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Integrated disease management of banded leaf and sheath blight caused by *Rhizoctonia solani* in proso millet

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ABSTRACT

An experiment was conducted to find out the effective treatment for integrated management of banded leaf and sheath blight caused by *Rhizoctonia solani* Kuhn in proso millet during *Kharif* and *Rabi*, 2021-2022 at Agricultural Research Station, Vizianagaram. *In vitro* studies of bioagents revealed that fungal bioagent, *Trichoderma asperellum* found most effective in supressing the mycelial growth (22.75 mm) with maximum per cent of inhibition (71.56 %). Similarly, *in vitro* evaluation of fungicides revealed that tebuconazole + trifloxystrobin 75 WG was found to be superior of the two fungicides in inhibiting the pathogen with 100, 83.44 and 64.38 per cent inhibition at 100, 50 and 25 per cent of recommended dosages. Field experiments during *Kharif* and *Rabi*, 2021-22 revealed that tebuconazole + trifloxystrobin offered greater protection against BLSB by reducing its disease severity with lowest PDI (15.55 % and 12.5 %) and highest grain (1359.77 and 1450.30 kg ha^{-1}) and fodder (3294.50 and 3401.93 kg ha^{-1}) yields in both *Kharif* and *Rabi* seasons, respectively. Screening of 25 proso millet genotypes revealed that none of the genotypes was immune or highly resistant. All the varieties were susceptible however, seven genotypes were moderately resistant, 12 were susceptible and six were highly susceptible.

Key words: *Rhizoctonia solani,* proso millet, integrated disease management, banded leaf and sheath blight

Proso millet (*Panicum miliaceum* L.), one of the most important minor millets in the Poaceae family, is cultivated since ancient days as a major food crop as well as feed and fodder for livestock in the tribal belts. In India, the crop is grown in many regions of our country *viz.,* Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Bihar, Uttar Pradesh and Uttarakhand (Sinha and Upadhyay, 1997) because of its notable characteristics of tolerating abiotic stress such as heat tolerance, escaping drought with its relatively low water requirement, fast maturity and short growing season. It is well adaptable to poor degraded lands, high elevated conditions and grows ably in all types of soil. It is grown on 0.42 lakh hectares in India, with a production of roughly 0.22 lakh tonnes and a productivity of 531 kg ha^{-1} in the year 2015-16 (Prabhakar *et al.,* 2017). In addition to these, proso millet is highly nutritious containing Carbohydrates (63.8 gm), protein (12.5 gm), crude fibre (14.2 gm), calcium (2.6 gm), fat (3.1 gm), mineral matter (2.7 gm), phosphorus (206 mg), and iron (158.9 mg) are all present in 100 grams of millet grain (Cedric *et al.,* 2017; Hemamalini *et al.,* 2020) with low glycemic index.

Proso millet is being incited by various biotic stresses which include various diseases such as smut, rust, blast, brown spot, foot rot, banded blight, and some other viral diseases. Banded blight incited by *Rhizoctonia solani* Kuhn. is one of the dreadful diseases in the successful cultivation of proso millet. This is one of the most extensive, devastative and versatile pathogens found in many different parts of the world having a wide host range causing seed decay, damping off, stem canker, root rot, aerial blight and seed or cob decay (Ogoshi, 1987) whereas, in millets it inflicts significant loss in grain yield and quality. In proso millet, banded blight incidence ranged from 2.4 – 8.6 grade with 50 – 97.6 per cent yield loss (Palanna *et al*., 2021). Furthermore, environmental conditions such as low light, cloudy days, high level of relative humidity accompanying excessive rainfall and optimum temperature prone the crop to BLSB (Ou, 1985). The pathogen overwinters as soil-borne sclerotia and mycelium in plant debris;

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these constitute the primary inoculum.

Identifying the banded leaf and sheath blight pathogen and analysing different isolates is prerequisite as it provides a basic understanding about the variability of an organism. Variability in cultural and virulence of pathogen is vital for the development of area specific resistant cultivars. So far, many attempts were made by the scientists to study morphological, pathogenic and molecular variability of *R. solani* isolates from varied geographical locations in the world (Sharma *et al.,* 2005 and Khodayari *et al*., 2009) and from India (Mishra *et al.,* 2014; Debbarma and Dutta, 2015). Therefore, research on morpho-cultural characterization aids us to categorize the pathogen based on various morphological characters.

Controlling the pathogen is found to be difficult due to its wide host range, ecological behaviour and mostly its high sclerotial survival rate under diverse environmental conditions. However, integrated disease management strategies *viz.,* chemical methods of control like fungicides, biological agents, use of resistant cultivars and other eco-friendly practices help in the successful management of the pathogen and lowers the disease to varying extent.

MATERIALS AND METHODS

Isolation of pathogen and inoculum preparation

Infected proso millet leaves showing characteristic blight symptoms with profuse mycelial growth under moist conditions were collected from *R. solani* infected fields. The pathogen was initially isolated on PDA and further purified by hyphal tip method and single sclerotial method (Moni *et al*., 2016; Thesiya *et al.,* 2023) and incubated at 28±2^{o}C for 5 days.

