Evaluation of potential fungicides, botanicals, biocontrol agents and their combination against *M. phaseolina* inciting root rot of sesame

Karibasappa CS, Bharati N Bhat and S Chander Rao

DOI: [https://doi.org/10.22271/chemi.2020.v8.i2aa.9016](https://doi.org/10.22271/chemi.2020.v8.i2aa.9016)

**Abstract**

The most effective fungicide (vitavax power), potential antagonist/ biocontrol agent (*T. viride*) and botanical (Neem oil) which were obtained during poisoned food technique and dual culture technique under *in vitro* conditions were further tested to know their individual as well as combined effect on seedling emergence, plant growth parameters and root rot incidence in potculture with susceptible variety (VRI-1) in *M. phaseolina* inoculated soil. The results indicated that combined seed treatment with *P. fluorescens*, neem oil and vitavax power recorded maximum germination percentage (93.33%), root (5.70 cm) and shoot length (11.9 cm), dry weight (0.28 g plant-1) and maximum percentage reduction of dry root rot (71.38%) followed by seed treatment with *P. fluorescens* and vitavax power (64.11%) and least reduction in root rot incidence (16.07%) observed in sesame seeds treated with only neem oil.

**Keywords:** *Pseudomonas fluorescens* and vitavax power, root rot, *Macrophomina phaseolina*

**Introduction**

Sesame (*Sesamum indicum* L.) is an important oil seed crop preferred due to rich its edible oil content (about 50%) and nutritious protein (about 23%) and having sufficient carbohydrate (15%) (Ranganatha *et al.*, 2012) [25]. The medicinal value of sesame seeds are accepted worldwide due to the rich source of linolic acid, Vitamin E, A, B1 and B2 (Brar and Ahuja, 1979) [4]. In India, sesame crop occupies an area of 1.77 Mha with production of 8.27 lakh tonnes and productivity of 426 kg ha⁻¹. In united Andhra Pradesh it is growing on 0.97 lakh ha with a production of 0.27 lakh tonnes and productivity of 341 kg ha⁻¹, (Indiastat, 2014-15). Sesame (*Sesamum indicum* L.) is under constant threat to many diseases. Among these root rot/stem rot caused by *Macrophomina phaseolina* (Tassi.) Goid (= *Rhizoctonia bataticola*) is the most important disease of sesame in India (Chattopadhyay and Sastry, 1998) [6]. It has become a potential threat for the profitable cultivation especially in the changing warm climate and intensive farming situations (Saharan *et al.*, 2005) [27]. The pathogen is responsible for seed rot, seedling decay, stem and root rot problem in sesame (Kolte, 1985; Verma *et al.*, 2005) [16, 32] and also resulted in poor seedling development and 5-100% yield loss of the crop (Aly *et al.*, 2006) [30]. The most common symptom of the disease is the sudden wilting of plants throughout the crop growth, mainly after the flowering phase. Due to severe infection, the stem becomes black and the roots rot shredding the bark exposing large number of black, minute sclerotia on the affected portions. The present investigation was carried out under glass house conditions to assess the potential effect of fungicides, botanicals, biocontrol agents and their combination against *M. phaseolina*.

**Materials and Methods**

The most effective fungicide (vitavax power), potential antagonist/biocontrol agent (*T. viride*) and botanical (Neem oil) which were obtained during poisoned food technique and dual culture technique under *in vitro* conditions were further tested to know their individual as well as combined effect on seedling emergence, plant growth parameters and root rot incidence in potculture with susceptible variety (VRI-1) in *M. phaseolina* inoculated soil.
Mass multiplication of the pathogen
The inoculum of the test pathogen, *M. phaseolina* maintained on agar slants was further multiplied on sorghum grains. One hundred grams of sorghum seeds were washed thoroughly in tap water and soaked overnight in 250 ml conical flasks with addition of 20 ml of 4 per cent dextrose. The flasks were then autoclaved for 20 min at 15 lbs. After cooling the flasks at room temperature they were shaken well to separate the sterilized grains and were inoculated with 2-3 discs of 4 day old culture of *M. phaseolina* and incubated at 28 ± 1°C for seven days in BOD incubator. After seven days, the inoculum was mixed with sterilized soil in pots at five per cent level (w/w).

