MANAGEMENT OF STEM ROT (*SCLEROTINIA TRIFOLIORUM*) IN BERSEEM THROUGH *TRICHODERMA ASPERELLUM*-ENRICHED ORGANIC SUBSTRATES ON FYM AND VERMICOMPOST

DALVINDER PAL SINGH[1]*, KISHOR CHAND KUMHAR[2], SATPAL[1], NEERAJ KHAROR[1], RAVISH PANCHTA[1], SATYAWAN ARYA[1] AND SWATI MEHRA[3]

[1]Forage Section, Department of Genetics and Plant Breeding [2] Department of Plant Pathology
[3]Department of Seed Science & Technology
CCS Haryana Agricultural University, Hisar-125 004 (Haryana), India
(e-mail: dsingh4@gmail.com)
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SUMMARY

Stem rot of berseem, caused by *Sclerotinia trifoliorum*, is a major constraint on forage production, resulting in significant yield losses. The study evaluated the efficacy of *Trichoderma asperellum*-enriched organic substrates in suppressing stem rot under field conditions. Results revealed that *Trichoderma asperellum*-enriched substrates, such as vermicompost and FYM, effectively reduced disease incidence and promoted better plant growth compared to untreated controls. The enriched substrates not only acted as carriers for *Trichoderma* but also improved soil health, thereby contributing to long-term disease suppression. This eco-friendly approach provides a sustainable alternative to chemical fungicides and can be recommended as a component of integrated management practices for stem rot in berseem.

Key words: *Trichoderma asperellum*, organic substrates, stem rot, Biocontrol, FYM, vermicompost, Berseem

Berseem (*Trifolium alexandrinum* L.) is the principal winter-season forage crop in northern India and provides highly nutritious green fodder for dairy and livestock production. In Haryana, berseem occupies a central position in fodder-based cropping systems due to its high biomass yield, palatability, and crude protein content. However, its productivity is seriously threatened by stem rot, caused by the soil-borne fungus *Sclerotinia sclerotiorum*, which infects stems and crowns, producing white cottony mycelium and sclerotia (Sharma *et al.*, 2024). Severe outbreaks can lead to complete crop failure under favourable weather conditions, especially in the irrigated tracts of Haryana, where high humidity and dense canopy persist.

Conventional approaches for stem rot management primarily rely on fungicides and crop sanitation; however, their efficacy is limited in fodder crops due to concerns over residue and the persistence of sclerotia in the soil (Khan *et al.*, 2020). This has led to the exploration of eco-friendly, sustainable alternatives (Singh, 2005). Biological control using *Trichoderma* spp. has received considerable attention due to their multiple mechanisms-mycoparasitism, antibiosis, competition, and induction of host defense responses-that suppress soil-borne pathogens (Sharma *et al.*, 2023). *Trichoderma asperellum*, in particular, has demonstrated strong antagonistic potential against *S. sclerotiorum* and is being increasingly integrated into organic substrates to enhance survival and field efficacy (Jat *et al.*, 2023).

Farmyard manure (FYM) and vermicompost are widely available organic amendments in Haryana's farming systems. When enriched with *Trichoderma asperellum*, these substrates not only serve as carriers of the bioagent but also improve soil health, stimulate beneficial microbial activity, and enhance plant growth (Kumar *et al.*, 2021; Pandey *et al.*, 2021). Studies across diverse cropping systems have demonstrated that *Trichoderma*-bioenriched vermicompost (Meena *et al.*, 2021) or FYM can significantly reduce disease incidence while improving plant vigour and yield (Yadav *et al.*, 2020). However, the systematic evaluation of these approaches for berseem stem rot management under Haryana conditions remains limited. The present study was conducted with the objectives to evaluate the efficacy of *Trichoderma asperellum-enriched vermicompost and FYM in suppressing Sclerotinia sclerotiorum-induced* stem rot of berseem and to assess the impact of these enriched organic substrates on disease incidence, plant growth, and forage yield under Haryana conditions, a farmer-friendly, sustainable management strategy for stem rot in berseem.

MATERIALS AND METHODS

Experimental Site and Crop

The experiments were conducted during rabi season 2022-23 and 2023-24 at the forage research farm of the Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar (29.15°N, 75.70°E, 215 m), under irrigated conditions. The soil of the experimental site was sandy loam, low in organic carbon, and neutral in reaction. The berseem (*Trifolium alexandrinum* L.) variety Mescavi was used as the test crop.