In vitro efficacy of fungicides and biocontrol agents (BCA)

In vitro evaluation of three biocontrol agents (*Trichoderma asperellum*, *Pseudomonas fluorescens* and *Bacillus subtilis*) was done following dual culture technique (Mortan and Stroube, 1955) and two fungicides (tebuconazole + trifloxystrobin 75 WG and propiconazole 25% EC) efficacy was tested by following poisoned food technique (Grover and Moore, 1961). The plates were replicated as triplicates and incubated at 28 ± 2 °C and per cent inhibition was calculated using the formula given by Vincent (1927).

$$I = \frac{C-T}{C} \times 100$$

Where, I = % inhibition, C = Colony diameter in check (mm) and T = Colony diameter in treatment (mm)

Field experiment for integrated disease management of BLSB during *Kharif* and *Rabi,* 2021-22

The field experiments were laid out in Randomized Complete Block Design (RCBD) with three replications maintaining spacing of 22.5 cm between rows and 10 cm between plants in both *Kharif* and *Rabi* seasons of 2021-22 by choosing the susceptible variety, Nilavoor local. Total eight treatments as mentioned in Table 1 were adopted. Two fungicides *viz.,* propiconazole (0.1%) and tebuconazole+trifloxistrobin (0.05%) and three potential biocontrol agents such as *Bacillus subtilis, Pseudomonas fluorescens* and *Trichoderma asperellum* and an organic input, Panchagavya (3%) [procured from a local Zero Budget Natural Farming (ZBNF)] farmer were used to evaluate their efficacy against banded leaf and sheath blight disease. After treating with fungicides, seeds were allowed to air dry before sowing whereas bioagent and panchagavya treated seeds were kept overnight in moist chamber so as to enable the antagonist to establish on seed surface. Unamended plots served as check. The fungi toxicants (propiconazole- 1 g lit^{-1} tebuconazole+trifloxistrobin- 0.5 g lit^{-1}, *B. subtilis @ 10* g lit^{-1} and Panchagavya-30 ml lit^{-1}) were applied in the form of spray on the above ground parts of plants. Spray of only water served as check. First foliar spray was given just at the appearance of the disease *i.e.,* at 30 days after sowing (DAS) whereas second foliar spray of propiconazole 0.1% was given at 14 days interval from the first spray *i.e.,* at 44 DAS. Observations on disease severity (PDI) were recorded twice at 14 days interval, once at 37 DAS and the other at 51 DAS after completion of administration of foliar sprays of the respective treatments using RBD with triplicates during 2021-22 *Kharif* and *Rabi* seasons.

Disease severity was observed by following standard evaluation scale (SES) for sheath blight (Table 2) and per cent disease index (PDI) was calculated for different treatments based on the

Table 1. List of treatments tested against BLSB of proso millet under sick plot conditions

Treatment	Application
T_1	Seed treatment with *Trichoderma asperellum* @ 10 g kg^{-1}+ soil application of *Trichoderma asperellum* @ (2 kg talc formulation mixed with 8 kg neem cake in 90 kg FYM incubated for 15 days).
T_2	Seed treatment with *Pseudomonas fluorescens* @ 10 g kg^{-1}+ soil application of *Pseudomonas fluorescens* @ (2 kg talc formulation mixed with 8 kg neem cake in 90 kg FYM incubated for 15 days).
T_3	Seed treatment with *Bacillus subtilis* @ 10 g kg^{-1}+ soil application of *Bacillus subtilis*@ (2 kg talc formulation mixed with 8 kg neem cake in 90 kg FYM incubated for 15 days).
T_4	Seed treatment with tebuconazole + trifloxystrobin 0.05% + foliar spray of tebuconazole + trifloxystrobin 0.05%.
T_5	Seed treatment with *Pseudomonas fluorescens* @ 10 g kg^{-1}seed + soil application of *Trichoderma asperellum* (2 kg talc formulation mixed with 8 kg neem cake in 90 kg FYM incubated for 15 days).+ foliar spray of *Bacillus subtilis* @ 10 g lit^{-1}
T_6	Seed treatment and foliar spray with 3% solution of Panchagavya
T_7 (standard check)	Seed treatment with propiconazole 0.1% + 2 foliar sprays of propiconazole @ 0.1% at 15 days interval.
T_8	Control

formula given by Wheeler (1969).

$$\text{PDI (\%)} = \frac{\text{Sum of individual disease ratings}}{\text{No.of observations assessed} \times \text{maximum disease rating}} \times 100$$

Area under disease progress curve (AUDPC)

The efficacy of different treatments was assessed based on AUDPC values using the formula given by Wilcoxson *et al*. (1975). In the present study, PDI (%) was recorded twice at 14 days of interval period for calculating the AUDPC.

$$\textbf{AUDPC} = \sum_{i=1}^{k} \frac{1}{2}(S_i + S_{i-1}) \times d$$

Where, S_i= Disease incidence at ith day of evaluation, k =Number of successive evaluation of the disease, d = Interval between i and i-1 evaluation of disease

$$\text{B:C ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}} \times 100$$

Yield parameters

Observations on yield attributing parameters like gain yield and fodder yield per plot (kg ha^{-1}) were recorded in the same trial at harvesting stage and benefit cost ratio (BC ratio) was calculated for each treatment by using the formula given below and compared with untreated check.