The seeds of sesame were imposed with the following treatments and sown in earthen pots of size 12 inch diameter which were filled with steam sterilized soil and inoculated with the soil borne pathogen *M. phaseolina* at five per cent level (w/w) which was mass multiplied on sorghum grains earlier.

I. Seed treatment with Vitavax Power
The seeds of sesame cv VRI-1 were surface sterilized in 5% sodium hypochlorite for 2 min then thoroughly washed in sterilized distilled water and air dried under aseptic conditions. These seeds were treated with Vitavax Power @ 2 g kg⁻¹ seed using gum (5 ml kg⁻¹) as sticker and the treated seeds were used for sowing.

II. Seed treatment with *T. asperellum* / *P. fluorescens*
The talc based bio-control agents *T. asperellum* @ 4 g kg⁻¹ seed and *P. fluorescens* 10 g kg⁻¹ seed were used for treating the surface sterilized seeds by using gum (5ml kg⁻¹) as sticker. The treated seeds were spread over a clean paper and dried in a cool shady place. The seeds were sown immediately after drying.

III. Combined seed treatment with fungicides, botanical and biocontrol agent
For treatments involving combinations of fungicide, biocontrol agent and botanical, the surface sterilized seeds were first treated with Vitavax Power, followed by neem oil, and then mixed with *Trichoderma asperellum* and *Pseudomonas fluorescens* at recommended doses using gum as sticker. The treated seeds were shade dried over a clean paper and used for sowing.

The experiment was conducted in completely randomized block design with twelve treatments and replicated three times. Data on seedling emergence was taken on 10 days after sowing. Per cent disease incidence and plant growth characters viz., shoot length, root length, shoot and root dry weights were recorded on 40 days after sowing and vigour index was also calculated. The details of treatments are mentioned in Table 1.

Germination Percentage (GP) was calculated using the formula

\[ GP = \frac{D}{S} \times 100\% \]

Where,

- \(D\) = Number of germinated seeds on the tenth day
- \(S\) = Number of total seeds sown

Vigour Index was calculated

Vigour index-I = \(\%\) Germination x Seedling growth (shoot length + root length)

Vigour index-II = \(\%\) Germination x Seedling dry matter

Per cent disease incidence (PDI) was calculated following the formula given below

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

Table 1: Details of the treatments imposed for Sesame root rot management under green house conditions

| Treatment Number | Treatments                                                                 |
|------------------|---------------------------------------------------------------------------|
| T₁               | Potential Fungal Antagonist (*Trichoderma viridae* @ 4 g kg⁻¹)           |
| T₂               | Potential Bacterial Antagonist (*Pseudomonas fluorescens* @ 10 g kg⁻¹)   |
| T₃               | Effective Botanical (Neem oil @ 10ml kg⁻¹)                                |
| T₄               | Effective Fungicide (Vitavax Power @ 2 g kg⁻¹)                            |
| T₅               | *Trichoderma viridae* @ 4 g kg⁻¹ (T₁) + *Pseudomonas fluorescens* @ 10 g kg⁻¹ (T₂) |
| T₆               | *Trichoderma asperellum* @ 4g kg⁻¹ (T₁) + Neem oil @ 10 ml kg⁻¹ (T₃)     |
| T₇               | *Pseudomonas fluorescens* @ 10 g kg⁻¹ (T₂) + Neem oil @ 10 ml kg⁻¹ (T₃)   |
| T₈               | *Pseudomonas fluorescens* @ 10 g kg⁻¹ (T₂) + Vitavax Power @ 2 g kg⁻¹ (T₄) |
| T₉               | Neem oil @ 10 ml g kg⁻¹ (T₁) + Vitavax Power @ 2 g kg⁻¹ (T₄)             |
| T₁₀              | *Trichoderma viridae* @ 4 g kg⁻¹ (T₁) + *Pseudomonas fluorescens* @ 10 g kg⁻¹ (T₂) + Neem oil @ 10 ml kg⁻¹ (T₃) |
| T₁₁              | *Pseudomonas fluorescens* @ 10 g kg⁻¹ (T₂) + Neem oil @ 10 ml kg⁻¹ (T₃) + Vitavax Power @ 2 g kg⁻¹ (T₄) |
| T₁₂              | Uncoated seed (Control) + pathogen                                      |