Pathogen Isolation and Maintenance

Sclerotinia sclerotiorum was isolated from naturally infected berseem stems collected from farmers' fields in Hisar and adjoining districts of Haryana. Diseased tissues were surface sterilised with 0.1% sodium hypochlorite, plated on potato dextrose agar (PDA), and incubated at 25 ± 1 °C. Pure cultures were obtained by the hyphal tip method, and pathogenicity was confirmed by artificial inoculation of potted berseem plants, thereby fulfilling Koch's postulates. The cultures were maintained on PDA slants at 4 °C for further use (Plate 1a).

Preparation of *Trichoderma asperellum* inocula

A well-characterized antagonistic isolate of *T. asperellum – KKTH 2 collect*ed from Biocontrol Laboratory, Department of Plant Pathology, CCSHAU, Hisar). Multiplication of the antagonistic fungus was on sterilized potato dextrose broth following 15 days incubation at 27±2 ^{0}C. Biomass (conidia and mycelia) was homogenized and 2 x10^8 colony forming units / per gram was determined through serial dilution plate inoculation technique.

Enrichment of organic Substrates

T. asperellum biomass was added to sterilized farmyard manure (FYM) and vermicompost at the rate of 2% v/w and incubated for 5, 10, 15, and 20 days at 28 ± 2 °C in the laboratory. The substrates were periodically turned to facilitate aeration and proper multiplication of bioagent. Finally, *Trichoderma*-enriched FYM and vermicompost were applied in the field to evaluate against the disease (Plate 1b).

Experimental design and treatments

The field experiment was laid out in a Randomized Block Design (RBD) with three replications. Each plot, measured at [5 × 3m], followed recommended agronomic practices for berseem cultivation, except for the treatments. Artificial inoculation of *S. sclerotiorum* (10 g colonized wheat grains per m²) was done at 30 days after sowing to ensure uniform disease pressure. The following treatments were evaluated after application of *Trichoderma asperellum* (2x10^9 cfu/ml) with FYM and vermicompost in the following concentrations:

T_1: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period , T_2: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period , T_3: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period, T_4: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period, T_5: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period, T_6: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period, T_7: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period, T_8: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period, T_9: FYM @ 10 t/ha only, T_{10}: Vermicompost @ 4 t/ha only, T_{11}: Control.

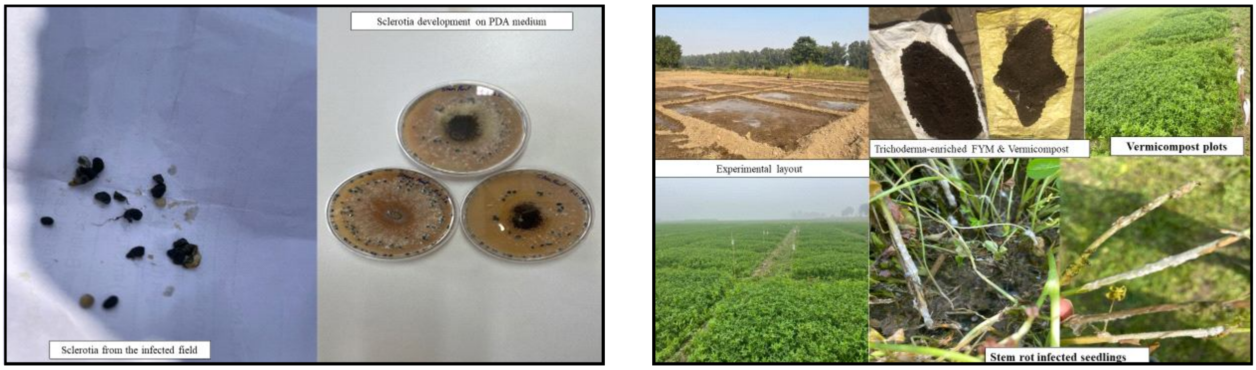

Plate 1 (a &b): Fruiting bodies and inoculum of stem rot of berseem pathogen; *T. asperellum* enrichment with vermicompost and FYM.

Organic amendments of FYM at 10 t/ha and Vermicompost at 4 t/ha were applied at the time of sowing and thoroughly mixed into the soil. FYM composition was N – 0.69%, P – 0.52%, K – 1.09% at (Price /kg: 3 Rs), and Vermicompost – N – 1.64%, P – 0.84%, K – 1.06% at (Price /kg: 4 Rs).