Screening for identification of resistant sources against banded leaf and sheath blight on proso millet

To find out the source of resistance, an experiment was conducted during *Kharif* season 2021-22 in the field of Agricultural Research Station, Vizianagaram under natural field conditions. A total of 25 proso millet entries were sown in two rows of three metre length, at a spacing of 30 × 10 cm with 3 replications. For every five entries two rows of susceptible and resistant checks were sown and evaluated altogether.

Table 2. Standard evaluation scale (SES) for sheath blight disease (IRRI, 2014)

0-9 scale	Disease severity	Reaction
0	No infection	Highly Resistant (HR)
1	Vertical spread of the lesion up to 20% of plant height	Resistant (R)
3	Vertical spread of the lesion up to 21-30% of plant height	Moderately Resistant (MR)
5	Vertical spread of the lesion up to 31- 45% of plant height	Moderately Susceptible (MS)
7	Vertical spread of the lesion up to 46-65% of plant height	Susceptible (S)
9	Vertical spread of the lesion up to 66-100% of plant height	Highly Susceptible (HS)

In each entry, plants were observed at different growth stages for symptoms for per centage of incidence and severity of disease. Disease grading was done as per the standard evaluation scale for sheath blight (SES), 0-9 scale (IRRI, 2014) mentioned in Table 2 and varietal performance was recorded. In each entry, plants were observed at different growth stages for symptoms of BLSB in order to record per cent disease incidence and severity.

The observations recorded in the various experiments of the study were statistically analysed by following the standard procedures given by Gomez and Gomez (1984). The statistical inference was drawn at $p<0.01$ and $p<0.05$ for *in vitro* and *in vivo* conditions, respectively.

RESULTS AND DISCUSSION

Efficacy of biocontrol agents and fungicides under *in vitro* conditions

Interaction between *R. solani* and biocontrol agents *viz*., *Trichoderma asperellum*, *Pseudomonas fluorescens* and *Bacillus subtilis*(all supplied from Biological Control Laboratory Vizianagaram) revealed that among the three biocontrol agents, fungal bioagent, *T. asperellum* found superior in inhibiting the mycelial growth (22.75 mm) of *R. solani* with maximum per cent inhibition over control (71.56). *B. subtilis* followed *T. asperellum* with 58.59% inhibition over control and 33.13 mm mycelial growth. Of the three bioagents, *P. fluorescens* recorded least mycelial inhibition (54.08 %) with highest mycelial growth (36.74 mm) (Table 3, Plate 1). Similar kind of results were obtained in the findings of Radhajeyalakshmi

Table 3. Efficacy of bioagents against radial growth of *R. solani* under *in vitro*

S.No	Bioagent	Radial growth (mm) of *R. solani* after 5 DAI*	Per cent inhibition
1	*T. asperellum*	22.75	71.56
2	*P. fluorescens*	36.74	54.08
3	*B. subtilis*	33.13	58.59
4	Pathogen check	80.00	-
	SEm±	0.92	
	CD (P ≤ 0.05)	1.30	
	CV (%)	4.28	

Mean of four replications; *DAI=Days after inoculation.

Plate 1. Eficacy of bioagents against radial growth of *R. solani* under *in vitro* conditions

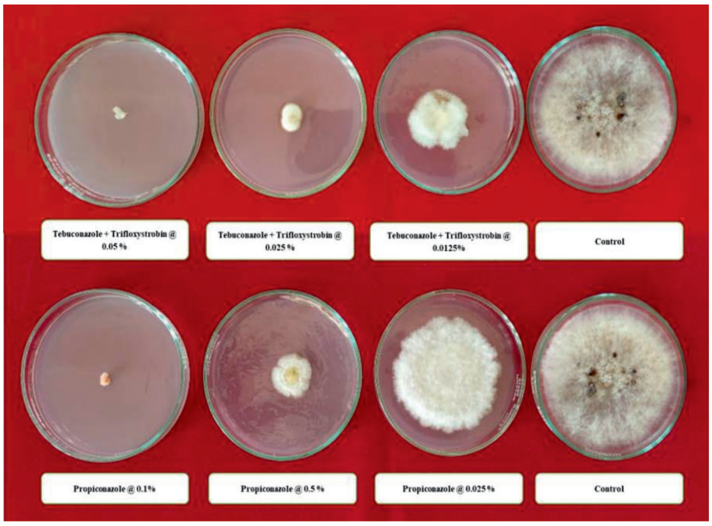

Plate 2. Evaluation of fungicides at different concentrations against radial growth of *R. solani* under *in vitro* conditions