**Statistical Analysis**
The data obtained in different experiments were statistically analyzed following completely randomized block design (CRD) as per the procedures suggested by Snedecor and Cochran (1967) [31] and Panse and Sukhatme (1978) [23]. The data pertaining to percentage were subjected to angular transformation wherever necessary.

**Results and Discussions**
a. **Effect on Germination percentage**
It is evident from the results presented in Table 2 and figure 1 that germination percentage was significantly higher in all the treatments as compared to control (56%). Maximum germination (93.33%) was observed in combined treatment of *P. fluorescens* + neem oil + vitavax power followed by seed treatment with *P. fluorescens* + vitavax power (87.2%) and
the minimum germination was recorded in treatment with only neem oil (62.8%).

b. Effect on Growth Parameters Dry weight
The results (Table 3) recorded that there was a significant increase in dry weight of plants by all the treatments when compared to control (0.15 g plant\(^{-1}\)) and the increase in dry weight ranged from (0.179 to 0.28 g plant\(^{-1}\)). Combined seed treatment with \(P.\) \textit{fluorescens}, neem oil and Vitavax power recorded maximum percentage increase in dry weight (86.66%) followed by combined seed treatment with \(P.\) \textit{fluorescens} and Vitavax power (73.33%) and the minimum increase was observed in seed treatment with neem oil (19.33%) compared to control plants.

c. Effect on Root Length
It is evident from the Table 3 that root length was significantly increased in all the treatments when compared to control (3.10 cm). Increase in root length ranged from 3.45 to 5.70 cm. Combined seed treatment with \(P.\) \textit{fluorescens}, neem oil and vitavax power recorded maximum percentage increase in root length (83.87%) followed by seed treatment with \(P.\) \textit{fluorescens} and vitavax power (77.41%) compared to control and the least per cent increase was observed in neem oil treated seeds (11.29%). Incresed growth response induced by micro flora is might be either due to antagonistic activity and biological control of plant pathogens in the soil or due to growth regulatory metabolites produced microbial agents in the soil (Kleopper and Schrroth,1981) [15]. Thus the rate of germination and dry weight of root and shoot were increased (Windham et al. 1986) [34]. Similar reports of increase in vegetative growth using fungicide and \textit{Trichodermia} spp. was also recorded in greengram (Rajeswari et al., 1999) [24], in chilli (Mamohndas and Sivaparakasam, 1994) [19], and in tomato (Manoranjitham et al., 2001) [21].

d. Effect on Dry Root Rot Incidence
Data on dry root rot disease incidence was recorded at 40 DAS and the results are presented in the Table 4 and figure 2. The results indicate that individual as well as combined seed treatment with \textit{T. viride}, neem oil and vitavax power significantly reduced dry root rot incidence ranging from 16.03 to 47 per cent compared to control (56%). Combined seed treatment with \(P.\) \textit{fluorescens}, neem oil and vitavax power recorded maximum percentage reduction of dry root rot (71.38%) followed by seed treatment with \(P.\) \textit{fluorescens} and vitavax power (64.11%) and least reduction in root rot incidence (16.07%) observed in sesame seeds treated with only neem oil.

In the present study the germination percentage, plant growth parameters significantly increased and percentage of dry root rot incidence was significantly reduced when fungicide, potential biocontrol agent and botanical were used in combination. These results are in agreement with the results obtained by previous workers. Mallaiha and Krishna Rao (2016) [20] reported that in pot culture studies combined sesame seed treatment with \textit{T. viride}, \textit{P. fluorescens}, Neem oil and thiram seed was found to be highly effective in increasing seedling emergence (91.3%), plant dry weight (98.6%), shoot length (73.9%) and root length (70.8%). Seed treatment with all four combinations was found to be superior in reducing dry root rot incidence (87.8%).

