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Effect of Mungbean Bud Necrosis Disease on Growth and Yield Parameters of Mungbean in Protected and Unprotected conditions

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ABSTRACT: Mungbean [(*Vigna radiata* (L.) Wilczek] is the important pulse crop after chickpea and pigeonpea in India which is called as "Queen of pulses", has prone to be infected by bud necrosis disease. In recent years the incidence of disease gradually increasing in mungbean growing areas of Karnataka. Effect of mungbean bud necrosis disease on growth and yield parameters was studied during *Kharif* 2021 at research plot and MARS, UAS, Raichur, Karnataka. The study reveals that, in first DOS (25th June 2021), highest (64.79%) yield loss was recorded in the plants infected at 25 DAS. Complete yield loss was observed in plants infected at 25 DAS in 2nd DAS (1st July). Similarly same trend was noticed in plants infected at 25, 33, 40 and 47 DAS in 3rd DOS (9th July). Whereas 100 percent yield loss recorded in plants infected at 25 & 33 DOS during 4th DOS (23rd July). While lowest per cent yield loss was recorded in 75 DAS in all four DOS. Mungbean bud necrosis disease was reduced to maximum extent by treating the seeds with imidacloprid 78FS at 10 ml/kg followed by three sprays with fipronil 5SC at 1ml/l and improved growth parameters with maximization of yield by avoiding 100 per cent yield loss.

Keywords: Yield loss, Pod weight, Imidacloprid, Fipronil, Thrips.

INTRODUCTION

Grain legumes are nature's precious gift to mankind and often named as 'poor man's meat' as these are rich in protein (16 – 50 %), essential elements, dietary fibre (10 – 23 %) and vitamins (Maphosa and Jideani 2017). Mungbean [(*Vigna radiata* (L.) Wilczek] is the important pulse crop after chickpea and pigeonpea in India which is called as "Queen of pulses". Worldwide, the crop is covering more than six million hectares per annum. However, Asia alone accounts for 90 per cent of world's mungbean production. India is the world's largest mungbean producer accounting for about 65 per cent of world's acreage and 54 percent of its global production. In India during 2021, about 5.13 million ha area was covered under greengram. Rajasthan (25.53 million ha), Karnataka (4.53 million ha), Maharashtra (3.28 million ha), Madhya Pradesh (1.82 million ha), Odisha (1.63 million ha) and Telangana (0.66 million ha) states are the major producers of greengram in India (Directorate of Economics & Statistics, 2021). Greengram enrich soil fertility through atmospheric nitrogen fixation with the help of *Rhizobium* bacteria in nodules and humus, thus playing a crucial role in sustainable agriculture. It is drought tolerant crop and suitable for dry land farming and predominantly used as intercrop with other crops (Nath *et al*., 2018). It is short duration crop (<60 days) with wide adaptability (Sharma *et al*., 2008). Mungbean is proned to be infected by several diseases. Among them bud necrosis disease is major one. In recent years, the incidence of disease gradually increasing in mungbean growing areas of Karnataka. The present investigation was carried out to study the effect of mungbean bud necrosis disease on growth and yield parameters of mungbean in protected and unprotected conditions.

MATERIAL AND METHODS

Estimation of yield loss due to mungbean bud necrosis disease in field (unprotected) conditions. Yield losses due to mungbean bud necrosis disease in field (unprotected) conditions were studied during *Kharif* 2021. The experiments were conducted in research plot and Centre for Agroclimatic studies, Main Agricultural Research Station, University of Agricultural Sciences, Raichur, Karnataka. The crop was sown in 5 × 3 m plot with spacing of 30 × 10 cm by using susceptible varietyy of greengram *i.e.* BGS-9 in four different dates at weekly intervals including one normal date followed by three delayed sowing *viz*., 25th June, 1st July, 9th July and 23rd July by following randomized complete block design and package of practices were followed as per UAS, Raichur, except for bud necrosis disease and thrips management. Development of bud necrosis disease in each date of

sowing was monitored regularly, soon after initiation of disease, at different stages of crop growth, at weekly interval, randomly five plants were tagged and observed for disease development and simultaneously different symptoms were recorded till the completion of crop. In addition to this, plant height, number of branches per plant, nodules per plant, thrips per leaf, number of pods per plant, pod weight per plant and finally yield was recorded in both infected and healthy plants. Yield loss was estimated by comparing the yield from healthy plants and infected plants using the following formula.

$$\text{Yield loss (\%)} = \frac{\text{Yield of healthy plants - Yield of infected plants}}{\text{Yield of healthy plants}} \times 100$$

Estimation of yield loss due to mungbean bud necrosis disease in protected conditions. Similarly yield loss assessment was carried out in other set of experiment by imposing different insecticides at research plot 163, Plant Pathology using susceptible variety of greengram *i.e.* BGS-9. The experiment was laid out in randomized completely block design with six treatments and four replications. Greengram seeds were treated with imidacloprid 48FS at 10 ml/kg seeds and sown in the field. Details of treatments are mentioned below.

Details of treatments

Treatments	Details
T_1	Seed treatment with Imidacloprid 48 FS at 10 ml/kg
T_2	T_1 + Dinotefuran 20 SG at 0.3 g/l (3 sprays)
T_3	T_1 + Fipronil 5 SC at 1 ml/l (3 sprays)
T_4	T_1 + *Pseudomonas fluorescens* spray at 5 g/l - best insecticide (Fipronil 5 SC at 1 ml/l) (2 sprays)
T_5	T_1 + Commercial neem 1500 ppm at 3 ml/l - *Pseudomonas fluorescens* spray at 5 g/l (2 sprays)
T_6	T_1 + Commercial neem 1500 ppm at 3 ml/l – best insecticide (Fipronil 5 SC at 1 ml/l) (2 sprays)
T_7	Control

After 30 days of sowing different insecticides were sprayed and repeated at 15 days interval. Appearance of disease was monitored regularly. Soon after disease appearance, randomly five plants were tagged in each treatment and disease progress was monitored. Later observations such as plant height, number of branches per plant, nodules per plant, thrips per leaf, number of pods per plant, pod weight per plant were recorded. Finally yield from different treatments was compared with control treatment and yield loss was calculated by using formula mentioned.