Table 4. Evaluation of fungicides at different concentrations against *R. solani* under *in vitro* conditions

Tr. No.	Fungicide	Colony diameter (mm)				Per cent inhibition			Mean (%)
		Recom-mended dose	50 % of rec-ommended dose	25% of recom-mended dose	Mean	Recom-mended dose	50 % of recom-mended dose	25% of recom-mended dose	
1	Tebuconazole + Trifloxystrobin 75 WG	0.00	13.25	28.5	13.92	100.00	83.44	64.38	82.61
2	Propiconazole 25% EC	0.00	21.00	55.5	25.50	100.00	73.75	30.63	68.13
	Mean	0.00	17.12	42.02		100.00	78.60	47.37	
	Control	80.00							
		Fungicide (F)	Concentration (C)	F x C					
	SEm±	0.45	0.45	0.45					
	CD ($P \leq 0.05$)	0.78	0.95	1.34					
	CV (%)	4.59							

Mean of four replications

et al. (2020) on *in vitro* efficacy of biological agents on maize BLSB caused by *Rhizoctonia solani* where *T. asperellum* was found to be most effective in suppressing the mycelilal growth of *R. solani.*

Evaluation of fungicides against radial growth of *R. solani* under *in vitro* conditions

Effect of two fungicides was studied against BLSB pathogen of proso millet through poison food technique (Table 4, Plate 2). Mycelial growth was completely suppressed at the recommended dosages of both the fungicides (tebuconazole + trifloxystrobin 75 WG @ 0.01 % and propiconazole 25% EC @ 0.1%). Lower mycelial growth was noticed at 50% of the recommended dose in tebuconazole + trifloxystrobin 75 WG (13.25 mm) and propiconazole 25% EC (28.25 mm). At 25% of the recommended dosage, both the fungicides failed to inhibit the pathogen as pathogen almost occupied the full Petriplate (55.5 mm) whereas, tebuconazole + trifloxystrobin 75 WG recorded 28.5 mm of mycelial growth. Overall, tebuconazole + trifloxystrobin 75 WG was found to be superior as both the fungicides is inhibiting the pathogen with 100, 83.44 and 64.38 per cent inhibition at recommended dosage, 50 % of recommended dosage and 25 % of recommended dosages respectively whereas, propiconazole 25% EC recorded 100, 73.75 and 30.63 per cent inhibition at recommended dosage, 50 % of recommended dosage and 25 % of recommended dosages, respectively.

It was observed that, with the decrease in the recommended dosage of concentration of the fungicides, the radial growth of the test pathogen was proportionally increased indicating that both the fungicides are to be applied only at recommended dosage of concentrations (*i.e.,*tebuconazole + trifloxystrobin 75 WG @ 0.01 % and propiconazole 25% EC @ 0.1%) and never to be applied lower than these recommended concentrations.

Kaur and Singh (2016) tested the efficacy of different fungicides including tebuconazole + trifloxystrobin 75 WG and propiconazole 25% EC at different concentrations against BLSB of rice reported that of all the fungicides, tebuconazole + trifloxystrobin 75 WG was found to be most effective fungicide in showing 100% growth inhibition.

Evaluation of different treatments under field conditions against BLSB during *Kharif* and *Rabi,* 2021-22

In the *Kharif* season 2021-22, at 37 DAS, T_4-Trifloxystrobin+Tebuconazole recorded the lowest BLSB disease severity (12.58%) which was at par with T_7- Propiconazole (14.43%). Similarly, T_5- *B. subtilis* + *P. fluorescens* + *T. asperellum* (20.72%), T_6-Panchagavya (21.09%) and T_1- *T. asperellum* (25.83) were also found superior over control. The maximum disease severity was recorded in the untreated plot (82.14%) followed by T_2- *P. fluorescens* (44.03%) and T_3- *B. subtilis* (31.08).

Table 5. Effect of bioagents, fungicides and organic input on PDI (%) under sick plot conditions (*Kharif*, 2021)

Tr. No.	Treatment	PDI (%) (37 DAS)	PDI (%) (51 DAS)	Inhibition over control (%)
T_1	*T. asperellum*	25.83 (30.51)[cd]	45.89 (42.64)[cd]	47.44
T_2	*P. fluorescens*	44.03 (41.55)[b]	63.57 (52.87)[b]	27.20
T_3	*B. subtilis*	31.08 (33.83)[c]	53.3 (46.89)[c]	38.96
T_4	Trifloxystrobin+Tebuconazole	12.58 (20.75)[e]	15.55 (23.22)[f]	82.20
T_5	*B. subtilis + P. fluorescens + T. asperellum*	20.72 (27.01)[d]	31.46 (34.12)[e]	63.97
T_6	Panchagavya	21.09 (22.01)[d]	39.23 (38.78)[d]	55.07
T_7	Propiconazole	14.43 (46.02)[e]	19.25 (26.02)[f]	77.95
T_8	Control	82.14 (51.82)[a]	87.32 (69.14)[a]	0.00
SEm±		1.17	1.50	
CD (P = 0.05)		3.57	4.60	
CV (%)		6.49	6.24	

Values in parentheses are arc sine transformed values; Mean of three replications; Values with the same alphabets are statistically not significant.

