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Integrated Modules for Management of Stem and Root Rot of Sesame

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Abstract: The field investigation was conducted over two consecutive kharif seasons in 2018 and 2019 for management of stem and root rot of sesame. The study included treatments with fungicides, plant extracts, bio-agents, organic amendments, and their combinations, with each treatment being replicated three times. Eight protective and systemic fungicides were used. Carbendazim + mancozeb application provided maximum disease control (74.05%) and highest yield (446.50 kg ha^{-1}) followed by application of carbendazim alone which provided 65.16% disease control and resulted in yield of 434.00 kg ha^{-1}. Among eight phyto-extracts, garlic clove extract was found best with maximum disease control of 57.23% and yield of 394.50 kg ha^{-1} followed by neem leaf extract with 49.85% disease control and 370.50 kg ha^{-1} yield. Eight fungal and bacterial bio-agents were also evaluated in which *Trichoderma viride* 1 was best. Six organic amendments were tested against the disease under field conditions. Among these, Neem cake was found best with 50.80% disease control and 395.00 kg ha^{-1} seed yield followed by vermi compost with 44.94% disease control and 362.50 kg ha^{-1} of yield. Amongst different integrated disease management modules, seed treated with 10% aqueous solution of garlic clove @ 2g kg^{-1} seed followed by foliar spray of carbendazim + mancozeb resulted in maximum disease control (81.63%) with highest seed yield (472 kg ha^{-1}).

Key words: Fungicides, plant extract, organic amendments, stem and root rot, sesame.

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Sesame (*Sesamum indicum* L.), commonly referred to as known as "Queen of oilseeds" is a major oilseeds crop. It comprises 50 to 52% oil, with a notable composition of linolenic acid (39%) and oleic acid (47%). Additionally, it provides a substantial energy content of 6,335 kcal/kg and demonstrates resistance to oxidation (Shyu and Hwang, 2002). Just like other field crops sesame is also attacked by several fungal and bacterial diseases (Kaur *et al.*, 2012). Among these, stem and root rot, also known as charcoal rot, is one of the most important disease. It is caused by *Macrophomina phaseolina*, a soil borne pathogen, non-host specific, heterogenous with wide adapatibility causes and is responsible for maximum yield loss in sesame (Kaur *et al.*, 2012). The fungus is capable of infecting 100 plant families and over 500 species worldwide

(Marquez *et al.,* 2021; Ghosh *et al.,* 2018). The pathogen is a facultative soil-borne organism that affects the xylem vessels of plants (Khan, 2007). Germinating microsclerotia produce germ tubes that penetrate vascular tissues through natural openings and establish colonization (Bressano *et al*., 2010; Wullie and Scott, 1988). During the initial stages of infection, no visible symptoms appear on the aerial parts of the plant, allowing the pathogen to remain latent (Pratt, 2006). Later in the season, infected plants exhibit wilting and necrosis due to the blockage of vascular bundles by microsclerotia and the secretion of toxic substances (Gupta *et al.,* 2012). It survives under adverse conditions by forming sclerotia and dormant mycelium on crop residues and in the soil. Its soil-borne nature makes its effective control very challenging (Panth *et al*., 2020; Cohen *et al*., 2022). Modest control of *Macrophomina* species by a few fungicides has been reported by Goswami *et al*. (2018) and Fawole *et al*. (2010) but it is not economically viable (Khan, 2007). Besides that the excessive application of chemicals may also contributes to the development of resistance to fungicides (Corkley *et al*., 2022). Therefore, nowadays, the intergrated disease management (IDM) approaches viz., usage of resistance varieties, bio-control agents and phyto-extracts and their combination with fungicides is gaining popularity for being economic and yet effective in disease control (Govindappa *et al.,* 2010). Keeping this in view, the investigation aimed to use integrated disease management practices, such as the use of fungicides, phyto-extracts, organic amendments, and antagonists, to minimize yield losses by suppressing or destroying the pathogen was studied.

Materials and Methods

Plant material and treatments: The present field experiement was conducted during the *kharif* seasons of 2018-19 and 2019-20 at Agronomy Farm of SKNAU, Jobner. The aim of this study was to evaluate the effects of different treatments on the incidence of stem and root rot and the seed yield of sesame (*in vivo*), using the cultivar VRI-1 as a check under artificial inoculation conditions.The inoculation was performed with 20 g of inoculum per meter of row, multiplied on sorghum grains. The experiment was arranged in a randomized block design (RBD) with three plants per replication in 2 m × 2 m plots.

