactive constituents such as azadirachtin with insecticidal activity and nimbin with reported antiviral properties, thereby offering environmentally sustainable options for YMD control. Azadirachtin disrupts insect growth, feeding, and reproduction, making neem highly effective against whiteflies and other YMD vectors. Neem oil and seed kernel extracts at concentrations of 3–10% significantly reduce vector populations and YMD incidence, with efficacy comparable to some synthetic insecticides. Neem extracts, including nimbin, exhibit broad-spectrum antimicrobial activity, including antiviral effects, which may contribute to direct suppression of plant viruses. Field studies show that foliar application of neem oil or seed kernel extract can lower YMD incidence by up to 40% and improve yield and seed quality in crops like mungbean, urdbean, and cucurbits(Sethuraman *et al.*, 2001; Saravanan, 2006; Kumar *et al.*, 2021; Hashmi *et al.*, 2024). In view of the considerable economic importance of YMD and the severe losses in mungbean associated with its outbreaks, the present study was conducted to assess the field performance of selected commercial botanicals, organic formulations, and conventional chemical insecticides in managing YMD in mungbean.

MATERIALS AND METHODS

Experimental Site and Design

Field experiments were conducted for two consecutive years 2024-2025 during the summer and Kharif seasons to evaluate the efficacy of plant extracts, organic products, micronutrients, and a chemical insecticide against yellow mosaic disease (YMD) at the experimental fields of ICAR-Indian Institute of Pulses Research (ICAR-IIPR), Kanpur, India. After standard land preparation, micro-plots of 3×2 m^2 were laid out, each consisting of eight rows with inter-row spacing of 30 cm and intra-row spacing of 10 cm. Two mungbean varieties, DGGV2 (susceptible to YMD) and Soorya (also known as IPM 512-1; resistant to YMD), were sown together following a randomized block design (RBD) with three replications (Figure 1a-b). The treatments (n=15) designated as T1 to T15, comprised foliar applications of seven botanical extracts, four organic products, two micronutrients, one insecticide, and an untreated control (Table 1).

Preparation of Botanical Materials

Fresh plant materials used in the study included leaves of Cannabis (*Cannabis sativa*), Calotropis (*Calotropis procera*), Kadamb (*Neolamarckia cadamba*), Marigold (*Tagetes erecta*), Lantana (*Lantana camara*), Castor (*Ricinus communis*), and flowers of *Calotropis procera*. Approximately 500 g of each plant material was collected, washed three times with distilled water, and shade-dried until completely moisture-free. The dried materials were ground into a fine powder using a mixer blender and stored in airtight containers for subsequent use.

Extraction of Botanical Crude Extracts

Ten grams of air-dried plant powder were mixed with 100 mL of 80% methanol in clean glass bottles and incubated on a rotary shaker at 190–220 rpm for 24 h at room temperature. After incubation, the extracts were filtered and the filtrates were collected, which was further concentrated by evaporating three-fourth of its original volume. The concentrated extracts were stored at 4 °C in airtight bottles as stock solutions and subsequently diluted to 5% (v/v) with distilled water for use in field applications.

Treatment application

The seeds of both cultivars (DGGV2 and Soorya) were treated with Rhizobium culture {@ 0.2 % (v/w)} and Trichoderma (@10 g/Kg) by mixing uniformly, prior to sowing. Further, treatments (T1-T15) were applied as foliar sprays at 20, 35, and 50 days after sowing (DAS) using a hand-operated sprayer. Care was taken to ensure uniform coverage of foliage in all plots during each spray schedule.