In the *Kharif* season 2021-22, at 51 DAS a similar trend of disease severity (PDI) was followed where the lowest PDI was recorded with T_4- Trifloxystrobin+Tebuconazole (15.55%) followed by T_7- Propiconazole (19.25%) whereas a significant variation of PDI was observed with the treatments of T_5- *B. subtilis+P. fluorescens+T. asperellum* (31.46%), T_6- Panchagavya (39.23%). However, T_1- *T. asperellum* (45.89%) and T_6- Panchagavya (39.23%) were found superior over control. The maximum disease severity was recorded in the untreated plot (87.32%%) followed by T_2- *P. fluorescens* (63.57%).

All the treatments have shown significant difference in reducing the disease severity with maximum inhibition percentage over control. The treatment T_4 recorded the highest inhibition percentage (82.20%) over control followed by the treatments T_7 (77.95), T_5 (63.97), T_6 (55.07), T_1 (47.44), T_3 (38.96) and T_2 (27.20) (Table 5, Fig. 1).

In 2021-22 *Rabi*, the disease severity was slightly lower than the previous season *Kharif,* 2021-22. This might be due the less congenial environmental conditions for the pathogen during the *Rabi* than the *Kharif* season. At 37 DAS, T_4- Trifloxystrobin+Tebuconazole recorded the lowest PDI (10.73%) showing not much significant difference with the PDI of T_7- Propiconazole (11.47%). The PDI of three treatments *i.e.,* T_5- *B. subtilis+ P. fluorescens+ T. asperellum*, T_6- Panchagavya and T_1- *T. asperellum* were found more or less uniform with PDI (%) of

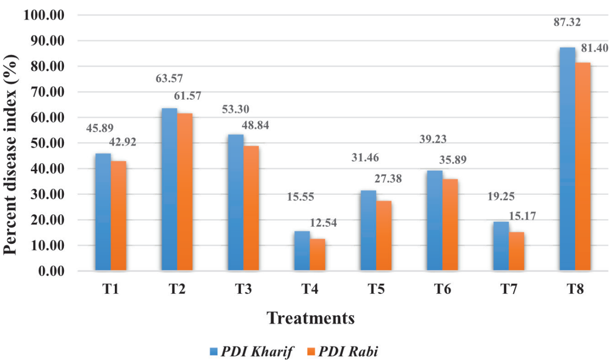

Fig. 1. Effect of bioagents, fungicides and biorationale application on PDI (%) under sick plot conditions during *Kharif* and *Rabi*, 2021

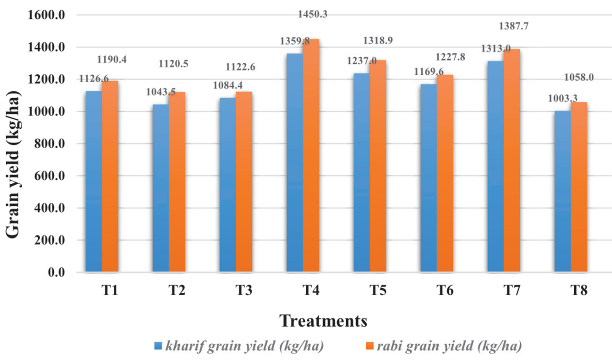

Fig. 2. Effect of bioagents, fungicides and biorationale application on grain yield (kg ha^{-1}) of proso millet during *Kharif* and *Rabi*, 2021-22

Table 6. Effect of bioagents, fungicides and organic input on PDI (%) under sick plot conditions (*Rabi*, 2021-22)

Tr. No.	Treatment	PDI (%) (37 DAS)	PDI (%) (51 DAS)	Inhibition over control (%)
T_1	*T. asperellum*	22.57 (28.35)[bc]	42.92 (44.31)[d]	47.27
T_2	*P. fluorescens*	41.44 (40.05)[d]	61.57 (51.67)[f]	24.36
T_3	*B. subtilis*	26.51 (30.96)[c]	48.84 (40.91)[e]	40.00
T_4	*Trifloxystrobin+Tebuconazole*	10.73 (19.11)[a]	12.54 (20.70)[a]	84.60
T_5	*B. subtilis + P. fluorescens + T. asperellum*	20.35 (26.79)[b]	27.38 (31.51)[b]	66.36
T_6	Panchagavya	21.83 (27.78)[b]	35.89 (36.78)[c]	55.91
T_7	Propiconazole	11.47 (19.76)[a]	15.17 (22.90)[a]	81.36
T_8	Control	49.58 (44.74)[e]	81.40 (64.43)[g]	0.00
SEm±		0.91	1.07	
CD ($P \leq 0.05$)		2.78	3.27	
CV (%)		5.30	4.72	

Values in parentheses are arc sine transformed values; Mean of three replications; Values with the same alphabets are statistically not significant.