Treatment with fungicides: Eight fungicide treatment viz., Carbendazim (0.2%) , Thiophanate methyl (0.1%), Hexaconazole (0.1%), Propiconazole (0.1%), Carboxin + Thiram (0.1%),), Tebuconazole (dose), Propineb (dose) and Carbendazim + Mancozeb (dose) were selected for a dry seed treatment and a foliar spray 40 DAS for control plots. Following above mentioned package and practices crop was raised and per cent disease incidence and seed yield were calculated as per formula given below:

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

Treatment with plant extract: To prepare the plant extract, fresh leaves or cloves of the botanicals under study were harvested and thoroughly washed with tap water. A 100-gram sample from each plant was washed 2 to 3 times with water and then air-dried at room temperature (25 ± 1°C) for six hours. After drying, the plant material was crushed to extract 100 grams of material using 100 ml of sterilized distilled water. The extract was then filtered through muslin cloth and centrifuged at 5000 rpm for 15 minutes to obtain the supernatant. The resulting supernatant was stored at 5°C for further use. For treatment, seeds of sesame cv. VRI-1 were soaked in prepared plant extract for 30 minutes and dried under shade. Whereas un-socked seeds under similar conditions were served as control. Seeds were sown in the first week of July, and the recommended agronomic practices were followed to cultivate the crop. Percent disease incidence and seed yield (kg ha^{-1}) were calculated as above.

Treatment with bio-control agents: Commercial formulations of fungal bio-agents were applied as a seed treatment at 4 g kg^{-1} of seeds, both individually and in combination with bacterial bio-agents at 6 g kg^{-1} of seeds, to control root rot disease. Prior to bio-agent application, sesame seeds (cv. VRI-1) were moistened with a 5% gum solution at 10 mL kg^{-1} of seeds. The crop was cultivated following standard agronomic practices, and the percentage of disease incidence and seed yield (kg ha^{-1}) were recorded.

Treatment with organic amendments: Six organic soil amendments vermicompost, mustard cake,

Table 1. Treatment combinations following Integrated disease management (IDM) practices

Treatments	Dose
ST Garlic extract + SA Neem cake	10% + 0.5 t ha^{-1}
ST *Trichoderma viride* + SA of Neem cake	4 g kg^{-1} seed + 0.5 t ha^{-1}
ST and Foliar Spray Carbendazim + Mancozeb + ST *Trichoderma viride*	2 g kg^{-1} seed or 0.2% foliar spray + 4g kg^{-1} seed
ST *Trichoderma viride* + ST Garlic extract	4 g kg^{-1} seed +10 %
SA Neem cake + ST and Foliar spray Carbendazim + Mancozeb	0.5 t ha^{-1} + 2 g kg^{-1} seed or 0.2% foliar spray
ST Garlic extract + ST and Foliar spray Carbendazim + Mancozeb	10% + 2 g kg^{-1} seed or 0.2% foliar spray
Control	

neem cake, poultry manure, goat manure, and farmyard manure (FYM) were tested for their impact on stem and root rot incidence and seed yield of sesame. The standard agronomic practices mentioned above were followed to raise the crop, and the percentage of stem and root rot incidence along with seed yield (kg ha^{-1}) were calculated.

Treatment with combination of soil amendment, fungicide, plant extract and bio-agents: Seven treatment combinations were evaluated to study their combined effect on root rot incidence and seed yield (Table 1). Neem cake was mixed with soil and allowed to decompose for one week before inoculating with *M. phaseolina* at 20 g inoculum m^{-1} row, multiplied on sorghum grains. After seven days of inoculation, sesame seeds were treated with the appropriate quantities of fungicide, bio-agent, and plant extract. Untreated seeds were used as a control for comparison. Standard agronomic practices were followed to raise the crop, and the percentage of stem and root rot incidence and seed yield (kg ha^{-1}) were calculated.

Results and Discussion

Effect of fungicides on stem and root rot incidence and seed yield: All the fungicide treatments significantly reduced the incidence of stem and root rot and exhibited significantly higher seed yield as compared with the control (Table 2). Amongst all, the treatment with Carbendazim + Mancozeb was found to be best as it showed the lowest mean incidence of stem and root rot and highest mean seed yield (14.17%, 446.50 kg ha^{-1}) as compared with the control (54.61%, 167.0 kg ha^{-1}) and all other fungicide treatments.