Disease severity and seed quality assessment

Disease severity was assessed as described in a previous study (Yadav *et al.*, 2021), on five tagged plants per plot, randomly selected at uniform spatial intervals following foliar application of treatments to ensure representative sampling. At physiological maturity, the tagged plants were harvested individually and threshed separately. Pods were collected, and seeds obtained from these plants were pooled and weighed to estimate total seed weight, and the average seed weight per plant was derived by dividing the pooled weight by five. From the pooled harvest per treatment, random samples of 100 seeds were drawn across three replications to determine hundred seed weight. These samples were further examined for seed quality assessment. Unhealthy seeds were identified based on virus-associated morphological and physical abnormalities characteristic of yellow mosaic disease (YMD), including shrivelling, poor or incomplete seed filling, reduced size, surface wrinkling, discoloration (pale yellow to brown), deformation, and loss of seed lustre as described in previous studies (Nene, 1973; Dhingra and Chenulu, 1985). Seeds exhibiting one or more of these symptoms were classified as unhealthy, separated from healthy seeds, and quantified. Both the number and cumulative weight of unhealthy seeds were recorded to assess the impact of YMD on seed quality.

Statistics

Replicated data recorded for disease severity, seed count and seed weight were subjected to statistical analyses using R program (R Core Team, 2024).

Table 1. Detail of treatments.

S.no	Treatments	Treatment Detail	Plant tissue	Doses
1	T1	Foliar spray of Cannabis leaf extract	Leaves	5% (v/v)
2	T2	Foliar spray of Calotropis leaf extract	Leaves	5% (v/v)
3	T3	Foliar spray of Calotropis flower extract	Flowers	5% (v/v)
4	T4	Foliar spray of Kadamb leaf extract	Leaves	5% (v/v)
5	T5	Foliar spray of Marigold leaf extract	Leaves	5% (v/v)
6	T6	Foliar spray of Castor leaf extract	Leaves	5% (v/v)
7	T7	Foliar spray of Lantana camara leaf extract	Leaves	5% (v/v)
8	T8	Foliar spray of Panchgavya		3% (v/v)
9	T9	Foliar spray of Jeevamurat		500ml/ha
10	T10	Foliar spray of Beejamurat		200ml/kg
11	T11	Foliar spray of Nimbicidine LC50		5ml/lit
12	T12	Foliar spray of Zinc oxide		75 ppm
13	T13	Foliar spray of Ferric oxide		75 ppm
14	T14	Foliar spray of Imidacloprid 17.8%		0.5ml/litre
15	T15	Control (Water)		-

RESULTS

Disease severity under different treatments

In the highly susceptible mungbean genotype DGGV2, YMD severity reached 100% across all treatments during both seasons (summer and Kharif) due to a severe disease outbreak. The intense infection adversely affected pod formation and seed development, resulting in uniformly unhealthy seeds across treatments. Consequently, treatment-wise effects on seed quality parameters could not be distinguished in DGGV2, and further seed analysis for this genotype was excluded from the study.

In the resistant variety Soorya, YMD severity in the untreated control was low during the summer season (6.67% in 2024 and 6.93% in 2025) but increased during the Kharif season (11.85% in both years). Across seasons, *Calotropis procera* was the most effective treatment, with 5% leaf extract applied as foliar spray in summer reducing disease severity to 4.67% (2024) and 5.33% (2025), and foliar spray in Kharif further lowering severity to 5.18% (2024) and 2.96% (2025), followed by Calotropis flower extract (**Tables 2 and 3**). All other botanical, organic, micronutrient, and chemical treatments resulted in comparatively higher YMD severity, while the insecticide Imidacloprid performed poorly relative to botanical treatments. However, treatment differences were statistically non-significant in both years and seasons, indicating that these reductions represent numerical trends rather than statistically distinct treatment effects.

Effect on number of unhealthy seed count and seed weight per 100 seed

In Soorya, the number and weight of unhealthy seeds per 100 seeds showed clear numerical variation among treatments in both summer and Kharif seasons across 2024 and 2025. In summer, plots treated with 5% *Calotropis procera* leaf extract recorded the lowest unhealthy seed counts (13.67 and 16.00) and lowest unhealthy seed weight (0.56 g in both years), followed by Calotropis flower extract, whereas the untreated control had the highest unhealthy seed counts (21.67 and 24.33) and highest unhealthy seed weight (0.91 g and 0.76 g), indicating greater proportions of shriveled and poorly filled seeds under unmanaged YMD conditions. A similar pattern was observed in Kharif, where Calotropis leaf extract again produced the lowest unhealthy seed counts (14.33 and 15.33) and lowest unhealthy seed weight (0.58 g and 0.59 g), while the untreated control recorded the highest values (23.33 and 22.00 unhealthy seeds; 0.72 g and 0.67 g unhealthy seed weight). Across both seasons, Imidacloprid-treated plots consistently showed relatively higher unhealthy seed counts and weights than botanical treatments (Tables 2 and 3). However, for both years differences among treatments were statistically non-significant in summer, whereas it was significant in the Kharif season.

