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Combined Efficacy of Bio Agents and Fungicides for the Effective Management of Major Finger Millet (*Eleucine coracana* L.Gaertn.) Diseases

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PTS, MR, VM and AN involved in designing of the study, field experiments and manuscript writing and correction. Authors TSK and SM have carried out the statistical analysis and literature collection. All authors read and approved the final manuscript.

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ABSTRACT

A detailed study was undertaken during 2021-23 to evaluate suitable management practices for major diseases of finger millet. Leaf blast disease was observed from 15 days after sowing (DAS) and showing an increasing trend up to 52 DAS. Whereas, *Helminthosporium* leaf spot was observed from 37 DAS till harvesting of the crop. Field experiments were conducted to evaluate the effect of different treatments comprises of fungicides and biocontrol agents at Centre of Excellence in Millets, Athiyandal, India and it was found that seed treatment with *B. subtilis* at 10g/kg of seed + spray of Azoxystrobin 25 SC @ 200 ml/ac at 25 and 40 days after sowing, was highly effective in controlling blast and *Helminthosporium* leaf spot after sowing was found to be very effective in controlling blast and *Helminthosporium* leaf spot.and recorded maximum yield when compared to other treatments and which is followed by seed treatment with *B. subtilis* at 10g/kg of seed + Tricyclazole 75 WP @ 500 g/Ha at 25 days after sowing.

Keywords: Finger millet; major diseases; management; biocontrol; fungicides.

1. INTRODUCTION

Finger millet (*Eleusine coracana* (L.) Gaertn.) is considered as significant among all millets due to its high nutritional value. It is mostly cultivated by subsistence farmers and crucial crop for food security due to its superior storage properties (Dida et al., 2007). Its exceptional adaptability to high heat, low moisture, and poor soil has drawn increasing attention from researchers (Shukla et al., 2015). Finger millet is susceptible to some fungal diseases but resistant to most pests. Sixteen fungal, three viral, and one bacterial pathogen have been reported to damage the finger millet; of which, blast disease is the most significant. Blast disease, which is caused by the fungus *Pyricularia grisea* Sacc. (Perfect stage *Magnaporthe grisea* (Hebert) Barr.), is the main obstacle to the profitable production of finger millet in all millet-growing regions of the world (Patro & Madhuri, 2014). Since the start of the century, blast disease has been documented in India, where it has been estimated that, depending on the weather, grain loss may reach upto 50 percent. The symptoms first show up as typical spindle-shaped spots on the leaf lamina with brown or reddish-brown margins and grey or whitish cores that grow and coalition to give the impression of blasting. Integrated approach to manage the major diseases is the need of the day. Besides, *Helminthosporium* leaf spot and grain mold are also become serious one when the climatic conditions becomefavourable. Dhiren and Chhetry (2022) reported the occurrence of brown spot by *H.nodulosum* and banded blight by *Rhizoctonia solani* in finger millet. Brown spot or seedling blight or leaf blight incited by *Helminthosporium nodulosum* (Berk and Curt.) is next only to blast both in severity and distribution. Severity of brown spot is high in maturity stage as compared to pre-flowering stage (Madhuri et al., 2014). Currently, fungicides and biocontrol agents are available to manage the plant diseases. The combination of biocontrol agents and fungicides application has greatly contributed for efficient disease management, however, the results are available only for limited diseases. Biocontrol agents have successfully utilized for management of variety of fungal pathogens such as powdery mildew (Mgonja et al., 2007; Anand et al., 2010), verticillium wilt disease (Yuan et al., 2017), and anthracnose (Hernandez-Montiel et al., 2018). Only limited field level findings are available for management of major diseases of finger millet. In view of above importance, field experiments were conducted to find out the combined effect of biocontrol agents and fungicides against major diseases of finger millet.