Vyas (1994) [33] reported that root rot of soybean caused by \textit{Macrophomina phaseolina} can be effectively controlled by integration of carbendazim with \textit{T. harzianum} (or) \textit{T. viride}. Jayasree et al. (2000) [13] reported that maximum root length and shoot length of sesame and black gram were recorded in combined seed treatment and soil application of \textit{T. harzianum} and \textit{P. fluorescens}.

Kishan et al. (1999) [14] observed that combination of fungicide (soil application) and conidia (seed coating) reduced the disease to 5% in his studies on management of sesame dry root-rot \textit{Rhizoctonia bataticola} (Taub.) Butl. through biological and chemical means.

Animisha et al. (2012) [2] observed that chickpea wilt incited by \textit{Fusarium oxysporum} can be effectively controlled by integration of \textit{T. viride}, carbendazim and neem cakes. Combined application of carbendazim, \textit{T. viride} and \textit{P. fluorescens} were superior in management of Pigeon pea wilt disease caused by \textit{Fusarium udum var cajani} (Mahesh et al. 2010) [18]. Combination of PBP 4G (\textit{T. viride}) for soil application and Pusa SSD (\textit{T. harzianum}) for seed treatment together with fungicide carboxin, provided the highest seed germination, shoot and root lengths and grain yield with the lowest incidence of wilt in chickpea under field conditions (Dubey et al. 2013) [9].

Sindhan et al. (2002) [29] reported satisfactory disease control when \textit{Pseudomonas fluorescens} was used as seed treatment along with carbendazim against \textit{Macrophomina phaseolina} in chickpea. It is attributed that carbendazim could arrest the pathogen and antagonists could parasitize the pathogen and promote growth by secreting growth promoting metabolites. Different workers have also been reported that \textit{P. fluorescens} was effective biocontrol agent for different fungal pathogens (Meyer et al., 1992; Buysens et al., 1996; Reimmann et al., 1988; Singh et al., 2006) [22, 5, 26, 30]. \textit{P. fluorescens} could act as strong elicitors of plant defense reactions (M‘ Piga et al., 1997) [17]. Recent studies imply that prior application of fluorescent \textit{pseudomonads} strengthens host cell wall structure that results in restriction of pathogen invasion in plant tissue (Benhamou et al., 2000; Chen et al., 2000; Coen et al., 2002; Dwivedi and Johri, 2003) [3, 7, 8, 10].

The present findings are supported by earlier workers who also reported that integration of biocontrol agent with compatible fungicide gave significantly higher disease control in several crops than obtained by either biocontrol agent (or) fungicide. (Henis et al. 1978, Sawant and Mukhopadhyay, 1990) [11, 28].

This is particularly relevant for soil borne pathogens such as \textit{M. phaseolina} where use of only fungicides for drenching the soil is not only deleterious to the environment but is also practically not feasible due to high cost as sesame is generally cultivated without much investment for crop production as well as protection.

Conclusions
The results indicated that germination percentage was significantly higher in all the treatments as compared to control (56%). Maximum germination (93.33%) was observed in combined treatment of \textit{P. fluorescens} + neem oil + vitavax power followed by seed treatment with \textit{P. fluorescens} + vitavax power (87.2%). Significant increase in dry weight of plants by all the treatments when compared to control (0.15 g plant\(^{-1}\)) and the increase in dry weight ranged from (0.179 to 0.28 g plant\(^{-1}\)). Combined seed treatment with \textit{P. fluorescens}, neem oil and Vitavax power recorded maximum percentage increase in dry weight (86.66%). Increase in root length
ranged from 3.45 to 5.70 cm. Combined seed treatment with *P. fluorescens*, neem oil and vitavax power recorded maximum percentage increase in root length (83.87%). Individual as well as combined seed treatment with *T. viride*, neem oil and vitavax power significantly reduced dry root rot incidence ranging from 16.03 to 47 per cent compared to control (56%). Combined seed treatment with *P. fluorescens*, neem oil and vitavax power recorded maximum percentage reduction of dry root rot (71.38%) followed by seed treatment with *P. fluorescens* and vitavax power (64.11%) and least reduction in root rot incidence (16.07%) observed in sesame seeds treated with only neem oil.