20.35, 21.83, 22.57, respectively. However, T_3 - *B. subtilis* (26.51%) was found superior than T_1- *T. asperellum* (22.57%). The maximum disease severity was recorded in the untreated plot (49.58%) followed by T_2- *P. fluorescens* (41.44%).

In the *Rabi* season 2021-22, at 51 DAS, all the treatments were found significantly different with one another except T_7- Propiconazole (15.17 %) which was being at par with T_4-Trifloxystrobin+Tebuconazole (12.54%). Maximum disease severity was noticed in the untreated plot (81.40%) followed by T_2- *P. fluorescens* (61.57%) and T_3-*B. subtilis* (48.54%).

All the treatments have shown significant variation in terms of inhibition over control (%) with the maximum inhibition observed with the treatment T_4 (84.60%) followed by the treatments T_7, T_8, T_6, T_1, T_3 and T_2 with the inhibition over control (%) of 81.36, 66.36, 55.91, 47.27 and 40.00 and 24.36, respectively (Table 6, Fig. 2).

In the present investigation, when compared to other treatments trifloxystrobin + tebuconazole was found to offer greater protection to proso millet crop against BLSB followed by propiconazole. These findings were supported with the work of Mohanty *et al.* (2020) who reported that trifloxystrobin+tebuconazole followed by propiconazole were found most effective in reducing the per cent disease index. Among different bio-control agents used, combination of *B. subtilis+ P. fluorescens+ T. asperellum* resulted in greater reduction in disease severity than the respective individual bio-control agents. However, efficacy of Panchagavya was found comparable with the combination of bioagents, *B. subtilis+ P. fluorescens+ T. asperellum* in reducing disease incidence and severity. When individual biocontrol agents are taken into consideration, *T. asperellum* ensured enhanced protection to banded blight pathogen followed by *B. subtilis* whereas least protection was given by *P. fluorescens.* These results were found corroborated with the findings of Patro *et al*. (2018b) who reported that lowest sheath blight incidence was recorded in the combination of *B. subtilis+ P. fluorescens+ T. asperellum, T. asperellum, B. subtilis* and *P. fluorescens* followed in order.

It was also observed that the disease severity of BLSB in proso millet was less in *Rabi* when compared to *Kharif.* This is because the experimental area received more monsoon showers by southwest monsoon during *Kharif* whereas, less rainfall was received by northeast monsoon during *Rabi*. The high rainfall coupled with more relative humidity during *Kharif* is congenial for pathogen for survival and spread whichfavoured the pathogen to increase disease severity during *Kharif.*

Effect of bioagents, fungicides and organic input on grain and fodder yield of proso millet

The data presented in Table 7 showed that of all the treatments, T_4- Trifloxystrobin +Tebuconazole

Table 7. Effect of bioagents, fungicides and organic input on grain yield and fodder yield of proso millet (*Kharif* and *Rabi*, 2021-22)

Tr. No.	Treatments	*Kharif*, 2021			*Rabi*, 2021-22		
		Grain yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	B:C ratio	Grain yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	B:C ratio
T_1	*T. asperellum*	1126.56^{cd}	2647.70^{cde}	1.39	1190.38^{cd}	2786.8^{cde}	1.47
T_2	*P. fluorescens*	1043.50^{d}	24950de	1.28	1120.47^{d}	2612.53^{de}	1.37
T_3	*B. subtilis*	1084.40^{d}	2456.67^{e}	1.32	1122.57^{d}	2758.57^{cde}	1.36
T_4	*Trifloxystrobin+Tebuconazole*	1359.77^{a}	3294.50^{a}	1.46	1450.30^{a}	3401.93^{a}	1.56
T_5	*B. subtilis + P. fluorescens + T. asperellum*	1237.00^{abc}	2801.93^{bcd}	1.43	1318.93^{abc}	2871^{cd}	1.52
T_6	Panchagavya	1169.63^{bcd}	2870.33^{bc}	1.39	1227.83^{bcd}	2958.67^{bc}	1.46
T_7	Propiconazole	1313.00^{ab}	3071.00^{ab}	1.45	1387.67^{ab}	3224^{ab}	1.54
T_8	Control	1003.33^{d}	2345.60^{e}	1.25	1058.00^{d}	2525.33^{e}	1.32
SEm±		50.26	101.50		53.16	100.49	
CD ($P \leq 0.05$)		153.92	310.86		162.82	307.76	
CV (%)		7.46	6.40		7.46	6.02	

Mean of three replications; Values with the same alphabets are statistically not significant.