Effect of plant extracts on stem and root rot incidence and seed yield: The results showed that all the plant extracts used in present study were significantly lower down the disease incidence over the control (Table 3). The significantly minimum disease incidence and maximum seed yield were recorded with garlic extract (22.83%, 394.50 kg ha^{-1}) over the control, it recorded maximum disease incidence with lowest seed yield (53.38 %, 177.00 kg ha^{-1}).

Effect of bio-control on stem and root rot incidence and seed yield: Fungal and bacterial bio-agents were evaluated for their effectiveness in reducing disease incidence and increasing seed yield. All treatments performed significantly better than the control (Table 4). Among them, seed treatment with *Trichoderma viride* 1 was the most effective, reducing stem and root rot incidence to 28.03% and achieving a higher seed yield of 392.00 kg ha^{-1} compared to the control, which yielded 183.00 kg ha^{-1}.

Effect of organic amendments on stem and root rot incidence and seed: Result shows that all the tested organic amendments significantly reduced incidence of stem and root rot over control during both the years as well as under pooled basis (Table 5). Neem cake was observed most effective organic amendment in reducing the disease incidence (25.22%) and significantly enhanced the seed yield (395 kg ha^{-1}). The maximum disease incidence (51.25%) was observed under control with lowest seed yield (177.50 kg ha^{-1}).

Effect of IDM practices on stem and root rot incidence and seed yield: The results showed that all integrated disease management practices used in this study significantly reduced the disease incidence of over the control during both the years as well as under pooled basis (Table 6). Among them, significantly minimum disease incidence (9.44%) with highest seed yield (472 kg ha^{-1}) were recorded with IDM module (T6) involves seed treatment and foliar spray with *Trichoderma viride* and Carbendazim + Mancozeb thus proved as most effective

Table 2. Effect of fungicides on stem and root rot incidence and seed yield of sesame applied through seed treatment and foliar spray under field conditions

Fungicides	Con. (%)	Per cent disease incidence*			PDI over control	Yield (kg ha^{-1})*			Yield increase over control (%)
		2018	2019	Pooled		2018	2019	Pooled	
Carboxin + Thiram	0.2	17.50 (24.73)	20.55 (26.96)	19.03 (25.86)	65.16	419.00	408.00	413.50	147.30
Thiophanate methyl	0.2	43.05 (41.01)	45.00 (42.13)	44.03 (41.57)	19.38	223.00	214.00	218.50	30.53
Hexaconazole	0.1	19.72 (26.36)	23.61 (29.07)	21.67 (27.74)	60.33	383.00	363.00	373.00	123.35
Propiconazole	0.2	27.50 (31.63)	30.27 (33.38)	28.89 (32.51)	47.11	351.00	333.00	342.00	104.79
Carbendazim	0.1	16.38 (23.87)	17.49 (24.72)	16.94 (24.30)	68.99	445.00	423.00	434.00	159.88
Tebuconazole	0.2	33.89 (35.60)	36.11 (36.94)	35.00 (36.27)	35.91	288.00	278.00	283.00	69.40
Propineb	0.2	39.16 (38.74)	41.94 (40.36)	40.55 (39.55)	25.75	255.00	245.00	250.00	49.70
Carbendazim + Mencozeb	0.2	12.78 (20.95)	15.56 (23.23)	14.17 (22.11)	74.05	453.00	440.00	446.50	167.06
Control		54.22 (47.42)	55.00 (47.87)	54.61 (47.65)	0.00	173.00	161.00	167.00	
SEm±		1.06	1.12	1.18		9.19	8.84	9.58	
CD (P=0.05)		3.27	3.45	3.62		28.30	27.24	29.50	
CV		6.27	6.11	7.40		9.19	8.84	9.58	

*Average of three replications. Figures in parentheses are angular transformed values

Table 3. Effect of plant extracts on stem and root rot incidence and seed yield of sesame applied through seed treatment and foliar spray under field conditions