Effect of treatments on seed weight per plant

Average seed weight per plant was significantly influenced by treatments in both summer and Kharif seasons during 2024 and 2025. Across seasons, seed treatment followed by foliar application of 5% *Calotropis procera* leaf extract consistently produced the highest seed weight (3.51–3.57 g in summer and 3.54–3.56 g in Kharif), remaining statistically superior to most other treatments (Tables 2 and 3). Calotropis flower extract also resulted in higher seed weights and was statistically comparable to the best treatment group. In contrast, the untreated control recorded the lowest seed weights (3.33–3.35 g in both seasons and years). The significant improvement in seed weight under Calotropis-based treatments reflects improved seed filling and a reduced negative impact of YMD on grain development.

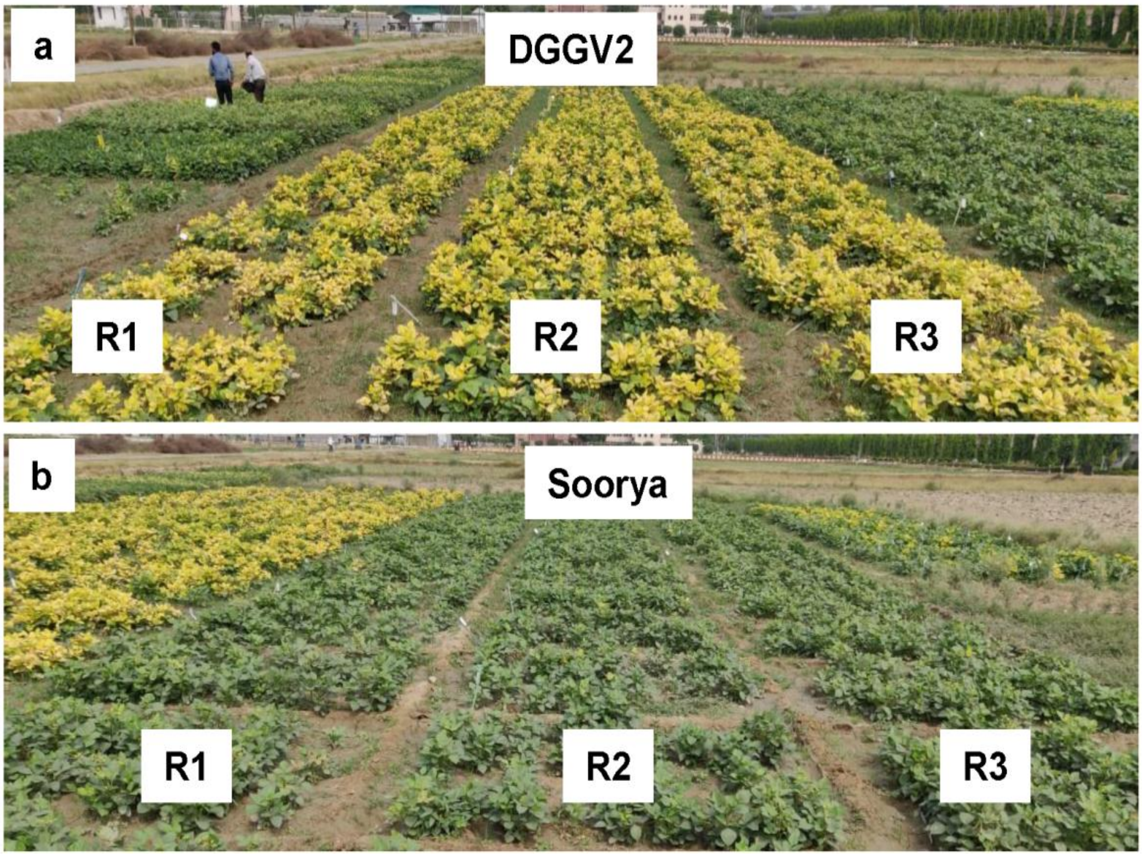

Figure 1 (a) Field layout with three replications (R1-R3) of 15 treatments considered in this study on DGGV2, and (**b)** Soorya. (**c**) Unhealthy and **(b)** healthy seeds of Soorya (IPM512-1) Mungbean studied in this study.

DISCUSSION

Yellow Mosaic Disease (YMD) remains one of the most destructive viral diseases of mungbean, particularly under agro-climatic conditions that favor whitefly proliferation. The present study assessed the field performance of selected botanicals, organic formulations, micronutrients, and a chemical insecticide for YMD management, with emphasis on disease severity and seed quality attributes.

The uniformly high disease severity observed in the susceptible genotype DGGV-2 across all treatments underscores the vulnerability of highly susceptible cultivars under severe epidemic pressure. The inability of any treatment to mitigate YMD effects in this genotype suggests that once systemic infection is established, external interventions exert limited influence on disease expression and seed health. This reinforces the central role of host resistance as the cornerstone of YMD management, as consistently reported in earlier studies (Nariani, 1960; Karthikeyan *et al.*, 2014; Naimuddin *et al.*, 2016; Mishra *et al.*, 2020). This response is further explained by the experimental conditions, as the ICAR-IIPR, Kanpur fields are a known hotspot for mungbean yellow mosaic India virus (MYMIV), the principal causal agent of YMD, resulting in intense and uniform disease pressure (Akram *et al.*, 2024).