$$\text{Yield loss (\%)} = \frac{\text{Potential yield of best treatment} - \text{Actual yield of treatment}}{\text{Potential yield of best treatment}} \times 100$$

RESULTS AND DISCUSSION

Estimation of yield loss due to mungbean bud necrosis disease in natural epiphytotic conditions. The bud necrosis infected symptomatic plants were tagged at 25, 33, 40, 47, 54, 61, 68 and 75 days after sowing on the onset of first appearance of the symptoms by selecting the five plants for each infection stage (at weekly interval). Bud necrosis infection in mungbean significantly affected plant height, branches, nodules, pods, pod weight and yield per plant in all infected stages (Plate 1). The maximum plant height (38.20, 29.40, 21.80 and 18.18 cm) was recorded in healthy plants for four different dates of sowing (25th June, 1st July, 9th July and 23rd July respectively) and it was significantly found better over all the plants shown symptoms at different days after infection (Table 1-4). Which was followed by 75 days after sowing (DAS) with recorded height of 27.03, 22.16, 19.20 and 16.14 cm respectively in all four dates of sowing. Whereas the minimum plant height (10.88, 8.98, 8.07 and 8.36 cm) was documented in the plants infected at 25 DAS in all four dates of sowing respectively. This data reveals that, time of appearance of the disease play crucial role in reducing the plant height and showed that early infection reduces plant height to the maximum extent compared to the late infected plants. Gopal and Upadhyaya (1991) reported that, due to bud necrosis disease in groundnut, plant height was reduced in all stages of infection. However, significant differences were observed, when the disease appeared at 70 days or earlier (24.0, 17.8, 16.2, 14.2 and 12.0 cm at 70, 60, 50, 40 and 30 DAS respectively) as compared to healthy control (37.6 cm).

Similarly, attempt was made to score the effect of mungbean bud necrosis disease on the number of branches formed for four different dates with respect to appearance of diseases at different growth stages (Table 1-4). More number of branches has been recorded in healthy plants with 9.80, 7.00, 5.80 and 4.60 in four dates of sowing respectively, followed by in plants where the disease appeared at 75 DAS (5.55, 4.20, 3.44 and 4.08 respectively in four dates of sowing). Whereas the minimum number of branches (2.90, 2.72, 2.20 and 1.64 respectively in four dates of sowing) were recorded in the plants infected at 25 DAS. The number of branches decreased with early appearance of the disease in all the four dates of sowing and inversely proportion to crop age.

Similar trend was observed with respect to the formation of nodules in all the four dates of sowing. The maximum numbers of nodules (22.00, 18.80, 15.20 and 14.40) were recorded in healthy plants in all the dates of sowing. In plants, where disease appeared at 75 (DAS), the numbers of nodules were 18.95, 16.20, 14.10 and 11.98 in all four dates of sowing respectively. Least number (8.07, 7.52, 6.84 and 6.00) of nodules

was recorded in infection at 25 DAS in all dates of sowing respectively (Table 1, 2, 3 and 4). The numbers of nodules were increased when stage of infection delayed from first initiation of symptoms at 25 DAS to 75 DAS.

With respect to the average number of pods per plant, more number of average pods (15.20, 9.60, 6.80 and 5.60 /plant) were recorded in healthy plants in all the dates of sowing respectively (Table 1-4). Comparatively increased number of pods per plant (8.05, 8.45, 9.40, 10.85, 12.75 and 13.70) was recorded at 40, 47, 54, 61, 68 and 75 DAS (days after sowing), as the disease delayed at different crop stages at first date of sowing (25th June 2021) respectively and least number of pods per plant (5.45) was recorded in plants where disease was noticed as early as 25 DAS in first date of sowing. Whereas, 1.72, 1.88, 2.64, 3.24 and 4.36 pods per plant was recorded during 47, 54, 61, 68 and 75 DAS in the diseased plants at second date of sowing (1st July 2021) respectively and least number of pods per plant (0.48 and 0.20) was recorded in plants where disease was initiated at 40 and 33 DAS in second date of sowing. No pods were formed in plants where disease recorded at 25 DAS in second date of sowing. Similarly in third date of sowing, less number of pods has been formed in all the stages of infection and no pods were formed in the plants where disease recorded at 47, 40, 33 and 25 DAS. In fourth date of sowing, less number of pods has been formed in all the stages of infection and no pods were formed in the plants where disease initiated at 33 and 25 DAS. The number of pods per plant was less when the plants affected by bud necrosis disease at early stage. The delay in the appearance of the disease will minimize the loss with respect to the number of pods produced per plants. Pensuk *et al.* (2002) estimated yield losses of over 50 per cent and up to 90-100 per cent in peanut growing areas of India due to Peanut bud necrosis disease (PBND). Plants infected early in development stage may not produce any pods, while plants infected in later stages produce some pods. Healthy greengram plants recorded more pod weight (6.42, 4.02, 2.86 and 2.34 g) in all four dates of sowing respectively. Whereas the lowest pod weight per plant (2.28, 0.00, 0.00 and 0.00 g) were recorded at 25 DAS in four dates of sowing (Table 1-4). The pod weight was increased, when stage of infection delayed from first appearance of symptoms at 25 to 75 DAS plants in four dates of sowing.

The maximum yield per plant of 0.71, 0.46, 0.32 and 0.27 g was recorded in the healthy plants of all the four dates of sowing respectively. It was significantly superior to rest of the parameters at different stages of infection and followed by 75 DAS (0.65, 0.20, 0.08 and 0.17 g). At 68 DAS, the pod yield was 0.61, 0.15, 0.08 and 0.13 g in all the four dates of sowing respectively. No yield was obtained in the plants infected at 25, 33, 40 and 47 DAS in third date of sowing and the plants infected at 25 and 33 DAS in fourth date of sowing as well as the plants infected at 25 DAS in second date of sowing (Table 1-4). The yield was gradually increased when stage of infection delayed from first appearance of symptoms at 25 to 75 dai plants. Moriones *et al.* (1998) studied the effect of plant age at the time of infection by *Tomato spotted wilt virus* on yield in tomato field. Plants which develop symptoms at 24, 38 or 45 days after transplanting yielded comparatively less and produced less and smaller tomatoes than those that developed symptoms at 60, 67 and 74 days after transplanting.