recorded highest grain yield in both the respective *Kharif* (1359.77 kg ha^{-1}) and *Rabi* (1450.3 kg ha^{-1}) seasons. T_7- Propiconazole with grain yield of 1313 kg ha^{-1} (*Kharif*), 1387.67 kg ha^{-1} (*Rabi*) and T_5- *B. subtilis + P. fluorescens + T. asperellum* with 1237 kg ha^{-1} (*Kharif*), 1318.93 kg ha^{-1} (*Rabi*) were found at par with T_4. However, T_6- Panchagavya in both *Kharif* (1169.63 kg ha^{-1}) as well as *Rabi* (1227.83 kg ha^{-1}) *was* found as good as T_5- *B. subtilis + P. fluorescens + T. asperellum*. Similarly, T_1- *T. asperellum* was found at par with T_6- Panchagavya in both the seasons. There was found no significant difference among the treatments T_2- *P. fluorescens*, T_3 – *B. subtilis* and T_8 - Control in either *Kharif* (1043.5, 1084.4 & 1003.33 kg ha^{-1}) or *Rabi* seasons (1120.4, 1122.5 & 1058 kg ha^{-1}) respectively while lowest grain yield recorded in the untreated plot in *Kharif* (1003.33 kg ha^{-1}) and *Rabi* season (1058 kg ha^{-1}).

In respect of fodder yield also, T_4- Trifloxystrobin +Tebuconazole has shown its supremacy with highest yield among all the treatments in *Kharif* (3294.5 kg ha^{-1}) as well as *Rabi* (3401.93 kg ha^{-1}) seasons followed by T_7- Propiconazole with 3071 kg ha^{-1}(*kharif*) and 3224 kg ha^{-1} (*Rabi*) which was being on par with T_4- Trifloxystrobin +Tebuconazole followed by T_6- Panchagavya (*Kharif*, 2870.33 kg ha^{-1} and *Rabi,* 2958.67 kg ha^{-1}). The least fodder yield was recorded with untreated plot in *Kharif* (2345.6 kg ha^{-1}*)* as well as *Rabi* (2525.33 kg ha^{-1}).

It was noticed that treatments with lowest disease severity (PDI %) recorded highest grain and fodder yield and vice versa indicating that there exits a positive correlation between the disease severity and yield. Hence lower the PDI, greater is the grain and fodder yields. Similar results were noticed in the findings of Patro *et al.* (2021) who reported that yield loss increased with increase in severity of disease in all small millets. Chouhan (2014) noticed reduction in plant characters like plant height (14.7%), productive tillers per plant (15.7%), panicle weight (12.8%), panicle length (14.2%), per plant grain yield (17.8%), 1000 grain weight (11.3%) and fodder yield per plant (19.4%) on susceptible genotypes of little millet due to incidence of *R. solani.*

Benefit cost ratio

The benefit cost ratio (BCR) of different treatments varied from 1.46 to 1.25 during *Kharif* while 1.56 to 1.32 during *Rabi* (Table 7). BCR of fungicidal treatment, T_4- Trifloxystrobin +Tebuconazole is highest followed by T_7- Propiconazole during both *Kharif* as well as *Rabi* implying they were best for farmers to raise their incomes. However, BCR of T_5- *B. subtilis + P. fluorescens + T. asperellum* was more

Table 9. Reaction of proso millet genotypes against banded leaf and sheath blight disease (*R. solani*)

S.No	Genotypes	Reaction	No. of entries
1	VP002(PMV464), TNAU 164, RAUP 27, IIMR 10, TNPm-313, TNPm-317, TNPm-318	MR	7
2	VP 010, VP 016, TNAU 164, TNPM 283, TNPM 230, GPUP 33, GPUP 34, IIMR 18, TNPM 283, TNPm-3108, TNPm-314	S	11
3	DHPM 6-3, PMNDL 5, TNAU 202, TNPm-311, TNPm-312, TNPm-315, TNPm-316	HS	7

Table 10. Screening for banded leaf and sheath blight resistance in proso millet genotypes

S.No	Entry	Per cent disease severity	Reaction
1	VP 010	64.44 (46.93)	S
2	VP 002(PMV464)	30.37 (35.31)	MR
3	VP 016	68.88 (48.69)	S
4	TNAU 164	31.48 (35.70)	MR
5	TNPM 283	67.40 (48.41)	S
6	TNPM 230	68.88 (48.57)	S
7	GPUP 33	65.92 (47.70)	S
8	GPUP 34	65.18 (47.19)	S
9	DHPM 60-4	62.22 (46.17)	S
10	DHPM 8-3	65.92 (47.44)	S
11	DHPM 6-3	77.03 (51.55)	HS
12	PMNDL 5	79.99 (53.01)	HS
13	RAUP 27	28.52 (34.61)	MR
14	IIMR 10	27.03 (34.02)	MR
15	IIMR 188	63.70 (46.67))	S
16	TNAU 202	88.88 (57.09)	HS
17	TNPm-310	60.73 (45.67)	S
18	TNPm-311	59.36 (45.21)	S
19	TNPm-312	90.36 (58.73)	HS
20	TNPm-313	29.63 (35.03)	MR
21	TNPm-314	54.07 (43.38)	S
22	TNPm-315	82.21 (53.74)	HS
23	TNPm-316	88.88 57.22)	HS
24	TNPm-317	29.63 (35.03)	MR
25	TNPm-318	28.89 (34.75)	MR
26	TNPm-230	14.07 (27.97)	R
27	Nilavoor local	92.58 (72.64)	HS
SEm±		1.57	
CD		4.46	
CV (%)		6.99	