In the resistant variety Soorya, application of *Calotropis procera* extracts resulted in numerical reductions in disease severity; however, these differences were not statistically significant, indicating limited observable effects under moderate disease pressure. Similar patterns have been documented in other crops, where *C. procera* extracts showed strong disease-suppressive activity under controlled conditions. For instance, aqueous and methanolic extracts significantly reduced Fusarium wilt severity in tomato and chickpea, with higher concentrations producing stronger effects, including up to 83.6% reduction in tomato under greenhouse conditions (Abo-Elyousr *et al.*, 2022; Zubairi *et al.*, 2025). Field studies in potato and wheat have also reported reductions in disease severity and yield improvement following *C. procera* treatments, although treatment effects were sometimes non-significant in resistant genotypes or under moderate disease intensity (Naz *et al.*, 2018; Abdul-Karim and Hussein, 2024; Hussain *et al.*, 2024).

The absence of statistically significant differences in disease severity among treatments in Soorya suggests that host resistance restricted symptom development, resulting in comparable disease pressure across treatments. Unhealthy seed count and unhealthy seed weight followed trends similar to disease severity, with Calotropis leaf extract treatments recording lower numerical values and untreated controls showing the highest levels. However, these differences were also statistically non-significant, indicating modest treatment effects on seed health under prevailing field conditions. This close association between disease severity and unhealthy seed formation aligns with earlier reports that YMD impairs seed quality primarily through disruption of photosynthesis and assimilate translocation during pod filling (Nene, 1973; Dhingra and Chenulu, 1985).

In contrast, average seed weight per plant was significantly influenced by treatments in both years, highlighting seed weight as a more sensitive indicator of treatment response under YMD stress. Although *C. procera* leaf extract treatments did not consistently produce significant reductions in visible disease severity, they were associated with improved seed filling and grain development. Similar physiological benefits have been reported in wheat, where *C. procera* leaf extracts increased grain number per spike, 100-grain weight, and overall yield, accompanied by enhanced photosynthetic pigments, protein content, phenolics, and defense-related enzyme activity (Naz *et al.*, 2018). In addition, optimal concentrations of *C. procera* extracts have been shown to improve seed germination and seedling vigor, likely due to bioactive compounds such as phenolics and flavonoids, although excessive concentrations may exert inhibitory effects (Al-Zahrani and Al-Robai, 2007; Yau *et al.*, 2022). Induction of plant defense responses, including antioxidant enzymes and pathogenesis-related proteins, may further reduce stress intensity and indirectly support improved seed development even when disease suppression is limited (Naz *et al.*, 2018).