In first date of sowing, the maximum yield loss to the extent of 64.79 per cent was recorded in the plants infected at 25 DAS. While lowest (8.45 %) yield loss was recorded in 75 DAS compare to healthy plants (Table 1). In second date of sowing, complete (100 %) yield loss was observed in the plants infected at 25 DAS. While lowest (56.52 %) yield loss was recorded in 75 DAS compare to healthy plants (Table 2). In third date of sowing, complete (100 %) yield loss was recorded in the plants infected at 25, 33, 40 and 47 DAS. While yield loss reduced to 75.00 per cent at 75 DAS of infection compare to healthy plants (Table 3). Whereas in fourth date of sowing, complete (100 %) yield loss was recorded in the plants infected at 25 and 33 DAS. While lowest (37.04 %) yield loss was noticed in 75 DAS compare to healthy plants (Table 4) (Fig. 1). The yield loss was gradually decreased as the crop stage of infection increased from first appearance of symptoms at 25 to 75 DAS. It is clear that, yield loss was more when the mungbean infected at early (seedling) stage compare to infection at adult plant stage. Rao *et al.* (1979), who found that *Tomato spotted wilt virus* on tomato considerably reduced plant height, root length and yield depending on growth stage of the plant at the time of infection. The plants infected within 45 days of sowing, 100 per cent fruit losses were observed. Crop loss decreased with increasing age of plants with infection. Kumar and Irulappan (1991) reported that, the plants which are infected at 30 days of sowing showed 100 per cent yield loss as compared to 45 and 60 days of sowing due to *Tomato spotted wilt virus* (TSWV) infection in tomato. Ladhalakshmi *et al.* (2005) observed complete yield reduction (100 %) was noticed in the plants affected by *Tobacco streak virus* within 30 days of sowing of blackgram. Beyond 30 days, the percentage of yield reduction was decreased (from 53.37 to 29.18 %). The lowest yield reduction (24.69 %) over control was observed in the plants with 70 days old. Jasani *et al.* (2018) reported that yield loss due to PBND in peanut mainly depends on the time of infection. If the infection occurs on young plants (before 60 days after sowing) pod yield loss was up to 100 per cent and if infection occurs after the plants start to produce pods, losses were minimum.

In first date of sowing, the highest (3.73) thrips population was recorded in the plants infected at 54 DAS. While lowest (2.13) thrips population was found at 25 DAS compare to healthy plants (Table 1). In second date of sowing, the highest (4.26) thrips population was noticed in the plants infected at 54 DAS. While lowest (1.13) thrips was noticed at 25 DAS (Table 2). In third date of sowing, the highest (4.40) thrips population was recorded in the plants infected at 47 DAS. While lowest (2.79) thrips population was observed at 25 DAS (Table 3). Whereas, in fourth date

of sowing, the highest (4.61) thrips population was noticed in the plants infected at 40 DAS. While lowest (2.26) thrips population was noticed at 75 DAS (Table 4).

The maximum disease incidence (37.20, 68.18, 94.79 and 82.13 %) was recorded at 75 DAS among all the four dates of sowing (25th June, 1st July, 9th July and 23rd July respectively) and it was significantly superior at different days after infection in all four dates of sowing (Table 1-4). Which was followed by 68 days after sowing (DAS) with disease incidence of 30.81, 48.20, 75.28 and 73.34 per cent respectively in all four dates of sowing. Whereas, the lowest disease incidence was recorded at 25 DAS (5.37, 9.89, 11.02 and 9.52 %) in all four dates of sowing (Table 1-4). This data reveals that, as age of the plants increases, disease incidence also increases and at 75 DAS highest disease was noticed, since early infected plants can serves as source of inoculums in the plots and helps for subsequent spread by thrips vectors.

Estimation of yield loss due to mungbean bud necrosis disease in protected conditions. Yield loss assessment experiment was carried out during *Kharif* 2021. The bud necrosis infected plants were tagged at 30, 45 and 60 days after sowing with the onset of first appearance of symptoms by selecting the five plants at each infection stage *i.e.*, before spray, after first spray and second spray and the data revealed that, at 30 DAS maximum disease incidence (10.67 %) and minimum plant height (4.63 cm), number of branches (1.07), number of nodules (0.56), number of pods per plant (1.97), pod weight (0.82 g) and yield per plant (0.09 g) were recorded in untreated check. Comparatively less disease incidence (7.23 %), maximum plant height (10.33 cm), number of branches (2.33), number of nodules (4.11), number of pods per plant (5.78), pod weight (2.42 g) and yield per plant (0.27 g) were recorded in the plot with seed treatment with imidacloprid 78FS at 10ml/kg followed by three sprays of fipronil 5SC at 1 ml/l and it was significantly superior over other treatments (Table 5).

At 45 DAS, maximum disease incidence of 23.81 per cent and the least incidence (13.97 %) were recorded in control and T_3 (seed treatment by imidacloprid 78FS at 10 ml/kg followed by three sprays of fipronil 5SC at 1 ml/l) respectively. Subsequently resulted in reduction of growth parameters in untreated check *viz*., plant height (13.40 cm), number of branches per plant (2.71), number of nodules (5.93), number of pods per plant (4.22), pod weight (1.76 g) and yield per plant (0.20 g) was recorded. Whereas comparatively good plant height (17.11 cm) and maximum number of branches per plant (6.22), number of nodules per plant (12.00), number of pods per plant (9.80), pod weight (4.10 g) and yield per plant (0.46 g) were observed in T_3 (seed treatment with imidacloprid 78FS at 10 ml/kg followed by three sprays of fipronil 5SC at 1 ml/l) and found significantly found better over other treatments (Table 6).