**Acknowledgements**

The authors would like to acknowledge the support of Professor Jayashankar Telangana State Agricultural University and the Indian Institute of Oilseeds Research, Hyderabad, India for providing financial as well as lab and glasshouse facilities in conducting this experiment.

**Table 2:** Effect of seed treatment with effective biocontrol agents, botanical and fungicide on seedling emergence of Sesame cv. VRI-1 in *M. phaseolina* infested soil in greenhouse conditions

| Treatment No. | Details of Treatment | Germination (%) | Increase over control (%) |
|---------------|----------------------|-----------------|--------------------------|
| T₁            | *Trichoderma viridae* (Tv1 @ 4 g kg⁻¹) + Pathogen | 68 (55.54) (55.54) | 21.42 |
| T₂            | *Pseudomonas fluorescens* (pf1 @ 10 g kg⁻¹) + Pathogen | 66 (54.32) (54.32) | 17.85 |
| T₃            | Neem oil (@ 10 ml kg⁻¹) + Pathogen | 62.8 (52.40) | 12.14 |
| T₄            | Vitavax power (@ 2 g kg⁻¹) + Pathogen | 80 (63.45) | 42.85 |
| T₅            | *Trichoderma viridae* + *Pseudomonas fluorescens* + Pathogen | 73.33 (58.91) | 30.94 |
| T₆            | *Trichoderma viridae* + Neem oil + Pathogen | 70.2 (56.91) | 25.35 |
| T₇            | *Pseudomonas fluorescens* + Neem oil + Pathogen | 68.66 (55.95) | 22.6 |
| T₈            | *Pseudomonas fluorescens* + Vitavax power + Pathogen | 87.2 (69.10) | 55.71 |
| T₉            | Neem oil + Vitavax power + Pathogen | 83.33 (65.93) | 48.8 |
| T₁₀           | *Trichoderma viridae* + *Pseudomonas fluorescens* + Neem oil + Pathogen | 74.6 (59.74) | 33.21 |
| T₁₁           | *Pseudomonas fluorescens* + Neem oil + Vitavax power + Pathogen | 93.33 (75.26) | 66.66 |
| T₁₂           | Inoculated control | 56 (48.43) | CD (p = 0.05) |

* Figures in the parentheses are angular transformed values and are the means of three replication.

**Fig 1:** Effect of seed treatment with effective biocontrol agents, botanical and fungicide on seedling emergence of Sesame cv. VRI-1 in *M. phaseolina* infested soil in greenhouse conditions
Table 3: Effect of seed treatment with effective biocontrol agents, botanical and fungicide on growth parameters of Sesame cv. VRI-1 in *M. phaseolina* infested soil in greenhouse conditions.