The relatively poor performance of imidacloprid in reducing disease severity and improving seed quality parameters may reflect increasing resistance in *Bemisia tabaci*, limited residual activity, or insufficient suppression of viruliferous adults prior to virus transmission. Similar declines in neonicotinoid efficacy have been reported in pulse-growing regions with prolonged insecticide use (Karthikeyan *et al.*, 2014; Naimuddin *et al.*, 2016), emphasizing the limitations of sole reliance on chemical control.

Overall, the consistent numerical superiority and statistically significant improvement in seed weight observed with *Calotropis procera* leaf extract indicate its potential as a botanical component in integrated YMD management strategies. While reductions in disease severity and unhealthy seed parameters were not statistically significant, the positive influence on seed development suggests meaningful agronomic benefits. Integration of botanical treatments with host resistance may enhance crop performance while reducing dependence on synthetic insecticides. Further studies on active phytochemicals, their modes of action, and multi-location validation would strengthen the case for Calotropis-based formulations in sustainable mungbean production systems.

AUTHOR'S CONTRIBUTION

AR and DK wrote the original manuscript. MA conceived the idea and supervised the study. AR performed the analysis and DK prepared the illustrations. MA edited and reviewed the manuscript. All authors read and approved the final version of the manuscript.

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Table 2. Effect of different treatments on yellow mosaic disease severity and seed health of mungbean (Soorya) in the summer season.

Treatment	Disease Severity (%)		Number of unhealthy seed /100 seed harvested		Seed weight (g) of unhealthy seeds		Total average seed weight/ plant (g)	
	2024	2025	2024	2025	2024	2025	2024	2025
T1	5.93±1.28	5.93±1.28	16.67±1.53	16.67±6.81	0.70±0.06	0.60±0.19	3.45±0.04^{bcd}	3.45±0.02^{g}
T2	4.67±0.00	5.33±1.28	13.67±2.52	16.00±2.65	0.56±0.11	0.56±0.05	3.51±0.02^{a}	3.57±0.01^{a}
T3	5.67±2.22	5.63±1.28	15.00±1.00	17.67±1.53	0.60±0.07	0.59±0.09	3.51±0.01^{a}	3.56±0.01^{ab}
T4	6.67±0.00	6.67±2.22	16.00±1.00	20.67±4.04	0.66±0.06	0.64±0.05	3.39±0.04^{ef}	3.49±0.04^{def}
T5	5.93±1.28	5.93±1.28	15.33±6.66	20.67±5.69	0.64±0.28	0.67±0.23	3.43±0.04^{cde}	3.50±0.03^{cde}
T6	6.67±2.22	6.67±2.22	18.67±2.89	19.00±2.65	0.73±0.03	0.66±0.10	3.42±0.04^{de}	3.48±0.02^{efg}
T7	6.67±2.22	6.67±2.22	18.33±4.04	20.00±2.65	0.77±0.17	0.67±0.04	3.43±0.04^{cde}	3.50±0.03^{de}
T8	6.67±0.00	5.93±1.28	14.67±3.79	20.67±2.52	0.62±0.16	0.67±0.04	3.46±0.01^{abcd}	3.45±0.02^{fg}
T9	5.93±1.28	5.93±1.28	15.67±2.31	21.67±1.15	0.63±0.15	0.64±0.02	3.43±0.07^{cde}	3.51±0.04^{cde}
T10	6.67±0.00	6.67±0.00	15.33±1.53	21.00±1.00	0.64±0.06	0.66±0.01	3.47±0.02^{abcd}	3.48±0.06^{efg}
T11	6.67±2.22	6.67±2.22	15.67±1.53	21.67±1.53	0.62±0.14	0.66±0.02	3.44±0.02^{cde}	3.47±0.04^{efg}
T12	5.67±0.00	5.23±1.28	15.00±2.65	18.67±3.51	0.59±0.05	0.63±0.14	3.48±0.02^{abc}	3.54±0.03^{abc}
T13	5.23±1.28	5.73±1.28	15.12±4.36	18.60±2.00	0.60±0.18	0.64±0.03	3.51±0.02^{ab}	3.53±0.02^{bcd}
T14	5.89±1.28	6.49±1.28	18.67±7.51	23.33±1.53	0.78±0.32	0.62±0.14	3.46±0.04^{abcd}	3.47±0.01^{efg}
T15	6.67±0.00	6.93±1.28	21.67±7.37	24.33±0.58	0.91±0.31	0.76±0.23	3.35±0.02^{f}	3.33±0.02^{h}
F stat	0.48^{NS}	0.43^{NS}	0.85^{NS}	1.80^{NS}	0.85^{NS}	0.42^{NS}	6.08**	23.30**
SE(m)	0.67	0.67	2.24	1.70	0.10	0.07	0.02	0.01
SE(d)	0.95	0.95	3.17	2.41	0.14	0.1	0.03	0.02
CV(%)	18.33	19.02	23.26	14.44	24.53	18.57	0.90	0.59