At 60 DAS, it has been noticed that, maximum disease incidence in untreated check (33.30 %) and the least incidence was recorded in T_3 (seed treatment with imidacloprid 78FS at 10 ml/kg followed by three sprays of fipronil 5SC at 1 ml/l) (16.69 %). Subsequently resulted in reduction in growth parameters in untreated check *viz*., plant height (19.93 cm), number of branches per plant (3.09), number of nodules (8.00), number of pods per plant (6.80), pod weight (2.85 g) and yield per plant (0.32 g) was recorded. Whereas comparatively maximum plant height (24.78 cm), number of branches per plant (6.78), number of nodules per plant (14.11), number of pods per plant (15.78), pod weight (6.60 g) and yield per plant (0.74 g) was observed in T_3 (seed seed treatment with imidacloprid 78FS at 10 ml/kg followed by three sprays of fipronil 5SC at 1 ml/l) and found significantly superior over other treatments (Table 7).

Finally it has been observed that, highest disease incidence was recorded in untreated check (43.39 %) and least was in T_3 (seeds treated with imidacloprid 78FS at 10 ml/kg followed by three sprays of fipronil 5SC at 1 ml/l) (17.36 %). Yield per plot and yield per hectare was also maximum in T_3 (seed treatment with imidacloprid 78FS at 10 ml/kg followed by three sprays of fipronil 5SC at 1 ml/l) (1054.33 g and 14.02 q) which was significantly superior compare to all other treatments and lowest yield was observed in untreated check (187.66 g and 2.51 q). Per cent yield loss has been calculated, wherein highest yield loss of 81.10 per cent have been recorded in untreated check, followed by T_1 (seed treatment with imidacloprid 78FS at 10 ml/kg) (70.83 %), T_2 (seed treatment with imidacloprid 78FS at 10 ml/kg followed by three sprays of dinotefuran 20SG at 0.3 g/l) (23.25 %), T_6 (seed treatment with imidacloprid 78FS at 10 ml/kg followed by commercial neem 1500 ppm at 3 ml/l followed by two sprays of fipronil 5SC at 1 ml/l) (15.69 %) and T_4 (seed treatment with imidacloprid 78FS at 10 ml/kg followed by *Pseudomonas fluorescens* spray at 5 g/ l followed by two sprays of fipronil 5SC at 1 ml/l) (12.55 %). Least yield loss was recorded in T_5 (seed treatment with imidacloprid 78FS at 10 ml/kg followed by commercial neem 1500 ppm at 3 ml/l followed by two sprays of *Pseudomonas fluorescens* spray at 5 g/l) (4.07 %) (Fig. 2). Mungbean bud necrosis disease was reduced to maximum extent by treating the seeds with imidacloprid 78FS at 10 ml/kg followed by 3 sprays with fipronil 5SC at 1 ml/l and improved growth parameters with maximization of yield by avoiding 100 per cent yield loss. This treatment is significantly superior to other treatments (Table 8). Thus by applying insecticides at appropriate time can avoid and reduce the disease incidence and maximize the yield. The pooled data of yield loss due to mungbean bud necrosis disease under unprotected and protected conditions are displayed in Table 9.

The results are in conformity with the observations made by Kandan *et al*. (2005) reported that, *Pseudomonas fluorescens* treated tomato plants showed improved growth and yield over control indicating the role of PGPR in reducing *Groundnut bud necrosis virus* (GBNV) in tomato. Thiribhuvanamala *et al*. (2013) found that, the application of *P. fluorescens* offered induced resistance against *Groundnut bud necrosis*

virus (GBNV) in tomato apart from increasing the yield. Vinaykumar (2014) reported that, seedling dip with imidacloprid 17.8 SL at 0.3 ml/l and foliar sprays of *P. fluorescens* at 5 g/l – thiamethoxam 25 WDG 0.2 g/l – neemoil (1500 ppm) at 5 ml/l at 15 days interval from planting was found effective with the less disease incidence (34.72%) and higher yield (29.12 t/ha) as compared to untreated check (69.44 %; 12.29 t/ha) respectively.

Plate 1: Effect of mungbean bud necrosis disease on plant growth parameters at different stages of infection.

Table 1: Effect of mungbean bud necrosis disease on growth and yield parameters at first date of sowing (25th June).

Infection at crop stage (DAS)	Plant height (cm)	No. of branches per plant	No. of nodules per plant	Thrips population per leaf	No. of pods per plant	Pod weight(g)	Yield per plant (g)	Yield loss (%)	Disease incidence (%)
25	10.88^{g}	2.90^{e}	8.07^{f}	2.13^{b}	5.45^{g}	2.28^{f}	0.25^{f}	64.79	5.37 (13.38)^{h}
33	12.13^{g}	3.00^{e}	10.35^{e}	2.26^{b}	6.05^{g}	2.57^{f}	0.29^{f}	59.15	10.49 (18.88)^{g}
40	12.67^{fg}	3.20^{de}	11.05^{de}	2.73^{bcd}	8.05^{f}	3.32^{e}	0.38^{e}	46.48	13.75 (21.76)^{f}
47	14.33^{f}	3.40^{de}	12.25^{d}	3.13^{cde}	8.45^{ef}	3.60^{de}	0.41^{de}	42.25	16.15 (23.69)^{e}
54	19.54^{e}	3.70^{cd}	12.40^{d}	3.73^{e}	9.40^{d}	3.98^{cd}	0.45^{cd}	36.62	22.30 (28.18)^{d}
61	22.70^{d}	4.20^{c}	15.75^{c}	3.26^{de}	10.85^{c}	4.40^{c}	0.49^{c}	30.85	26.19 (30.78)^{c}
68	24.80^{c}	5.30^{b}	16.70^{c}	2.80^{bcd}	12.75^{b}	5.32^{b}	0.61^{b}	14.08	30.81 (33.72)^{b}
75	27.03^{b}	5.55^{b}	18.95^{b}	2.46^{bc}	13.70^{b}	5.72^{b}	0.65^{b}	8.45	37.20 (37.59)^{a}
Healthy plant	38.20^{a}	9.80^{a}	22.00^{a}	0.33^{a}	15.20^{a}	6.42^{a}	0.71^{a}	_	-
S. Em (±)	0.69	0.23	0.60	0.25	0.40	0.15	0.02	_	0.23
CD (P≤0.05)	1.99	0.66	1.78	0.69	1.02	0.43	0.05	_	0.60

*Figures in parentheses are arc sine transformed values

Table 2: Effect of mungbean bud necrosis disease on growth and yield parameters at second date of sowing (1st July).