| Treatment No. | Details of Treatment                      | Root Length (cm) | Increase over control (%) | Shoot Length (cm) | Increase over control (%) | Vigour index I | Dry Weight (g) | Increase over control (%) | Vigour index II |
|---------------|------------------------------------------|------------------|---------------------------|------------------|---------------------------|----------------|---------------|---------------------------|----------------|
| T1            | *Trichoderma viridae* (Tv1 @ 4 g kg⁻¹) + Pathogen | 4.12             | 32.9                      | 8.50             | 34.49                     | 1,089.36       | 0.185         | 23.33                     | 12.58          |
| T2            | *Pseudomonas fluorescens* (pf1 @ 10 g kg⁻¹) + Pathogen | 3.83             | 23.54                     | 7.80             | 23.41                     | 1,017.06       | 0.181         | 20.66                     | 11.95          |
| T3            | Neem oil (@ 10ml kg⁻¹) + Pathogen         | 3.45             | 11.29                     | 6.98             | 10.44                     | 898.04         | 0.179         | 19.33                     | 11.24          |
| T4            | Vitavax power (@ 2 g kg⁻¹) + Pathogen     | 5.00             | 61.29                     | 10.55            | 66.93                     | 1,244.00       | 0.230         | 58.00                     | 18.40          |
| T5            | *Trichoderma viridae* + *Pseudomonas fluorescens* + Pathogen | 4.75             | 53.22                     | 9.95             | 57.43                     | 1,096.28       | 0.215         | 43.33                     | 15.77          |
| T6            | *Trichoderma viridae* + Neem oil + Pathogen | 4.56             | 47.09                     | 9.50             | 50.31                     | 1,018.60       | 0.205         | 36.66                     | 14.39          |
| T7            | *Pseudomonas fluorescens* + Neem oil + Pathogen | 4.32             | 39.35                     | 8.95             | 41.61                     | 948.881        | 0.190         | 26.66                     | 13.04          |
| T8            | *Pseudomonas fluorescens* + Vitavax power + Pathogen | 5.50             | 77.41                     | 11.58            | 83.22                     | 1,260.04       | 0.260         | 73.33                     | 22.67          |
| T9            | Neem oil + Vitavax power + Pathogen       | 5.10             | 64.51                     | 10.85            | 71.67                     | 1,133.29       | 0.250         | 66.66                     | 20.83          |
| T10           | *Trichoderma viridae* + *Pseudomonas fluorescens* + Neem oil + Pathogen | 4.85             | 56.45                     | 10.20            | 61.39                     | 943.69         | 0.220         | 46.66                     | 16.41          |
| T11           | *Pseudomonas fluorescens* + Neem oil + Vitavax power + Pathogen | 5.70             | 83.87                     | 11.90            | 88.29                     | 1,183.42       | 0.280         | 86.66                     | 26.13          |
| T12           | Inoculated control                        | 3.10             | 6.32                      | 527.52           | 0.150                     | 8.4            |               |                           |                |
|               | CD (p = 0.05)                             | 0.34             | 0.85                      | 42.38            | 0.025                     | 0.76           |               |                           |                |
|               | SE(m) ±                                  | 0.11             | 0.29                      | 14.43            | 0.009                     | 0.26           |               |                           |                |
|               | CV (%)                                   | 4.42             | 5.30                      | 2.43             | 7.053                     | 2.81           |               |                           |                |

Table 4: Effect of seed treatment with effective biocontrol agents, botanical and fungicide on root rot incidence of Sesame cv. VRI-1 in *M. phaseolina* infested soil in greenhouse conditions

| Treatment No. | Details of Treatment                      | Per cent disease incidence | Decrease over control (%) |
|---------------|------------------------------------------|-----------------------------|---------------------------|
| T1            | *Trichoderma viridae* (Tv1 @ 4 g kg⁻¹) + Pathogen | 39.9 (39.16)                | 28.75                     |
| T2            | *Pseudomonas fluorescens* (pf1 @ 10 g kg⁻¹) + Pathogen | 43 (40.96)                  | 23.21                     |
| T3            | Neem oil (@ 10ml kg⁻¹) + Pathogen         | 47 (43.26)                  | 16.07                     |
| T4            | Vitavax power (@ 2 g kg⁻¹) + Pathogen     | 28.33 (32.14)               | 49.41                     |
| T5            | *Trichoderma viridae* + *Pseudomonas fluorescens* + Pathogen | 31.6 (34.19)               | 43.57                     |
| T6            | *Trichoderma viridae* + Neem oil + Pathogen | 33.82 (35.54)              | 39.61                     |
| T7            | *Pseudomonas fluorescens* + Neem oil + Pathogen | 35.8 (36.74)               | 36.07                     |
| T8            | *Pseudomonas fluorescens* + Vitavax power + Pathogen | 20.1 (26.62)               | 64.11                     |
| T9            | Neem oil + Vitavax power + Pathogen       | 24.7 (29.79)               | 55.86                     |
| T10           | *Trichoderma viridae* + *Pseudomonas fluorescens* + Neem oil + Pathogen | 30.1 (33.26)               | 46.25                     |
| T11           | *Pseudomonas fluorescens* + Neem oil + Vitavax power + Pathogen | 16.03 (23.58)              | 71.38                     |
| T12           | Inoculated control                        | 56 (48.43)                 |                           |