NS= Non-significant, **= p<0.01

Table 3. Effect of different treatments on yellow mosaic disease severity and seed health of mungbean (Soorya) in the Kharif season.

Treatment	Disease Severity (%)		Number of unhealthy seed /100 seed harvested		Seed weight (g) of unhealthy seeds		Total average seed weight/ plant (g)	
	2024	2025	2024	2025	2024	2025	2024	2025
T1	7.40 ± 0.73^{cd}	7.41 ± 0.72^{b}	16.66 ± 0.88^{c}	18.00 ± 0.57^{bc}	0.65 ± 0.00^{bc}	0.64 ± 0.01^{ab}	3.42 ± 0.01^{cd}	3.45 ± 0.02^{bcd}
T2	5.18 ± 0.74^{ef}	2.96 ± 0.74^{d}	14.33 ± 0.33^{d}	15.33 ± 0.66^{cd}	0.58 ± 0.00^{f}	0.58 ± 0.00^{e}	3.56 ± 0.00^{a}	3.54 ± 0.01^{a}
T3	6.66 ± 0.00^{de}	5.18 ± 0.74^{c}	15.33 ± 0.88^{cd}	16.00 ± 1.00^{cd}	0.59 ± 0.03^{ef}	0.59 ± 0.00^{de}	3.53 ± 0.00^{ab}	3.50 ± 0.00^{ab}
T4	8.88 ± 0.00^{b}	7.41 ± 0.75^{b}	18.66 ± 1.66^{b}	16.66 ± 1.20^{cd}	0.62 ± 0.00^{de}	0.64 ± 0.00^{ab}	3.48 ± 0.01^{abc}	3.47 ± 0.01^{abc}
T5	6.66 ± 0.00^{de}	8.15 ± 0.74^{b}	18.33 ± 2.33^{b}	17.66 ± 0.66^{bc}	0.64 ± 0.00^{cd}	0.64 ± 0.00^{ab}	3.47 ± 0.01^{bcd}	3.47 ± 0.01^{abc}
T6	8.88 ± 0.00^{b}	7.41 ± 0.73^{b}	17.66 ± 0.88^{bc}	16.00 ± 0.57^{cd}	0.65 ± 0.00^{bc}	0.63 ± 0.01^{bc}	3.48 ± 0.00^{abc}	3.46 ± 0.01^{bcd}
T7	6.66 ± 0.00^{de}	8.15 ± 0.74^{b}	16.66 ± 0.33^{c}	18.00 ± 0.57^{bc}	0.64 ± 0.00^{cd}	0.61 ± 0.00^{cd}	3.45 ± 0.01^{cd}	3.44 ± 0.01^{cd}
T8	8.14 ± 0.72^{bc}	8.15 ± 0.73^{b}	17.00 ± 1.00^{c}	16.66 ± 0.66^{cd}	0.64 ± 0.00^{cd}	0.62 ± 0.00^{cd}	3.43 ± 0.00^{cd}	3.47 ± 0.00^{abc}