Infection at crop stage (DAS)	Plant height (cm)	No. of branches per plant	No. of nodules per plant	Thrips population per leaf	No. of pods per plant	Pod weight(g)	Yield per plant (g)	Yield loss (%)	Disease incidence (%)
25	8.98^{g}	2.72^{e}	7.52^{g}	1.13^{b}	0.00^{e}	0.00^{f}	0.00^{e}	100.00	9.89 (18.34)^{h}
33	9.78^{fg}	2.80^{e}	7.84^{g}	2.26^{c}	0.20^{e}	0.08^{f}	0.01^{e}	97.82	13.04 (21.16)^{g}
40	10.90^{f}	3.04^{de}	9.56^{f}	3.33^{d}	0.48^{e}	0.21^{f}	0.02^{e}	95.65	23.27 (28.83)^{f}
47	14.42^{e}	3.24^{cde}	12.70^{e}	3.53^{de}	1.72^{d}	0.72^{e}	0.08^{d}	82.61	28.74 (32.41)^{e}
54	17.54^{d}	3.44^{cd}	13.88^{d}	4.26^{e}	1.88^{d}	0.77^{de}	0.09^{d}	80.43	34.86 (36.19)^{d}
61	19.24^{c}	3.52^{cd}	14.88^{cd}	3.60^{de}	2.64^{c}	1.06^{d}	0.13^{c}	71.74	41.27 (39.97)^{c}
68	20.02^{c}	3.80^{bc}	15.64^{bc}	3.13^{cd}	3.24^{c}	1.35^{c}	0.15^{c}	67.39	48.20 (43.96)^{b}
75	22.16^{b}	4.20^{b}	16.20^{b}	3.00^{cd}	4.36^{b}	1.82^{b}	0.20^{b}	56.52	68.18 (55.65)^{a}
Healthy plant	29.40^{a}	7.00^{a}	18.80^{a}	0.33^{a}	9.60^{a}	4.02^{a}	0.46^{a}	-	-
S. Em (±)	0.49	0.20	0.46	0.31	0.24	0.10	0.01	-	0.25
CD (P≤0.05)	1.41	0.58	1.32	0.87	0.69	0.285	0.03	-	0.47

*Figures in parentheses are arc sine transformed values

Table 3: Effect of mungbean bud necrosis disease on growth and yield parameters at third date of sowing (9th July).

Infection at crop stage (DAS)	Plant height (cm)	No. of branches per plant	No. of nodules per plant	Thrips population per leaf	No. of pods per plant	Pod weight(g)	Yield per plant (g)	Yield loss (%)	Disease incidence (%)
25	8.07^{g}	2.20^{f}	6.84^{g}	2.79^{c}	0.00^{e}	0.00^{e}	0.00^{e}	100.00	11.02 (19.38)^{h}
33	8.78^{fg}	2.40^{ef}	7.60^{fg}	3.53^{cde}	0.00^{e}	0.00^{e}	0.00^{e}	100.00	23.75 (29.17)^{g}
40	9.62^{f}	2.64^{def}	7.88^{f}	3.80^{de}	0.00^{e}	0.00^{e}	0.00^{e}	100.00	32.05 (34.47)^{f}
47	13.24^{e}	2.80^{de}	11.24^{e}	4.40^{e}	0.00^{e}	0.00^{e}	0.00^{e}	100.00	50.09 (45.05)^{e}
54	15.42^{d}	2.92^{cd}	12.92^{d}	4.00^{de}	0.60^{d}	0.25^{d}	0.03^{d}	90.63	60.55 (51.09)^{d}
61	17.22^{c}	3.04^{bcd}	13.16^{cd}	3.73^{de}	1.16^{c}	0.49^{c}	0.05^{c}	84.38	73.09 (58.74)^{c}
68	18.70^{b}	3.36^{bc}	13.92^{bc}	3.53^{cde}	1.60^{bc}	0.65^{b}	0.08^{b}	75.00	75.28 (60.19)^{b}
75	19.20^{b}	3.44^{b}	14.10^{b}	3.13^{cd}	1.76^{b}	0.70^{b}	0.08^{b}	75.00	94.79 (76.95)^{a}
Healthy plant	21.80^{a}	5.80^{a}	15.20^{a}	0.67^{a}	6.80^{a}	2.86^{a}	0.32^{a}	-	-
S. Em (±)	0.34	0.16	0.28	0.33	0.16	0.06	0.01	-	0.50
CD (P≤0.05)	0.98	0.46	0.80	0.91	0.45	0.17	0.02	-	1.29

*Figures in parentheses are arc sine transformed values

Table 4: Effect of mungbean bud necrosis disease on growth and yield parameters at fourth date of sowing (23rd July).

Infection at crop stage (DAS)	Plant height (cm)	No. of branches per plant	No. of nodules per plant	Thrips population per leaf	No. of pods per plant	Pod weight(g)	Yield per plant (g)	Yield loss (%)	Disease incidence per plot (%)
25	8.36^{f}	1.64^{g}	6.00^{g}	3.40^{cd}	0.00^{f}	0.00^{f}	0.00^{e}	100.00	9.52 (17.96)^{h}
33	8.56^{f}	2.16^{fg}	6.20^{g}	3.86^{de}	0.00^{f}	0.00^{f}	0.00^{e}	100.00	21.75 (27.79)^{g}
40	8.80^{f}	2.36^{ef}	7.12^{f}	4.61^{e}	0.4^{f}	0.17^{f}	0.02^{e}	92.59	34.56 (36.00)^{f}
47	10.18^{e}	2.64^{ef}	7.56^{ef}	4.01^{de}	1.24^{e}	0.50^{e}	0.05^{d}	81.48	49.63 (44.79)^{e}
54	12.58^{d}	2.80^{de}	8.12^{e}	3.88^{de}	1.72^{d}	0.72^{d}	0.08^{cd}	70.37	57.44 (49.28)^{d}
61	15.34^{c}	3.36^{cd}	9.24^{d}	3.46^{cd}	2.4^{c}	1.00^{c}	0.12^{cd}	55.56	67.09 (55.00)^{c}
68	15.96^{bc}	3.68^{bc}	10.48^{c}	2.60^{bc}	2.64^{c}	1.13^{c}	0.13^{bc}	51.85	73.34 (58.92)^{b}
75	16.14^{b}	4.08^{ab}	11.98^{b}	2.26^{b}	3.36^{b}	1.44^{b}	0.17^{b}	37.04	82.13 (65.00)^{a}
Healthy plant	18.18^{a}	4.60^{a}	14.40^{a}	1.00^{a}	5.6^{a}	2.34^{a}	0.27^{a}	-	-
S. Em (±)	0.24	0.19	0.22	0.32	0.15	0.06	0.02	-	0.54
CD (P≤0.05)	0.69	0.56	0.63	0.89	0.44	0.18	0.04	-	1.00

*Figures in parentheses are arc sine transformed values

Table 5: Effect of mungbean bud necrosis disease on growth and yield components in protected conditions (Infection at 30 DAS).