CD (p = 0.05) 0.80
SE(m) ± 0.27
CV (%) 1.34

* Values in the parentheses are angular transformed and are the means of three replication
Fig 2: Effect of seed treatment with effective biocontrol agents, botanical and fungicide on root rot incidence of Sesame cv. VRI-1 in *M. phaseolina* infested soil in greenhouse conditions

References

1. Aly A, Sattarand AMA, Omar MR. Susceptibility of some Egyptian cotton cultivars to charcoal rot disease caused by *Macrophomina phaseolina*. J Agric. Sci. 2006; 31:5025-5037.
2. Animisha S, Zacharia S, Jaiswal KK, Pandey P. Integrated management of chickpea wilt incited by *Fusarium oxysporum* f. sp. *ciceris*. J Agric. Sci. 2012; 7(5):284-290.
3. Benhamou N, Gagne S, Quere DL, Dehbi L. Bacterial mediated induced resistance in cucumber, beneficial effect of the endophytic bacterium *Serratia plymuthica* on the protection against infection by *Pythium ultimum*. Phytopathology. 2000; 90:45-56.
4. Brar GS, Ahuja KL. Sesame its culture, genetics, breeding and biochemistry. Annual Review of Plant Physiology. Kalyani Publishers, New Delhi. 1979, 245-313.
5. Buysens S, Heungens K, Poppe J, Hofte M. Involvement of pyochelin and pyoverdin in suppression of Pythium induced damping of tomato by *Pseudomonas aeruginosa*. Appl. Environ. Microbiol. 1996; 62:865-871.
6. Chattopadhyay C, Sastry KR. Important diseases of sesame and their management options. (Oilseeds). Aditya Books Pvt. Ltd., New Delhi. 1998; V:419-448.
7. Chen C, Belanger RR, Benhamou N, Paulitz TZ. Defense enzymes induced in cucumber roots by treatments with plant growth promoting rhizobacteria (PGPR) and *Pythium aphanidermatum*. Physiol. Mol. Plant P. 2000; 56:13-23.
8. Conrath U, Pieterse CMJ, Mauch Mani B. Priming in plant pathogen interactions. Trends Plant Sci. 2002; 7:210-216.
9. Dubey SC, Tripathi A, Singh B. Integrated management of *fusarium* wilt by combined soil application and seed dressing formulations of *Trichoderma* spp. to increase grain yield of chickpea. Int. J Pest Manage. 2013; 59:47-54.
10. Dwivedi D, Johri BN. Antifungals from fluorescent pseudomonads, biosynthesis and regulation. Curr. Sci. 2003; 85:1693-1703.
11. Henis Y, Ghaffar A, Baker R. Integrated control of *Rhizoctonia solani* damping-off of radish, effect of successive plantings, PCNB, and *Trichoderma harzianum* on pathogen and disease. Phytopathology. 1978; 68:900-907.
12. Indiastat. http://www.indiastat.com/agriculture/2/stats.aspx. 2014-15.
13. Jayasree K, Shanmugham, Raguchander T, Ramanatham A, Samiyappan R. Evaluation of *Pseudomonas fluorescens*-1(pf-1) against blackgram andsesame root rot disease. J Biol. Control. 2000; 14(2):55-61.
14. Kishan R, Tripathi NN, Singh R. Management of sesame dry root-rot *Rhizoctonia bataticola* (Taub.) Butl. through biological and chemical means. Sesame and Safflower News letter. 1999; 14:72-75.
15. Kleopper JW, Schroth MN. Relationship of *in vitro* antibiosis of plant growth promoting rhizobacteria to plant growth and the displacement of root Microflora. Phytopathology. 1981; 71:1020-1024.
16. Kolte SJ. Diseases of Annual Edible Oilseed Crops Vol.II. Rapeseed-Mustard and Sesame Diseases. CRC Press Inc. Boca Raton Florida, USA, 1985, 83-112.
17. M’Piga P, Belanger RR, Paulitz TC, Benhamou N. Increased resistance to *Fusarium oxysporum* f.sp. *radicis-lycopersici* in tomato plants treated with endophytic
bacterium *Pseudomonas fluorescens* strain 63-28. Physiol. Mol. Plant P. 1997; 50:301-320.