Plant extracts	Con. (%)	Per cent disease incidence*			PDI over control	Yield (kg ha^{-1})*			Yield increase over control (%)
		2018	2019	Pooled		2018	2019	Pooled	
Aak (*Calotropis gigantea)*	10	45.94 (42.67)	50.10 (45.06)	48.02 (43.87)	10.04	200.00	183.00	191.50	7.90
Datura (*Datura stramonium)*	10	36.48 (37.16)	38.50 (38.35)	37.49 (37.76)	29.77	249.00	225.00	237.00	50.28
Tulsi (*Ocimum tenuiflorum)*	10	34.55 (36.00)	37.36 (37.68)	35.96 (36.84)	32.64	276.00	256.00	266.00	27.11
Giloy (*Tinospora cordifolia)*	10	38.99 (38.64)	42.68 (40.79)	40.84 (39.72)	23.50	235.00	215.00	225.00	33.89
Garlic (*Allium sativum)*	10	20.94 (27.23)	24.72 (29.81)	22.83 (28.54)	57.23	405.00	384.00	394.50	122.88
Neem (*Azadirachta indica)*	10	25.38 (30.25)	28.16 (32.05)	26.77 (31.16)	49.85	381.00	360.00	370.50	109.03
Ginger (*Zingiber officinale)*	10	27.60 (31.69)	29.27 (32.75)	28.44 (32.22)	46.73	331.00	318.00	324.50	83.05
Turmeric (*Curcuma longa)*	10	30.94 (33.80)	31.33 (34.04)	31.14 (33.92)	41.67	296.00	280.00	288.00	62.71
Control		52.27 (46.30)	54.49 (47.58)	53.38 (46.94)	0.00	183.00	171.00	177.00	
SEm±		1.81	2.07	1.99		18.35	15.88	16.75	
CD (P=0.05)		5.56	6.38	6.12		56.54	48.93	51.59	
CV		7.99	8.53	11.41		9.95	9.20	11.36	

* Average of three replications. Parenthesis are angular transformed value

Table 4. Effect of Bio- agents on stem and root rot incidence and seed yield of sesame applied through seed treatment and foliar spray under field conditions

Treatments	Con. (%)	Per cent disease incidence*			PDI over control	Yield (kg ha^{-1})*			Yield increase over control (%)
		2018	2019	Pooled		2018	2019	Pooled	
Trichoderma harzianum 1	4	33.49	36.10	34.80	35.29	325.00	315.00	320.00	74.86
		(35.36)	(36.93)	(36.15)					
Trichoderma viride 1	4	26.11	29.94	28.03	47.88	401.00	383.00	392.00	114.21
		(30.73)	(33.17)	(31.96)					
Trichoderma harzianum 2	4	36.40	38.60	37.50	30.25	311.00	292.00	301.50	64.75
		(37.11)	(38.41)	(37.76)					
Trichoderma viride 2	4	29.83	31.55	30.69	42.92	381.00	365.00	373.00	103.83
		(33.10)	(34.17)	(33.64)					
Pseudomonas fluorescens	6	47.21	50.27	48.74	9.35	231.00	218.00	224.50	22.68
		(43.40)	(45.15)	(44.28)					
Bacillus subtilis	6	49.20	53.37	51.29	4.63	203.00	191.00	197.00	7.65
		(44.54)	(46.93)	(45.74)					
Trichoderma hamatum	4	38.88	41.38	40.13	25.37	263.00	248.00	255.50	39.62
		(38.57)	(40.04)	(39.31)					
Trichoderma asperellum	4	42.16	45.83	44.00	18.18	250.00	235.00	242.50	32.51
		(40.49)	(42.61)	(41.55)					
Control	-	52.44	55.1	53.77	0.00	188.00	178.00	183.00	
		(46.40)	(47.93)	(47.16)					
SEm±		2.08	2.49	2.36		13.30	12.27	12.62	
CD (P=0.05)		6.40	7.66	7.26		40.97	37.80	38.88	
CV		8.09	9.01	11.66		7.22	7.01	8.53	

* Average of three replications. Parenthesis are angular transformed value

Table 5. Effect of organic amendments on stem and root rot incidence and seed yield of sesame applied through soil application under field conditions