Treatments	Disease incidence (%)	Plant height (cm)	No. of branches per plant	No. of nodules per plant	No. of pods per plant	Pod weight (g)	Yield per plant (g)
T_1 : Seed treatment with Imidacloprid 48FS at 10ml/kg	5.60 (13.62)	7.89^{ab}	1.56^{bc}	2.43^{b}	2.00^{c}	0.84^{c}	0.09^{c}
T_2 : T_1 + Dinotefuran 20SG at 0.3g/l (3 sprays)	6.47 (14.65)	8.56^{ab}	2.11^{ab}	2.55^{b}	4.95^{ab}	2.07^{ab}	0.23^{ab}
T_3 : T_1 + Fipronil 5SC at 1ml/l (3 sprays)	7.23 (15.58)	10.33^{a}	2.33^{a}	4.11^{a}	5.78^{a}	2.42^{a}	0.27^{a}
T_4 : T_1 + *Pseudomonas fluorescens* spray at 5g/ l - Fipronil 5SC at 1ml/l (2 sprays)	6.83 (15.09)	7.78^{ab}	2.00^{ab}	3.44^{ab}	3.45^{bc}	1.44^{bc}	0.16^{bc}
T_5 : T_1+ Commercial neem 1500 ppm at 3ml/l - *Pseudomonas fluorescens* spray at 5g/ l (2 sprays)	7.10 (15.38)	7.00^{bc}	1.67^{abc}	2.56^{b}	4.34^{ab}	1.81^{ab}	0.20^{ab}
T_6 : T_1 + Commercial neem 1500 ppm at 3ml/l -Fipronil 5SC at 1ml/l (2 sprays)	6.60 (14.86)	6.44^{bc}	2.11^{ab}	2.44^{b}	4.45^{ab}	1.86^{ab}	0.21^{ab}
T_7 : Control	10.67 (19.06)	4.63^{c}	1.07^{c}	0.56^{c}	1.97^{c}	0.82^{c}	0.09^{c}
S. Em (±)	0.75	0.90	0.24	0.45	0.54	0.23	0.03
CD (P≤0.05)	2.69	2.78	0.73	1.38	1.66	0.69	0.09

*Figures in parentheses are arc sine transformed values.

Table 6: Effect of mungbean bud necrosis disease on growth and yield components in protected conditions (Infection at 45 DAS).

Treatments	Disease incidence (%)	Plant height (cm)	No. of branches per plant	No. of nodules per plant	No. of pods per plant	Pod weight (g)	Yield per plant (g)
T_1 : Seed treatment with Imidacloprid 48FS at 10ml/kg	18.10 $(25.18)^{c}$	12.33^{c}	3.45^{b}	9.89^{a}	5.34^{c}	2.23^{c}	0.25^{c}
T_2 : T_1 + Dinotefuran 20SG at 0.3g/l (3 sprays)	14.40 $(22.29)^{a}$	14.67^{bc}	5.22^{a}	7.56^{b}	8.08^{b}	3.38^{b}	0.38^{b}
T_3 : T_1 + Fipronil 5SC at 1ml/l (3 sprays)	13.97 $(21.94)^{a}$	17.11^{ab}	6.22^{a}	12.00^{a}	9.80^{a}	4.10^{a}	0.46^{a}
T_4: T_1 + *Pseudomonas fluorescens* spray at 5g/ l - Fipronil 5SC at 1ml/l (2 sprays)	16.03 $(23.59)^{b}$	17.56^{a}	3.00^{b}	7.45^{b}	7.13^{b}	2.98^{b}	0.33^{b}
T_5: T_1+ Commercial neem 1500 ppm at 3ml/l - *Pseudomonas fluorescens* spray at 5g/ l (2 sprays)	16.39 $(23.89)^{b}$	17.22^{ab}	3.78^{b}	10.56^{a}	8.29^{b}	3.47^{b}	0.39^{b}
T_6: T_1 + Commercial neem 1500 ppm at 3ml/l – Fipronil 5SC at 1ml/l (2 sprays)	16.47 $(23.94)^{bc}$	16.45^{ab}	3.44^{b}	11.00^{a}	7.56^{b}	3.15^{b}	0.35^{b}
T_7 : Control	23.81 $(29.21)^{d}$	13.40^{c}	2.71^{b}	5.93^{b}	4.22^{c}	1.76^{c}	0.20^{c}
S. Em (±)	0.53	0.88	0.41	0.75	0.46	0.19	0.02
CD (P≤0.05)	1.25	2.72	1.24	2.31	1.42	0.59	0.07

*Figures in parentheses are arc sine transformed values.

Table 7: Effect of mungbean bud necrosis disease on growth and yield components in protected conditions (Infection at 60 DAS).