18. Mahesh M, Saifulla Mahammad S, Srinivasa. Shashidhar KR. Integrated management of pigeon pea wilt caused by *Fusarium udum*. Eur. J Biol. Sci. 2010; 2:1-7.

19. Mahmohndas TP, Sivaprakasam K. Biological control of damping off disease in chilli nursery in crop disease innovative techniques and management. Kalyani Publishers, Ludhiana. 1994, 203.

20. Mallaiah B, Krishna Rao V. Survey and virulence studies on dry root rot of greengram [*Vigna radiate* (L.) Wilczek] incited by *Macrophomina Phaseolina* (Tassi) Goid. Int. J Trop. Agric. 2016; 34(3):521-527.

21. Manoranjitham SK, Prakasam V, Rajappan K. Bio-control of damping off of tomato caused by *Pythium aphanidermatum*. Indian Phytopathol. 2001; 54(1):59-61.

22. Meyer W, Morawetz R, Borner T, Kubicek CP. The use of DNA fingerprinting analysis in the classification of some species of the *Trichoderma* aggregate. Curr. Genet. 1992; 21:27-30.

23. Panse VG, Sukhatme PV. Statistical method for Agricultural Workers. Indian Council of Agricultural Research, New Delhi. 1978, 361.

24. Rajeswari B, Chandrasekhara Rao K, Pramod Chandra Kumar C. Efficacy of antagonists and carbendazim against dry root rot of mungbean (*Vigna radiate* (L.). Wilczek) incited by *Macrophomina phaseolina* (Tassi) Goid under glass house conditions. J Biol. Control. 1999; 13:93-99.

25. Ranganatha ARG, Lokesha R, Tripathi A, Aasfa T, Paroha S. Shrivastava MK. Sesame Improvement - present status and future strategies. J Oilsseeds Res. 2012; 29(1):1-26.

26. Reimmann C, Rella M, Haas D. Integration of replication defective R68.45-like plasmids into the *Pseudomonas aeruginosa* chromosome. J Gen. Microbiol. 1988; 134:1515-1523.

27. Saharan GS, Naresh M, Sangwan MS. *Diseases of Oilseed Crops*. Indus Publishing Company, New Delhi. 2005, 643.

28. Sawant I, Mukhopadhyay AN. Integration of metalaxyl with *Trichoderma harzianum* for the control of *Pythium* damping off in sugar beet. Phytopathology. 1990; 43:535-541.

29. Sindhan GS, Hooda I, Karwasra SS. Biological control of dry root rot of chickpea caused by *Rhizoctonia bataticola*. Plant Dis. Res. 2002; 17(1):68-71.

30. Singh A, Verma R, Shanmugam V. Extracellular chitinases of fluorescent pseudomonads antifungal to *Fusarium oxysporum f.sp. dianthi* causing carnation wilt. Curr. Opin. Microbiol. 2006; 52:310-316.

31. Snedecor GW, Cochran GW. Statistical Methods. Oxford and IBH Publishing Company, New Delhi, 1967, 593.

32. Verma ML, Mehta N, Sangwan MS. Fungal and bacterial diseases of sesame In *Diseases of Oil seed Crops*. Indus Publishing Company, New Delhi 2005, 634.

33. Vyas SC. Integrated biological and chemical control of dry root rot on soybean. Indian J Mycol. Pl. Path. 1994; 24:132-134.

34. Windham MT, Elad Y, Baker R. A mechanism for increased plant growth induced by *Trichoderma* spp. Phytopathology. 1986; 76:518-521.