Values in parentheses are arc sine transformed values; Mean of three replications

Table 8. Effect of bioagents, fungicides and biorationale application on AUDPC (*Kharif* and *Rabi,* 2021-22)

Tr. No.	Treatment	AUDPC *Kharif,* 2021	AUDPC *Rabi,* 2021-22
T_1	*T. asperellum*	502.09	458.43
T_2	*P. fluorescens*	753.17	721.07
T_3	*B. subtilis*	590.64	527.43
T_4	*Trifloxystrobin+Tebuconazole*	196.89	162.87
T_5	*B. subtilis + P. fluorescens + T. asperellum*	365.28	334.11
T_6	Panchagavya	422.24	404.04
T_7	Propiconazole	235.76	186.50
T_8	Control	973.96	916.86

or less similar and comparable with the fungicide treatments. Therefore, T_5- *B. subtilis + P. fluorescens + T. asperellum* would be an ideal treatment for integrated disease management.

Effect of bioagents, fungicides and organic input on area under disease progress curve (AUDPC)

AUDPC was estimated for all the treatments during *Kharif* and *Rabi* seasons, 2021-22. Treatment T_4-Trifloxystrobin+Tebuconazole exhibited low AUDPC of 196.89 against the untreated check (973.96) during *Kharif*, 2021 which indicates its dominance over the tested treatments. Maximum AUDPC (753.17) was observed in T_2- *P. fluorescens*. Similar pattern of results was obtained in the *Rabi* season also, where minimum AUDPC (162.87) was observed in T_4-Trifloxystrobin+Tebuconazole and maximum AUDPC (721.07) was noticed in T_2- *P. fluorescens* against the untreated plot (916.86) (Table 8, Fig 3).

Screening for identification of resistant sources against banded leaf and sheath blight of proso millet

Identification of resistant lines by utilizing the available varietal resistance to overcome the yield loss against major diseases was found to be an essential component of an integrated disease management. Resistant varieties have the potentiality to arrest or inhibit pathogen activity so that little or no symptoms seen upon pathogen infection. As resistant varieties enable farmers to limit or sometimes eliminate pesticides are cost effective and also beneficial as they don't show harmful impact on the environment, therefore, selection of resistant varieties for any disease is an ideal approach.

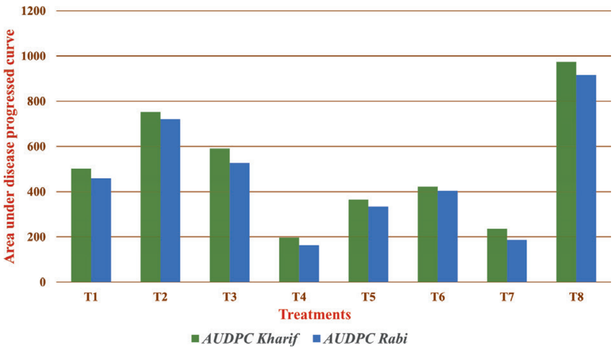

Fig 3. Effect of bioagents, fungicides and organic input on AUDPC during *Kharif* and *Rabi,* 2021-22

Hence, in the present study, a total of 25 proso millet genotypes collected from different states of India were screened under sick plot conditions. None of the genotypes was highly resistant and resistant. The screening reports of Patro *et al.* (2015), Patro *et al*. (2017), Patro *et al*. (2018a), Patro *et al*. (2018c), Patro *et al*,(2020b) on proso millet against BLSB also revealed that no variety was found to be immune and also none found to be resistant against BLSB. However, in our current investigation 7 genotypes were moderately resistant (1.1-3.0 grade), 11 were susceptible (5.1-7.0 grade) and 7 were found highly susceptible (7.1-9.0 grade) with the disease severity ranged from 14.07% (TNpm-230) to 92.58% (Nilavoor local) (Table 9, Table 10).

Patro *et al.* (2015) screened 18 proso millet genotypes and reported resistant to moderately resistant genotypes *viz.* DhPrMv 2164 (29.23%) and DhPrMv 2769 (28.90%). Similarly, Patro *et al*. (2017) screened eleven varieties of proso millet and reported that minimum disease severity (64.00%) was recorded in TNAU 145 whereas it was 90.67 % in check.

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