Treatments	Per cent disease incidence*			PDI over control	Yield (kg ha^{-1})*			Yield increase over control (%)
	2018	2019	Pooled		2018	2019	Pooled	
Vermicompost	26.82	29.61	28.72	44.94	367.00	358.00	362.50	104.23
	(31.19)	(32.97)	(32.09)					
Mustard cake	29.16	30.55	29.86	41.74	338.00	321.00	329.50	85.63
	(32.68)	(33.55)	(33.12)					
Neem cake	24.60	25.83	25.22	50.80	405.00	385.00	395.00	122.54
	(29.73)	(30.55)	(30.14)					
Poultry manure	30.83	31.10	30.97	39.57	292.00	273.00	282.50	59.15
	(33.73)	(33.90)	(33.81)					
FYM	35.27	38.05	36.66	28.46	230.00	218.00	224.00	26.20
	(36.43)	(38.09)	(37.26)					
Goat manure	31.38	34.44	32.91	35.78	278.00	253.00	265.50	49.58
	(34.07)	(35.93)	(35.01)					
Control	50.83	51.66	51.25	0.00	185.00	170.00	177.50	0.00
	(45.48)	(45.95)	(45.71)					
SEm±	1.34	1.63	1.71		9.27	8.58	9.80	
CD (P=0.05)	4.12	5.01	5.26		28.57	26.43	30.19	
CV	7.08	8.18	11.32		6.37	7.26	7.50	

* Average of three replications. Parenthesis are angular transformed value

Table 6. Effect of IDM practices on disease incidence and seed yield of sesame under field conditions

Treatments	Per cent disease incidence*			PDI over control	Yield (kg ha^{-1})*			Yield increase over control (%)
	2018	2019	Pooled		2018	2019	Pooled	
Seed treatment and foliar spray with garlic extract @ 10% + soil application of neem cake @ 5 q ha^{-1} -T_1	16.94 (24.30)	19.44 (26.16)	18.19 (25.25)	64.60	366.00	346.00	356.00	111.90
Seed treatment and foliar spray with *Trichoderma viride* @ 4 g kg^{-1} seed + soil application of neem cake @ 5 q ha^{-1} -T_2	20.00 (26.57)	22.21 (28.12)	21.11 (27.35)	58.93	315.00	290.00	300.00	80.06
Seed treatment and foliar spray with*Trichoderma viride* @ 4 g kg^{-1} seed + carbendazim+ mancozeb @ 2 g kg^{-1} seed-T_3	12.49 (20.70)	14.72 (22.56)	13.61 (21.64)	73.52	431.00	417.00	424.00	152.38
Seed treatment and foliar spray with *Trichoderma viride* @ 4 g/kg seed + garlic extract @ 10%-T_4	18.05 (25.14)	20.27 (26.76)	19.16 (25.96)	62.71	345.00	326.00	335.50	99.70
Soil application of neem cake @ 5 q ha^{-1} seed treatment and foliar spray with carbendazim + mancozeb @ 2 g kg^{-1} seed-T_5	15.27 (23.00)	16.94 (24.30)	16.11 (23.66)	68.66	406.00	384.00	395.00	135.12
Seed treatment and foliar spray with garlic extract @ 10% + carbendazim + mancozeb @ 2 g kg^{-1} seed-T_6	9.16 (17.62)	9.72 (18.17)	9.44 (17.89)	81.63	483.00	461.00	472.00	180.95
Control-T_7	50.83 (45.48)	51.94 (46.11)	51.39 (45.79)	0.00	175.00	161.00	168.00	
SEm$\pm$	1.15	1.18	1.20		7.23	6.80	7.15	
CD (P=0.05)	3.53	3.64	3.71		22.29	20.96	22.03	
CV	9.74	9.22	9.79		7.37	7.35	7.36	

* Average of three replications. Parenthesis are angular transformed value.

IDM option for managing stem and root rot of sesame. Among all the treatments, significantly maximum disease incidence (51.39 %) was recorded under control with minimum seed yield (168 kg ha^{-1}).