Observations and data collection

Disease assessment was conducted after the disease initiation dates i.e. 5th January 2022 and 8th January 2023. Stem rot incidence was recorded by counting the number of infected plants out of the total plants in randomly selected quadrats (1 m²). Observations were recorded for Germination percentage, Seedling disease incidence, Cut-wise stem rot data recording, Efficacy of *Trichoderma asperellum* agent with enriched organic substrates and Estimation of CFU of *Trichoderma asperellum* after 5, 10, 15, and 20 DOI (days of incubation)

Microbial population dynamics

Soil samples from the rhizosphere were collected at 45 and 90 days after sowing. Populations of *Trichoderma asperellum*, total fungi, and bacteria were enumerated by serial dilution plating on selective media (*Trichoderma*-selective medium, Martin's Rose Bengal agar, and nutrient agar).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) appropriate for RBD using the OPSTAT statistical package. Treatment means were compared at P d" 0.05 using the least significant difference (LSD) test. Percent data were arcsine-transformed before analysis.

Experimental results

During *Rabi* 2022-23, the results achieved were mentioned as follows:

a. Germination percentage: Highest germination of Berseem *var.* Mescavi was observed in treatment T_8, i.e., vermicompost enriched with *Trichoderma asperellum* at 20-day incubation period, which was at par with T_7 and T_6, followed by T_4, i.e., FYM at 20 DOI, as compared to the untreated control (Table 1).

b. Seedling disease incidence (%): T_8, *i.e.*, Vermicompost enriched with *Trichoderma asperellum* at 20 days of incubation period, had the lowest disease incidence, which was at par with T_7 and T_6, followed by T_4, i.e., FYM at 20 DOI. T_4 levels were significantly lower than those in the untreated control (Table 1).

TABLE 1
Observations regarding seedling germination percentage (average), disease incidence (%) of berseem (Mescavi) during *Rabi* 2022-23

S. No.	Treatments	Germination (%)	Disease incidence (%)
1.	T_1	36.42	26
2.	T_2	38.47	25
3.	T_3	42.65	22
4.	T_4	46.58	19
5.	T_5	47.19	22
6.	T_6	49.94	20
7.	T_7	50.76	16
8.	T_8	52.26	14
9.	T_9	31.86	27
10.	T_{10}	35.92	24
11.	T_{11}	26.48	31
	CD	5.07	6.28
	SEm(±)	1.70	2.11

a. Cut-wise stem rot data recording: The lowest stem rot disease incidence was observed in T8, which was vermicompost enriched with Trichoderma asperellum, at 20 days of the incubation period, matching the incidence in T7 and T6, and was followed by T4, which was FYM, at 20 days of the incubation period. It was significantly lower than the untreated control during all three cuts of Berseem var. Mescavi (Table 2).

d. Cut-wise yield data : The highest yield was found in treatment T_8, i.e., vermicompost enriched with *Trichoderma asperellum* at 20 days of incubation period, which was at par with treatment T_7 and T_6, followed by T_4, i.e., FYM at 20 DOI, and was significantly higher than the untreated control during all three cuts of Berseem *var.* Mescavi (Table 3).

e. Estimation of CFU of *Trichoderma asperellum* after 5, 10, 15, and 20 days incubation period. The 20-day incubation period had the highest *Trichoderma asperellum* colony-forming units in both the vermicompost and FYM per gram of soil (Table 4).

During *Rabi* 2023-24, the results achieved were mentioned as follows:

a. Germination percentage: Highest germination of berseem var. Mescavi was observed in treatment T_8 i.e., vermicompost enriched with *Trichoderma asperellum* at a 20-day incubation period, which was comparable to T_7, T_6, and T_4 i.e., FYM at 20 DOI (Table 5).

b. Seedling disease incidence (%)

T_8, i.e., Vermicompost enriched with *Trichoderma asperellum* at 20 days of incubation period

TABLE 2

Cut wise stem rot disease incidence in berseem (Mescavi) during *Rabi* 2022-23.