T9	7.40 ± 0.74^{cd}	8.00 ± 0.68^{b}	18.00 ± 1.55^{bc}	18.00 ± 0.57^{bc}	0.65 ± 0.00^{bc}	0.64 ± 0.00^{ab}	3.46 ± 0.02^{bcd}	3.49 ± 0.00^{abc}
T10	8.14 ± 0.74^{bc}	7.41 ± 0.74^{b}	18.00 ± 1.52^{bc}	18.00 ± 0.57^{bc}	0.66 ± 0.00^{b}	0.62 ± 0.00^{cd}	3.48 ± 0.00^{abc}	3.47 ± 0.00^{abc}
T11	8.88 ± 0.00^{b}	7.95 ± 0.66^{b}	19.33 ± 0.88^{b}	19.66 ± 0.82^{b}	0.65 ± 0.00^{bc}	0.63 ± 0.00^{bc}	3.48 ± 0.03^{abc}	3.45 ± 0.02^{bcd}
T12	4.44 ± 0.00^{f}	4.98 ± 0.54^{c}	16.00 ± 0.57^{cd}	15.33 ± 0.33^{cd}	0.61 ± 0.00^{de}	0.58 ± 0.00^{e}	3.50 ± 0.00^{abc}	3.46 ± 0.01^{bcd}
T13	6.66 ± 0.00^{be}	7.41 ± 0.74^{b}	16.66 ± 0.88^{c}	16.00 ± 0.57^{cd}	0.61 ± 0.00^{de}	0.60 ± 0.00^{de}	3.50 ± 0.00^{abc}	3.42 ± 0.01^{cd}
T14	8.14 ± 0.74^{bc}	8.11 ± 0.72^{b}	20.66 ± 0.88^{ab}	21.33 ± 0.88^{ab}	0.69 ± 0.00^{a}	0.66 ± 0.00^{a}	3.46 ± 0.01^{bcd}	3.43 ± 0.00^{cd}
T15	11.85 ± 0.74^{a}	11.85 ± 0.74^{a}	23.33 ± 1.20^{a}	22.00 ± 0.57^{a}	0.72 ± 0.00^{a}	0.67 ± 0.00^{a}	3.35 ± 0.01^{d}	3.34 ± 0.00^{d}
F stat	13.76**	7.02**	3.98**	7.57**	16.62**	14.45**	10.90**	9.63**
SE(m)	0.47	0.73	1.10	0.73	0.00	0.00	0.01	0.01
SE(d)	0.67	1.04	1.56	1.04	0.01	0.01	0.02	0.01
CV(%)	10.79	17.27	10.76	7.25	2.50	1.87	0.75	0.66

**= $p<0.01$

Table 4. Pooled observations of effect of different treatments on yellow mosaic disease severity and seed health of mungbean **(**Soorya**)** in the summer season