Treatments	Disease incidence (%)	Plant height (cm)	No. of branches per plant	No. of nodules per plant	No. of pods per plant	Pod weight (g)	Yield per plant (g)
T_1 : Seed treatment with Imidacloprid48FS at 10ml/kg	26.51 $(30.99)^{d}$	17.89^{c}	4.43^{bc}	7.17^{c}	9.80^{c}	4.10^{c}	0.46^{d}
T_2 : T_1 + Dinotefuran 20SG at 0.3g/l (3 sprays)	19.29 $(26.05)^{bc}$	21.78^{abc}	4.67^{bc}	8.66^{bc}	12.45^{b}	5.20^{b}	0.58^{c}
T_3 : T_1 + Fipronil 5SC at 1ml/l (3 sprays)	16.69 $(24.11)^{a}$	24.78^{a}	6.78^{a}	14.11^{a}	15.78^{a}	6.60^{a}	0.74^{a}
T_4: T_1 + *Pseudomonas fluorescens* spray at 5g/ l - Fipronil 5SC at 1ml/l (2 sprays)	19.06 $(25.87)^{bc}$	22.67^{ab}	5.56^{ab}	11.89^{a}	12.94^{b}	5.41^{b}	0.61^{bc}
T_5 : T_1+ Commercial neem 1500 ppm at 3ml/l - *Pseudomonas fluorescens* spray at 5g/ l (2 sprays)	17.78 $(24.93)^{ab}$	22.33^{ab}	5.00^{abc}	11.67^{a}	12.11^{b}	5.06^{b}	0.57^{c}
T_6 : T_1 + Commercial neem 1500 ppm at 3ml/l – Fipronil 5SC at 1ml/l (2 sprays)	20.47 $(26.90)^{c}$	23.33^{ab}	5.66^{ab}	11.34^{ab}	14.52^{a}	6.07^{a}	0.68^{ab}
T_7 : Control	33.30 $(35.24)^{e}$	19.93^{bc}	3.09^{c}	8.00^{c}	6.80^{d}	2.85^{d}	0.32^{e}
S. Em (±)	0.51	1.27	0.62	0.97	0.49	0.21	0.02
CD (P≤0.05)	1.11	3.91	1.92	2.99	1.51	0.64	0.08

*Figures in parentheses are arc sine transformed values.

Table 8: Assessment of avoidable yield loss under protective conditions due to mungbean bud necrosis disease.

Treatments	Disease incidence (%) at			Final disease incidence (%)	Yield per plot (g)	Yield (q/ha)	Yield loss (%)	Avoidable yield loss (%)
	30 DAS (before spray)	45 DAS (after 1st spray)	60 DAS (after 2nd spray)					
T_1 : Seed treatment with Imidacloprid 48FS at 10ml/kg	5.60 (13.62)	18.10 (25.18)^{c}	26.51 (30.99)^{d}	33.51 (35.37)^{e}	307.33^{f}	4.09^{f}	70.83	29.17
T_2 : T_1 + Dinotefuran 20SG at 0.3g/l (3 sprays)	6.47 (14.65)	14.40 (22.29)^{a}	19.29 (26.05)^{bc}	23.96 (29.30)^{cd}	809.33^{e}	10.76^{e}	23.25	76.75
T_3 : T_1 + Fipronil 5SC at 1ml/l (3 sprays)	7.23 (15.58)	13.97 (21.94)^{a}	16.69 (24.11)^{a}	17.36 (24.62)^{a}	1054.33^{a}	14.02^{a}	0.00	100.00
T_4: T_1 + *Pseudomonas fluorescens* spray at 5g/ l - Fipronil 5SC at 1ml/l (2 sprays)	6.83 (15.09)	16.03 (23.59)^{b}	19.06 (25.87)^{bc}	22.39 (28.23)^{c}	921.66^{c}	12.26^{c}	12.55	87.45
T_5: T_1+ Commercial neem 1500 ppm at 3ml/l - *Pseudomonas fluorescens* spray at 5g/ l (2 sprays)	7.10 (15.38)	16.39 (23.89)^{b}	17.78 (24.93)^{ab}	18.45 (26.14)^{b}	1011.33^{b}	13.45^{b}	4.07	95.93
T_6 : T_1 + Commercial neem 1500 ppm at 3ml/l – Fipronil 5SC at 1ml/l (2 sprays)	6.60 (14.86)	16.47 (23.94)^{bc}	20.47 (26.90)^{c}	24.47 (29.64)^{d}	888.33^{d}	11.82^{d}	15.69	84.31
T_7 : Control	10.67 (19.06)	23.81 (29.21)^{d}	33.30 (35.24)^{e}	43.39 (41.21)^{f}	187.66^{g}	2.51^{g}	81.10	18.90
S. Em (±)	0.75	0.53	0.51	0.66	1.42	0.02	-	-
CD (P≤0.05)	2.69	1.25	1.11	1.36	4.11	0.05	-	-

*Mean of three replications, Figures in parentheses are arc sine transformed values.

Table 9: Yield loss due to mungbean bud necrosis disease under unprotected and protected conditions.

Unprotected condition (natural epiphytotic condition)					Protected condition	
Infection at crop stage (DAS)	Yield loss (%) at				Treatments	Yield loss (%)
	1st date of sowing (25/06/2021)	2nd date of sowing (01/07/2021)	3rd date of sowing (09/07/2021)	4th date of sowing (23/07/2021)		
25	64.79	100.00	100.00	100.00	T_1 : Seed treatment with Imidacloprid 48FS at 10ml/kg	70.83
33	59.15	97.82	100.00	100.00	T_2 : T_1 + Dinotefuran 20SG at 0.3g/l (3 sprays)	23.25
40	46.48	95.65	100.00	92.59	T_3 : T_1 + Fipronil 5SC at 1ml/l (3 sprays)	0.00
47	42.25	82.61	100.00	81.48	T_4 : T_1 + *Pseudomonas fluorescens* spray at 5g/ l - Fipronil 5SC at 1ml/l (2 sprays)	12.55
54	36.62	80.43	90.63	70.37	T_5 : T_1+ Commercial neem 1500 ppm at 3ml/l - *Pseudomonas fluorescens* spray at 5g/ l (2 sprays)	4.07
61	30.85	71.74	84.38	55.56	T_6 : T_1 + Commercial neem 1500 ppm at 3ml/l – Fipronil 5SC at 1ml/l (2 sprays)	15.69
68	14.08	67.39	75.00	51.85	T_7 : Control	81.10
75	8.45	56.52	75.00	37.04		