Treatments	1St cut	2nd cut	3rd cut
T_1: FYM @ 10 t/ha + *Trichoderma asperellum*@ 2.0% with 5 days incubation period	22.5 (29.51)*	24.29 (26.62)	20.10 (26.62)
T_2: FYM @ 10 t/ha + *Trichoderma asperellum*@ 2.0% with 10 days incubation period	20.93 (29.31)	23.98 (25.83)	19.01 (25.82)
T_3: FYM @ 10 t/ha + *Trichoderma asperellum*@ 2.0% with 15 days incubation period	19.59 (28.42)	22.68 (25.24)	18.20 (25.24)
T_4: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period	17.36 (26.00)	19.24 (23.80)	16.29 (23.79)
T_5: Vermicompost @ 4 t/ha + *Trichoderma asperellum*@ 2.0% with 5 days incubation period	21.12 (27.65)	21.56 (25.98)	19.20 (25.97)
T_6: Vermicompost @ 4 t/ha + *Trichoderma asperellum*@ 2.0% with 10 days incubation period	18.69 (27.21)	20.93 (24.54)	17.26 (24.53)
T_7: Vermicompost @ 4 t/ha + *Trichoderma asperellum*@ 2.0% with 15 days incubation period	17.21 (26.25)	19.58 (23.65)	16.11 (23.65)
T_8: Vermicompost @ 4 t/ha + *Trichoderma asperellum*@ 2.0% with 15 days incubation period	15.39 (24.00)	16.57 (22.04)	14.11 (22.04)
T_9: FYM @ 10 t/ha only	24.96 (32.29)	28.56 (28.81)	23.25 (28.81)
T_{10}: Vermicompost @ 4 t/ha Only	20.25 (29.05)	23.59 (26.74)	20.26 (26.74)
T_{11}: Control	32.97 (36.40)	35.23 (30.10)	26.53 (30.99)
SE±(m)	0.28	1.68	1.89
CD at 5%	0.83	4.63	0.43

*Figures in parentheses are angular transformed values.

TABLE 3

Cut wise yield data of berseem (Mescavi) during *Rabi* 2022-23

Treatments	1St cut	2nd cut	3rd cut
T_1: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period	33.56	32.59	30.95
T_2: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period	34.59	33.08	32.5
T_3: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period	35.68	34.58	32.83
T_4: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period	36.58	35.39	33.58
T_5: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period	34.29	33.64	32.65
T_6: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period	35.96	34.8	33.51
T_7: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period	36.54	35.9	34.2
T_8: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period	37.59	37.96	35.28
T_9: FYM @ 10 t/ha only	28.11	27.54	26.5
T_{10}: Vermicompost @ 4 t/ha Only	30.21	31.96	29.38
T_{11}: Control	23.26	22.97	21.24
SE±(m)	0.39	0.43	0.53
CD at 5%	1.17	1.28	1.58

had the lowest disease incidence, which was at par with T_7 and T_4 (Table 5).

c. Cut-wise stem rot data recording

The lowest stem rot disease incidence was observed in T8, which was vermicompost enriched with *Trichoderma asperellum* at 20 days of the incubation period, matching T7 and T6, followed by T4, which was FYM, at 20 DOI. It was significantly lower than the untreated control during all three cuts of Berseem *var.* Mescavi (Table 6).

d. Cut-wise yield data

Highest yield was recorded in treatment T_8 (Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 20-day incubation period) which was at

TABLE 4

Colony-forming units' estimation of *Trichoderma asperellum* after 5, 10, 15, and 20 days of incubation period

S. No.	Days after incubation	Average Colony-forming units/gm soil
1.	5	0.67
2.	10	1.33
3.	15	1.67
4.	20	1.68

par with treatment T_7 Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 15 15-day incubation period) and T_4 (FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 20-day incubation period) during all three cuts of berseem *var.* Mescavi (Table 7).

e. Estimation of CFU of *Trichoderma asperellum* after 5, 10, 15, and 20 days incubation period

The 20-day incubation period had the highest *Trichoderma asperellum* colony-forming units in both the vermicompost and FYM per gram of soil (Table 8).

TABLE 5

Observations regarding seedling germination percentage (average), disease incidence (%) of berseem (*Mescavi*) during *Rabi* 2023-24.

S. No.	Treatments	Germination (%)	Disease incidence (%)
1.	T_1	38.40	26
2.	T_2	40.45	27
3.	T_3	44.63	24
4.	T_4	49.56	19
5.	T_5	49.27	24
6.	T_6	51.92	23
7.	T_7	52.74	18
8.	T_8	54.24	16
9.	T_9	33.84	29
10.	T_{10}	37.90	26
11.	T_{11}	28.46	33
	SEm(±)	1.67	2.09
	C.D. at 5%	5.05	6.24

Discussion

The present study clearly demonstrated that the application of *Trichoderma asperellum*-enriched organic amendments (FYM and vermicompost) significantly reduced stem rot incidence in berseem and improved plant growth and forage yield under

TABLE 6

Cut wise Stem Rot disease incidence in berseem (*Mescavi*) during *Rabi* 2023-24.