Treatment	Average Disease Severity (%)	Percent decrease over control	Average Number of unhealthy seed /100 seed harvested	Percent decrease over control	Average Seed weight (g) of unhealthy seeds	Percent decrease over control	Average (Summer) seed weight/ plant (g)	Percent decrease over control
T1	3.58±0.82	19.55	16.67±1.80	6.33	0.65±0.05	0.18	3.44±0.00	0.11
T2	3.21±0.98	27.87	14.83±1.07	8.17	0.55±0.03	0.28	3.55±0.01	0.22
T3	3.95±0.78	11.24	16.33±0.76	6.67	0.59±0.02	0.24	3.53±0.00	0.20
T4	4.07±0.95	8.54	18.33±1.43	4.67	0.65±0.02	0.18	3.43±0.02	0.10
T5	3.45±0.82	22.47	18.00±2.51	5.00	0.65±0.09	0.18	3.46±0.01	0.13
T6	4.19±0.82	5.84	18.83±1.01	5.17	0.69±0.03	0.14	3.45±0.01	0.10
T7	3.70±0.97	16.85	19.17±1.30	3.83	0.72±0.05	0.11	3.46±0.00	0.13
T8	3.70±0.89	16.85	17.67±1.78	5.33	0.64±0.04	0.19	3.46±0.02	0.13
T9	3.45±0.82	22.47	18.67±1.49	4.33	0.63±0.03	0.20	3.47±0.03	0.14
T10	3.95±0.87	11.24	18.17±1.35	4.83	0.65±0.01	0.18	3.46±0.00	0.13
T11	3.70±0.97	16.85	18.67±1.45	4.33	0.63±0.03	0.20	3.45±0.01	0.12
T12	3.82±0.90	14.16	19.83±1.40	3.17	0.61±0.04	0.24	3.51±0.00	0.18
T13	3.95±0.70	11.24	19.00±1.52	4.00	0.62±0.05	0.21	3.51±0.01	0.18
T14	3.45±0.56	22.47	21.00±2.23	2.00	0.70±0.09	0.13	3.46±0.00	0.13
T15	4.45±0.69	0.00	23.00±2.00	0.00	0.83±0.10	0.00	3.33±0.01	0.00
F stat	1.76**		1.70**		1.04**		14.08**	
C.D	1.33		4.15		0.16		0.03	

SE(m)	0.33		1.47		0.05		0.01	
SE(d)	0.66		2.07		0.08		0,01	
CV(%)	21.68		18.54		22.03		0.94	

**= p<0.01

Table 5. Pooled observation of effect of different treatments on yellow mosaic disease severity and seed health of mungbean (Soorya) in the Kharif season

Treatment	Average Disease Severity (%)	Percent decrease over control	Average Number of unhealthy seed /100 seed harvested	Percent decrease over control	Average Seed weight (g) of unhealthy seeds	Percent decrease over control	Average (Summer) seed weight/ plant (g)	Percent decrease over control
T1	7.40±0.00	37.55	17.33±1.02	5.33	0.64±0.02	0.06	3.44±0.01	0.11
T2	4.07±1.12	65.65	14.83±0.85	7.84	0.58±0.04	0.12	3.55±0.00	0.22
T3	5.92±0.74	50.04	15.67±2.21	7.00	0.59±0.02	0.11	3.52±0.01	0.19
T4	8.14±0.74	31.31	17.67±1.23	5.00	0.63±0.05	0.07	3.47±0.03	0.14
T5	7.40±0.74	37.55	18.90±1.64	3.77	0.64±0.05	0.06	3.47±0.02	0.14
T6	8.14±0.74	31.31	16.83±1.45	5.84	0.64±0.03	0.06	3.47±0.00	0.14
T7	7.40±0.74	37.55	17.33±1.56	5.34	0.62±0.06	0.08	3.44±0.01	0.11
T8	8.14±0.00	31.31	16.83±1.49	5.84	0.63±0.04	0.07	3.45±0.00	0.12
T9	7.70±0.30	35.02	18.00±1.53	4.67	0.65±0.05	0.05	3.47±0.02	0.14
T10	7.77±0.37	34.43	18.00±1.82	4.67	0.64±0.04	0.06	3.47±0.03	0.14
T11	8.40±0.47	29.11	19.50±1.91	3.17	0.64±0.06	0.06	3.46±0.01	0.13
T12	4.74±0.28	60.00	15.67±1.29	7.00	0.60±0.07	0.10	3.48±0.01	0.15
T13	7.03±0.37	40.68	16.33±2.11	6.34	0.60±0.03	0.10	3.47±0.02	0.15
T14	8.12±0.02	31.48	21.00±1.85	1.67	0.67±0.06	0.03	3.45±0.01	0.12
T15	11.85±0.00	0.00	22.67±1.78	0.00	0.70±0.09	0.00	3.33±0.03	0.00
F stat	0.94**		9.28**		29.26**		18.18**	
C.D	1.24		1.91		0.01		0.02	
SE(m)	0.43		0.67		0.00		0.01	
SE(d)	0.62		0.95		0.00		0.01	
CV(%)	14.15		9.57		2.20		0.72	

**= p<0.01

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