Our results showing the efficacy of seed treatment with carbendazim + mancozeb and followed by a foliar spray are in line with those reported by Singh *et al*. (2003), Choudhary *et al*. (2004) and Kumar and Jain (2004), who demonstrated that carbendazim effectively inhibited maximum mycelial growth under in vitro conditions (Table 2). Results also showed that yield following application of all the botanicals was significantly higher than the control (Table 3), with garlic clove extract showing the lowest disease incidence and the highest grain yield, followed by neem leaf extract. These results align well with those of Mandhare and Suryawanshi (2009), who reported that 10% aqueous solutions of garlic clove and neem leaf extracts inhibited *Rhizoctonia bataticola* in chickpea by 77.77% and 64.44% respectively. Similarly, Thombre and Kohire (2018) demonstrated that a 10% foliar spray of *Allium sativum* and *Allium cepa* effectively controlled disease. Higher concentrations of plant extracts demonstrated a marked increase in the inhibition of the pathogen under controlled conditions, effectively leading to a significant reduction in soil-borne pathogens. These results are consistent with previous studies by Sharma (2009) and Kumar *et al.* (2011). The effectiveness of garlic clove extract against *M. phaseolina* has also been supported by Ullah *et al*. (2007), Ammajamma *et al.* (2009); Rani *et al.* (2009) and Afzal *et al.* (2010). These plant extracts may contain some antifungal compound like alkaloid, phenol, gum, resins, steroids and essential oils. Allicin is a major component of garlic, which have antimicrobial properties and minimized the growth of the pathogen due to sulphur (Diallyl thio sulphinate) compounds (Sindhan *et al*., 2002: de Groot, 1972) which have strong toxic properties against the pathogen. Allicin is easily permeable and its protein contain thiol group which showed the exchange reaction with thiol- disulphide

(Slusarenko, 2008). Many workers (Ashraf and Javaid, 2007; Sharma, 2009; Kumar *et al*., 2011) have show that the *Azadirachta indica* (neem) extract was most effective growth inhibitor of *Macrophomina phaseolina*. However, in the present study neem leaf extract was not as effective as garlic extract. This might be due to differences in isolates of *M. phaseolina* and concentration of antifungal constituents present in plant species (Bandopadhyay, 2002).

In the presented data, different bio agents antagonists *viz. Trichoderma viride , T. harzianum, T.hamatum, T. asperallum Pseudomonas fluorescens and Bacillus subtalis* obtained from the rhizosphere of different crops were evaluated under laboratory conditions (Table 5). These bio- agents had the ability to check the radial growth of *M. phaseolina* to varying extent. The presented data revealed that all these bio agents significantly reduced the mycelial growth of *M. phaseolina*. However, *T. viride (*1) was found most effective with minimum disease incidence (29.03%) with 392.00 kg ha^{-1} grain yield and *Bacillus subtalis* was least effective over control. Bio-control agents operate through three primary mechanisms: antibiosis, competition, and mycoparasitism. These mechanisms enable them to directly combat pathogens and exhibit antagonistic effects that help suppress root rot. *Trichoderma* species were suppress the infection and multiplication of soil borne pathogen through metabolites produced by them (Pant and Mukhopadhyay, 2001; Gurjar *et al*., 2012; Harman, 2006; Monteiro *et al.,* 2010; Indra and Gayatri, 2002) and Akramin *et al*. (2009). *Trichoderma* species produced many metabolites against pathogen that are trichodermin, viridin, ethyl acetate, beta glucanase and beta glucosidase etc which have lethal effect on pathogen (Bailey and Melnick, 2013).

Among organic amendments, neem cake significantly reduced disease incidence (25.22%), followed by vermicompost (28.72%), compared to the control (Table 6). Similar observations were reported by Jaiman *et al*. (2009), who studied root rot incidence. Their findings demonstrated that the addition of organic cakes through soil application can reduce both pre- and post-emergence of the pathogen.

IDM modules have been effectively used against soil borne pathogen in past. Our results (Table 6) revealed that the all the treatments significantly reduced disease incidence and increased yield *vis a vis* control. Patel and Anahosur (2001) and Christopher *et al*. (2008) studied chickpea roots and observed that seed treatment with carbendazim, combined with soil drenching using *Trichoderma harzianum*, significantly reduced the fungal populations of *Fusarium sp.* and *Macrophomina phaseolina*.

References

Afzal, R., Mughal, S.M., Munir, M., Sultana, K., Qureshi, R., Arshad, M. and Laghari, M.K. 2010. Mycoflora associated with seeds of different sunflower cultivars and its management. *Pakistan Journal of Botany* 42(1): 435-445.

Akramin, A., Ibrahimov, A.S., Zafari, D.M. and Valizadeh, E. 2009. Control of Fusarium rot of bean by combination of *Trichoderma harzianum* and *Trichoderma asperellum* in green house condition. *Agriculture Journal* 4: 121-123.