Treatments	1^{St} cut	2^{nd} cut	3^{rd} cut
T_1: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period	23.40 (30.53)*	25.18 (27.24)	20.98 (26.87)
T_2: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period	21.83 (30.28)	24.53 (26.39)	20.15 (26.28)
T_3: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period	20.45 (29.35)	23.57 (26.17)	19.12 (26.41)
T_4: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period	18.28 (26.58)	20.38 (24.75)	17.32 (24.49)
T_5: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period	22.34 (28.56)	22.64 (26.88)	20.33 (26.16)
T_6: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period	19.62 (28.14)	21.86 (23.45)	18.64 (25.32)
T_7: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period	18.36 (27.12)	20.82 (24.58)	17.23 (24.53)
T_8: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period	16.27 (24.87)	17.63 (23.21)	15.38 (23.24)
T_9: FYM @ 10 t/ha only	25.78 (33.17)	29.62 (29.87)	24.51 (29.13)
T_{10}: Vermicompost @ 4 t/ha Only	21.32 (29.78)	24.64 (27.72)	21.16 (26.97)
T_{11}: Control	33.45 (36.79)	37.32 (31.15)	27.76 (31.14)
SE±(m)	0.31	1.87	1.94
C.D. at 5%	0.91	5.32	0.45

*Figures in parentheses are angular transformed values.

field conditions. Among the treatments, vermicompost enriched with *T. asperellum* was the most effective, followed by FYM enriched with *T. asperellum*. These results are consistent with earlier findings that integrated use of organic substrates and bioagents enhances the suppressive potential against soil-borne pathogens (Pandey *et al.,* 2021; Sharma *et al.,* 2022). The superiority of vermicompost-based enrichment may be attributed to its finer texture, higher microbial activity, and better nutrient availability, which create a conducive microenvironment for the proliferation of *Trichoderma* spp. and rapid colonization of the rhizosphere (Meena *et al.,* 2021). Several studies have reported that vermicompost serves as an efficient carrier material for *Trichoderma* owing to its rich organic matter and balanced C: N ratio, which support the long-term survival of introduced antagonists (Yadav *et al.,* 2020; Jat *et al.,* 2023).

The mechanism of disease suppression by *T. asperellum* involves a combination of mycoparasitism, antibiosis, and induction of systemic resistance in host plants (Kumar *et al.,* 2021). In the present study, enriched substrates not only reduced stem rot incidence but also enhanced plant height, tillering, and green fodder yield, suggesting that *Trichoderma* inoculation improved root health and nutrient uptake. This is in line with earlier reports that *Trichoderma* inoculation improves nitrogen use efficiency and biomass accumulation in forage crops under field conditions in Haryana (Wonglom *et al.,* 2024). The present study demonstrated that enrichment of organic substrates with *Trichoderma asperellum* significantly reduced the incidence of stem rot (*Sclerotinia trifoliorum*) in berseem. Application of *Trichoderma asperellum*-enriched substrates improved plant vigour and suppressed disease severity compared to untreated controls. These results agree with earlier findings that *Trichoderma* species exhibit antagonistic activity against soil-borne pathogens through mechanisms such as mycoparasitism, antibiosis, competition, and induction of systemic resistance (Harman 2006; Vinale *et al.,* 2008). The significant reduction of *Sclerotinia sclerotiorum* through *Trichoderma-asperellum* enriched amendments corroborates reports from other legume systems. Choudhary *et al.* (2022) demonstrated that

TABLE 8

Colony-forming unit's estimation of *Trichoderma asperellum* after 5, 10, 15, and 20 days of incubation

S. No.	Days after incubation	Average Colony-forming units/gm soil
1.	5	0.69
2.	10	1.38
3.	15	1.69
4.	20	1.70

TABLE 7

Cut-wise yield data of berseem (*Mescavi*) during *Rabi* 2023-24.