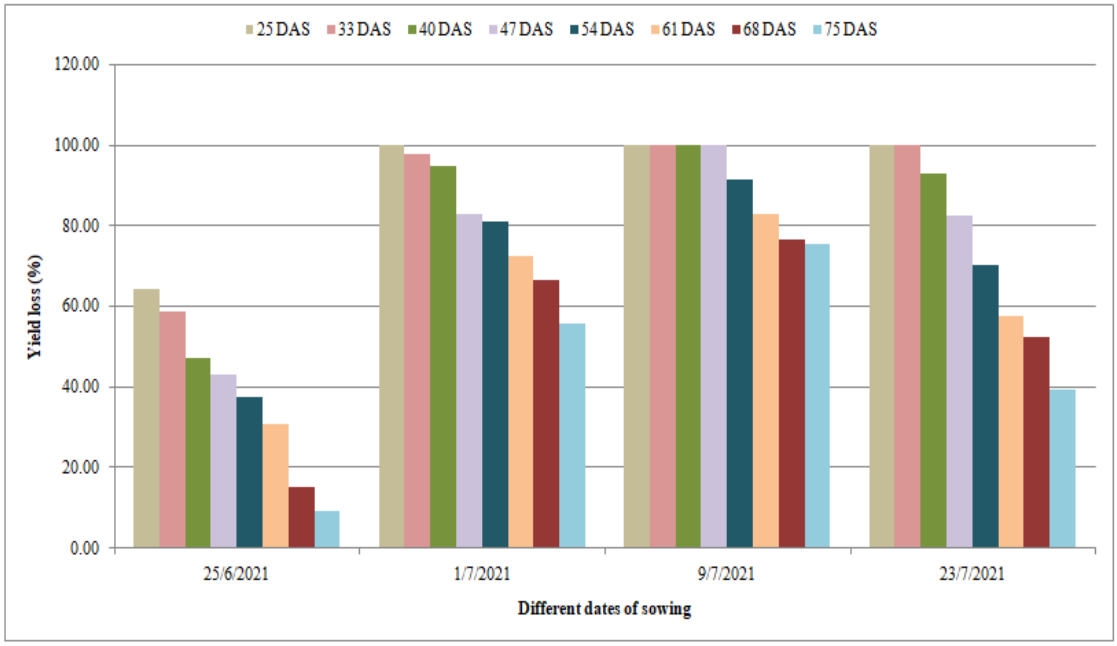
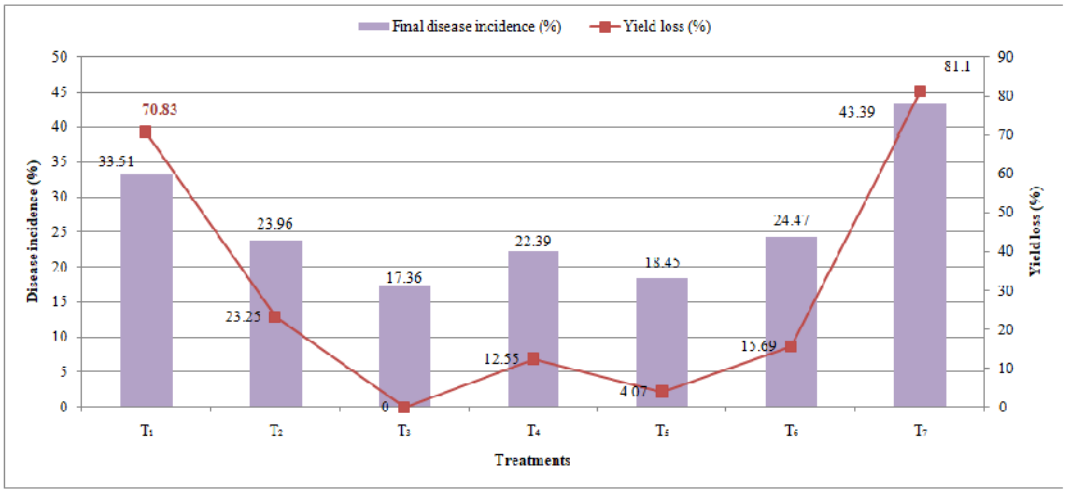


Fig. 1. Yield loss in mungbean influenced by bud necrosis disease at different growth stages and different dates of sowing during *Kharif* 2021.



T_1: Seed treatment with Imidacloprid 48FS at 10ml/kg
T_2: T_1 + Dinotefuran 20SG at 0.3g/l (3 sprays)
T_3: T_1 + Fipronil 5SC at 1ml/l (3 sprays)
T_4: T_1 + *Pseudomonas fluorescens* spray at 5g/ l - Fipronil 5SC at 1ml/l (2 sprays)
T_5: T_1+ Commercial neem 1500 ppm at 3ml/l - *Pseudomonas fluorescens* spray at 5g/ l (2 sprays)
T_6: T_1 + Commercial neem 1500 ppm at 3ml/l – Fipronil 5SC at 1ml/l (2 sprays)
T_7: Control

Fig. 2. Yield loss in mungbean due to bud necrosis disease under protective conditions during *Kharif* 2021.

CONCLUSION

In all the four dates of sowing, the growth and yield parameters such as plant height, number of branches per plant, number of nodules per plant, number of pods per plant, pod weight and yield per plant were maximum in healthy plants, followed by in plants where disease started at 75, 68, 61, 54, 47, 40 and 33 DAS, these parameters were minimum in plants where disease appeared at 25 DAS. As age of the plants increases, disease incidence also increases and at 75 DAS highest disease was noticed, since early infected plants can serves as source of inoculums in the plot and helps for subsequent spread by thrips vectors. The yield loss was gradually decreased as the crop stage of infection increased from first appearance of symptoms at 25 DAS (64.79, 100, 100 & 100 %) to 75 DAS (8.45, 56.52, 75.00 & 37.04 %) respectively in all four dates of sowing. Hence, yield loss was more when the mungbean infected at early stage compare to infection at adult plant stage. Mungbean bud necrosis disease was reduced to maximum extent by treating the seeds with imidacloprid 78FS at 10 ml/kg followed by three sprays with fipronil 5SC at 1 ml/l and improved growth parameters with maximization of yield by avoiding 100 per cent yield loss. This treatment is significantly superior to other treatments.

FUTURE SCOPE

This study helps us to know the extent of yield loss due to mungbean bud necrosis disease in both protected and unprotected conditions and also its effect on growth and yield parameters of mungbean due to bud necrosis disease.

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Conflicts of Interest. None.

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