Ammajamma, R., Hegde, Y.R., Lingaraju, S., Sreedevi, S.C. and Hegde, L. 2009. Studies on biological management of *Rhizoctonia bataticola* infecting *Coleus forskohlii*. *Biomedicine Journal* 4(1): 28-32.

Ashraf, H. and Javaid, A. 2007. Evaluation of antifungal activity of Meliaceae family against *Macrophomina phaseolina*. *Mycopathology* 5(2):81-84.

Bailey, B.A. and Melnick, R.L. 2013. The endophytic Trichoderma. In: Trichoderma: Biology and Applications (Eds. P.K. Mukherjee, B.A. Horwitz, U.S. Singh, M. Mukherjee and M. Schmoll), pp. 152-172. CABI, Wallingford, UK.

Bandopadhyay, A.K. 2002. A current approach to the management of root diseases in bast fibre plants with conservation of natural and microbial agents. Journal of Mycopathological Research 40 (1):57-62.

Bressano, M., Giachero, M.L., Luna, C.M. and Ducasse, D.A. 2010. An *in vitro* method for examining infection of soybean roots by *Macrophomina phaseolina*. *Physiological Molecular Plant Pathology* 74: 201-204.

Choudhary, C.S., Singh, S.N. and Prasad, S.M. 2004. *In vitro* effectiveness of chemicals to control *Macrophomina phaseolina* (Tassi.) Goid. causing stem and root rot of sesame. *Journal of applied Biology* 14(1): 46-47.

Christopher, B.J., Usharani, S. and Udhaya Kumar, R. 2008. Management of dry root rot (*Macrophomina phaseolina* (Tassi.) Goid. of urd bean (*Vigna mungo* (L.) Hepper) by the integration of antagonists (*Trichoderma virens*) and organic amendments. *Mysore Journal of Agricultural Sciences* 42(2): 241-246.

Cohen, R., Elkabetz, M., Paris, H.S., Gur, A., Dai, N., Rabinovitz, O. and Freeman, S. 2022. Occurrence of *Macrophomina phaseolina* in Israel: Challenges for disease management and crop germplasm enhancement. *Plant Disease* 106(1): 15-25.

Corkley, I., Fraaije, B. and Hawkins, N. 2022. Fungicide resistance management: Maximizing the effective life of plant protection products. *Plant Pathology* 71(1): 150-169.

De Groot, R.C. 1972. Growth of wood inhibiting fungi in saturated atmosphere of monoterpenoids. *Mycologia* 64: 863-870.

Fawole, O.B., Aliko, and Olowonihi, T.E. 2010. Effects of a Carbendazim-Mancozeb fungicidal mixture on soil microbial populations and some enzyme activities in soil. *Agrosearch* 10: 65-74.

Ghosh, T., Biswas, M.K., Guin, C. and Roy, P. 2018. A review on characterization, therapeutic approaches and pathogenesis of *Macrophomina phaseolina*. *Plant Cell Biotechnology and Molecular Biology* 19: 72-84.

Goswami, S.K., Singh, V., Chakdar, H. and Choudhary, P. 2018. harmful effects of fungicides-current status. *International Journal of Agriculture, Environment and Biotechnology* 11: 1011-1019

Govindappa, M., Lokesh, S., Rai, V.R., Naik, V.R. and Raju, S.G. 2010. Induction of systemic resistance and management of safflower *Macrophomina phaseolina* root-rot disease by biocontrol agents. *Archives of Phytopathology and Plant Protection* 43(1/3): 26-40.

Gupta, G.K., Sharma, S.K. and Ramteke, R. 2012. Biology, epidemiology and management of the pathogenic fungus *Macrophomina phaseolina* (Tassi) Goid with special reference to charcoal rot of soybean (*Glycine max* (L.) Merril. *Journal of Phytopathology* 160: 167-180.

Gurjar, M.S., Shahid, Ali, Masood A. and Kangabam, S.S. 2012. Efficacy of plant extracts in plant disease management. *Agricultural Sciences* 3: 425-433.

Harman, G.E. 2006. Overview of mechanisms and uses of Trichoderma spp. *Phytopathology* 96: 190-194.

Indra, N. and Gayathri, T. 2002. Antagonism of *Trichoderma* spp. against *Macrophomina phaseolina* causing root rot of black gram. *Plant Disease Research* 17(1): 142-144.