Treatments	1St cut (q/ha)	2nd cut (q/ha)	3rd cut (q/ha)
T_1: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period	154.00	197.75	184.13
T_2: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period	159.56	200.75	196.56
T_3: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period	167.81	210.69	198.38
T_4: FYM @ 10 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period	177.69	219.61	205.13
T_5: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 5 days incubation period	158.00	203.94	197.31
T_6: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 10 days incubation period	174.75	210.50	203.06
T_7: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 15 days incubation period	178.38	220.55	207.06
T_8: Vermicompost @ 4 t/ha + *Trichoderma asperellum* @ 2.0% with 20 days incubation period	184.94	229.88	213.63
T_9: FYM @ 10 t/ha only	125.69	165.50	159.19
T_{10} : Vermicompost @ 4 t/ha Only	138.81	192.94	176.94
T_{11} : Control	95.38	135.94	126.44
SE±(m)	2.94	3.56	3.19
C.D. at 5%	8.85	10.40	9.81

Trichoderma asperellum-enriched FYM reduced collar rot of chickpea, while Pandey *et al.* (2021) observed effective management of white mold in soybean using *Trichoderma*-based vermicompost. The enrichment of organic amendments not only increases the populations of antagonists but also enhances soil microbial diversity, a key component of sustainable disease management (Gupta *et al.*, 2023). The use of *Trichoderma*-enriched substrates is an eco-friendly and sustainable approach compared to chemical fungicides, which often lead to residual toxicity and the development of pathogen resistance (Mukherjee *et al.*, 2012). Considering the fodder crop ecosystem, where chemical residues may enter livestock feed chains, biological control strategies hold greater promise.

Organic substrates such as farmyard manure and vermicompost provided a favourable environment for Trichoderma multiplication, which enhanced their efficiency in colonising the rhizosphere and suppressing pathogen growth. Similar observations were made by Singh *et al.* (2008), who reported improved suppression of *Sclerotinia* in legumes when *Trichoderma* was combined with organic amendments. Furthermore, enriched organic formulations also contribute to soil health by increasing microbial diversity, nutrient availability, and enzyme activities, thereby creating an unfavourable environment for the pathogen Sharma *et al.*, (2014). From a practical perspective, the use of *Trichoderma asperellum* in organic carrier substrates such as FYM and vermicompost is eco-friendly, cost-effective, and compatible with farmers' practices in berseem-growing regions of Haryana and North India. Considering that berseem is a multi-cut forage crop grown under intensive, irrigated conditions, integrating bioagents with organic amendments provides dual benefits ie. disease suppression and improved soil fertility.

Overall, the current study confirms that integration of *Trichoderma* with organic substrates not only suppresses *Sclerotinia trifoliorum* but also enhances soil fertility and crop productivity Konappa *et al.*, 2018. This aligns with the principles of integrated disease management (IDM) and supports sustainable forage production systems (Sharma *et al.*, 2022; Xin *et al.*, 2023). These findings emphasize that *T. asperellum*-enriched vermicompost or FYM could be recommended as a promising strategy for managing berseem stem rot under field conditions. Further long-term multilocation trials across diverse agro-ecological zones of Haryana are needed to validate these results and develop a farmer-friendly package of practices.

CONCLUSIONS

The present investigation revealed that the application of *Trichoderma asperellum*-enriched organic substrates, particularly vermicompost and FYM, significantly suppressed stem rot of berseem caused by *Sclerotinia sclerotiorum* and improved crop growth and green fodder yield. Among the tested treatments, vermicompost enriched with *T. asperellum* proved most effective, followed closely by FYM enriched with T. asperellum. The dual benefits of disease suppression and improved plant vigour highlight the potential of such bioformulations as a sustainable alternative to chemical fungicides. The enhanced efficacy of vermicompost-based enrichment can be attributed to its high microbial activity, favorable nutrient profile, and compatibility with the rhizosphere microbiome, which facilitates better establishment of *Trichoderma*. Similarly, enriched FYM serves as a farmer-friendly, cost-effective option that supports long-term soil fertility and disease management. These findings have substantial implications for forage crop production systems in Haryana and North India, where berseem is a major rabi fodder. Adoption of *Trichoderma-asperellum-enriched* organic amendments can reduce dependence on chemical inputs, improve soil health, and ensure sustainable fodder production under intensive cropping systems.

Vermicompost and FYM enrichment: Incorporation of *T. asperellum* at 20 ml/kg vermicompost/FYM, applied @ 2% v/w, should be adopted for effective suppression of stem rot disease and improved fodder yield. Integration with existing practices: These bioformulations can be integrated with recommended nutrient management practices for berseem, ensuring both disease control and soil fertility improvement. Awareness and capacity building: On-farm demonstrations and farmer training programs in berseem-growing districts of Haryana should be conducted to promote large-scale adoption of this eco-friendly technology.

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