Kaur, S., Dhillon, G.S., Brar, S.K., Valled, G.E., Chand, R. and Chouhan, V.B. 2012. Emerging phytopathogen *Macrophomina phascolina*: Biology, economic importance and current diagnostic trends. *Critical Review in Microbiology* 38(2): 1-16.

Khan, S.N. 2007. *Macrophomina phaseolina* as causal agent for charcoal rot of sunflower. *Mycopathology* 5(2):11-118.

Kumar, R.K. and Jain, S.C. 2004. *Macrophomina phaseolina* in clusterbean (*Cyamopsis tetragonoloba*) seed and its control. *Journal of Mycology and Plant Pathology* 34(3): 833-835.

Kumar, S., Aeron, A., Pandey, P. and Maheshwari, D.K. 2011. Ecofriendly management of charcoal rot and wilt diseases in sesame (*Sesamum indicum* L.) Bacterial in Agrobiology. *Crop Ecosystems* xx: 387-405.

Marquez, N., Giachero, M.L., Declerck, S. and Ducasse, D.A. 2021. *Macrophomina phaseolina:* General characteristics of pathogenicity and methods of control. *Frontiers in Plant Science* 12: 634397.

Monteiro, V.N., Silva, R.D.N., Steindorff, A.S., Costa, F.T., Noronha, E.F., Ricart, C.A.O., Sousa, M.V.D., Vainstein, M.H. and Ulhoa, C.J. 2010. New insights in *Trichoderma harzianum* antagonism of fungal plant pathogens by secreted protein analysis. *Current Microbiology* 61(4): 298-305.

Pant, R. and Mukhopadhyay, A.N. 2001. Integrated management of seed and seedling rot complex of soybean. *Indian Phytopathology* 54(3): 346-350.

Panth, M., Hassler, S.C. and Baysal-Gurel, F. 2020. Methods for management of soilborne diseases in crop production. *Agriculture* 10(1): 16.

Patel, S.T. and Anahosur 2001. Potential antagonism of *T. harzianum* against *Fusarium spp. Macrophomina phaseolina* and *Sclerotium rolfsii*. *Indian Journal of Mycology and Plant Pathology* 31: 365-369.

Pratt, R.G. 2006. A Direct observation technique for evaluting sclerotium germination by *Macrophomina phaseolina* and effects of bio-control materials on the survival of sclerotia in soil. *Mycopathologia* 162:121-131.

Rani, S.U., Udayakumar, R. and Christopher, D.J. 2009. Bio-efficacy of plant extracts and bio-control agents against *Macrophomina phaseolina*. *Annals of Plant Protection Sciences* 17(2): 389-393.

Sharma, V. 2009. Assessing the fungi toxic potential of some angiospermic leaves against *Macrophomina phaseolina*. *Indian Journal of Forestry* 32(4):605-606

Sindhan, G.S., Hooda, I. and Karwasra, S.S. 2002. Biological control of dry root rot of chickpea caused by *Rhizoctonia bataticola*. *Plant Disease Research* 17(1): 68-71.

Singh, S., Yadav, J.P.S., Tripathi, N.N. and Kalita, M.K. 2003. Comparative efficacy of fungitoxicants in controlling root rot of cotton caused by *Rhizoctonia solani* Kühn. *Annals of Agri Bio Research* 8(1): 61-63.

Shyu, Y.S. and Hwang, L.S. 2002. Antioxidative activity of the crude extract of lignin glycosides from unroasted Burma black sesame meal. *Food Research Internationa* 35: 357-365.

Slusarenko, A.J., Patel, A. and Portz, D. 2008. Control of plant diseases by natural products: Allicin from garlic as a case study. *European Journal of Plant Pathology* 121: 313-322.

Thombre, B.B. and Kohire, O.D. 2018. Integrated management of *Macrophomina bligh*t of mungbean (*Vigna radiata L.) caused by Macrophomina phaseolina (Tassi)* Goid. *Indian Phytopathology* 71: 423-429.

Ullah, M.H., Khan, M.A., Sahi, S.T. and Habib, A. 2007. Evaluation of plant extracts against charcoal rot of sunflower caused by *Macrophomina phaseolina* (Tassi) Goid. *Pakistan Journal of Phytopathology* 19(1): 113-117.

Wullie, T.D. and Scott, D.H. 1988. Charcol rot of soybeans- current status. In: *Soybean Diseases of North Central Region*. APS Press Indianapolis, IN, pp. 106-113.

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