2. MATERIALS AND METHODS

2.1 Survey on the Occurrence of Major Diseases of Finger Millet

Fixed plot survey was carried out to assess the occurrence of major diseases of finger millet at Centre of Excellence in Millets, Athiyandal, Tamil Nadu. The crop was raised during *Kharif* season of 2021-22 to 2022-23 and maintained without any plant protection measures so as to study the occurrence of the various diseases of the crop variety ATL 1. The incidence of blast and *Helminthosporium* leaf spot were recorded regularly using standard scale and per cent disease index was calculated using formula. The leaf blast incidence was recorded using standard evaluation system (Babu et al., 2013). The score 1: Small brown specks of pinhead size without sporulating centre, 2: Small roundish to slightly elongated, necrotic grey spots, about 1–2mm in diameter with a distinct brown margin and lesions are mostly found on the lower leaves, 3: Lesion type is the same as in scale 2, but significant numbers of lesions are on the upper leaves, 4: Typical sporulating blast lesions, 3mm or longer infecting less than 2% of the leaf area, 5: Typical blast lesions infection in 2–10% of the leaf area, 6: Blast lesions infecting 11–25% leaf area, 7: Blast lesions infecting 26–50% leaf area, 8: Blast lesions infecting 51–75% leaf area and 9: More than 75% leaf area affected.

Per cent disease index (PDI) was calculated as

$$\text{PDI}\ (\%) = \frac{\text{Sum of score of rating class}}{\text{Total number of observation}} \times \frac{\text{Maximum disease index}}{100}$$

2.2 Field Experiments

Field experiments were carried out during 2021-22 and 2022-23 at Centre of Excellence in Millets, Athiyandal, India using ATL 1 variety. The treatments *viz*., seed treatment with *Bacillus subtilis* at 10g/kg of seed + foliar spray of *B.subtilis* at 0.1 % at 25 days after sowing and 40 DAS, seed treatment with *B. subtilis* at 10g/kg of seed + Spray of Tricyclazole 75 WP @ 500 g/ha at 25 DAS, seed treatment with *B. subtilis* at 10g/kg of seed + Azoxystrobin 25 SC @ 200 ml/ac at 25 DAS, Spray of Carbendazim 50WP @ 500 g/ha at 25 DAS and untreated control were followed in the experiments. The parameters viz., disease incidence and yield were recorded from the trials and analysed statistically. The incidence of leaf blast was recorded using standard scale mentioned in previous paragraph and percent disease index was calculated as per formula mentioned above. The neck and finger blast were recorded at dough stage of the crop. Neck blast is recorded as the percentage of ears showing infection on the peduncle and finger blast as the percentage of fingers affected (Nagaraja et al., 2007) in following ways:

$$\text{Neck blast}\ (\%) = \frac{\text{Number of ears showing infection on peduncle or neck}}{\text{Total number of ears in all the plants in two rows}} \times 100$$

$$\text{Finger blast}\ (\%) = \frac{\text{Number of fingers infected in randomly selected five plants}}{\text{Total number of ears}} \times 100$$

The grain mold incidence was recorded as percentage of earhead showing mold infection at physiological maturity stage.

2.3 Statistical Analysis

The replications data used for statistical analysis. The data was analyzed by analysis of variance (ANOVA) of randomized block design (RBD). Data for correlation studies from each experiment were analysed by one-way analysis of variance using IBM SPSS (v. 28.0).

3. RESULTS AND DISCUSSION

The occurrence of the major diseases during 2021-22 and 2022-23 seasons are shown in Fig. 1 and Fig. 2. The results revealed that leaf blast was observed starting at 10 days after sowing and reached its maximum index level at 45 DAS in both years. Later, *Helminthosporium* leaf spot observed from 35 DAS and noticed till the maturity of the crop. Whereas neck blast was observed from 85 DAS and finger blast was observed from 90 DAS in both the years and noticed till the harvest of the crop. The incidence of grain mold was also observed from 85 DAS onwards.

Field experiments were conducted during 2021-22 and 2022-23 and the results are presented in Table 1. The results of the study revealed that all the treatments taken in the trials were significantly reduced the blast, *Helminsthosporium* leaf spot and grain mold incidence in both years. Among the treatments, seed treatment with *B. subtilis* at 10g/kg of seed + spray of Azoxystrobin 25 SC @ 200 ml/ac at 25 DAS and 40 DAS has recorded the lowest incidence of all diseases followed by seed treatment with *B. subtilis* at 10g/kg of seed + spray of Tricyclazole 75 WP @ 500 g/ha at 25 DAS and 40 DAS. The seed treatment with *B. subtilis* at 10g/kg of seed + spray of Azoxystrobin 25 SC @ 200 ml/ac at 25 DAS and 40 DAS has recorded the lowest incidence of all diseases followed by seed treatment with *B. subtilis* at 10g/kg of seed + spray of Tricyclazole 75 WP @ 500 g/ha at 25 and 40 DAS also noticed lesser incidence of the disease incidence and the effect was inferior than that of fungicides treatments.

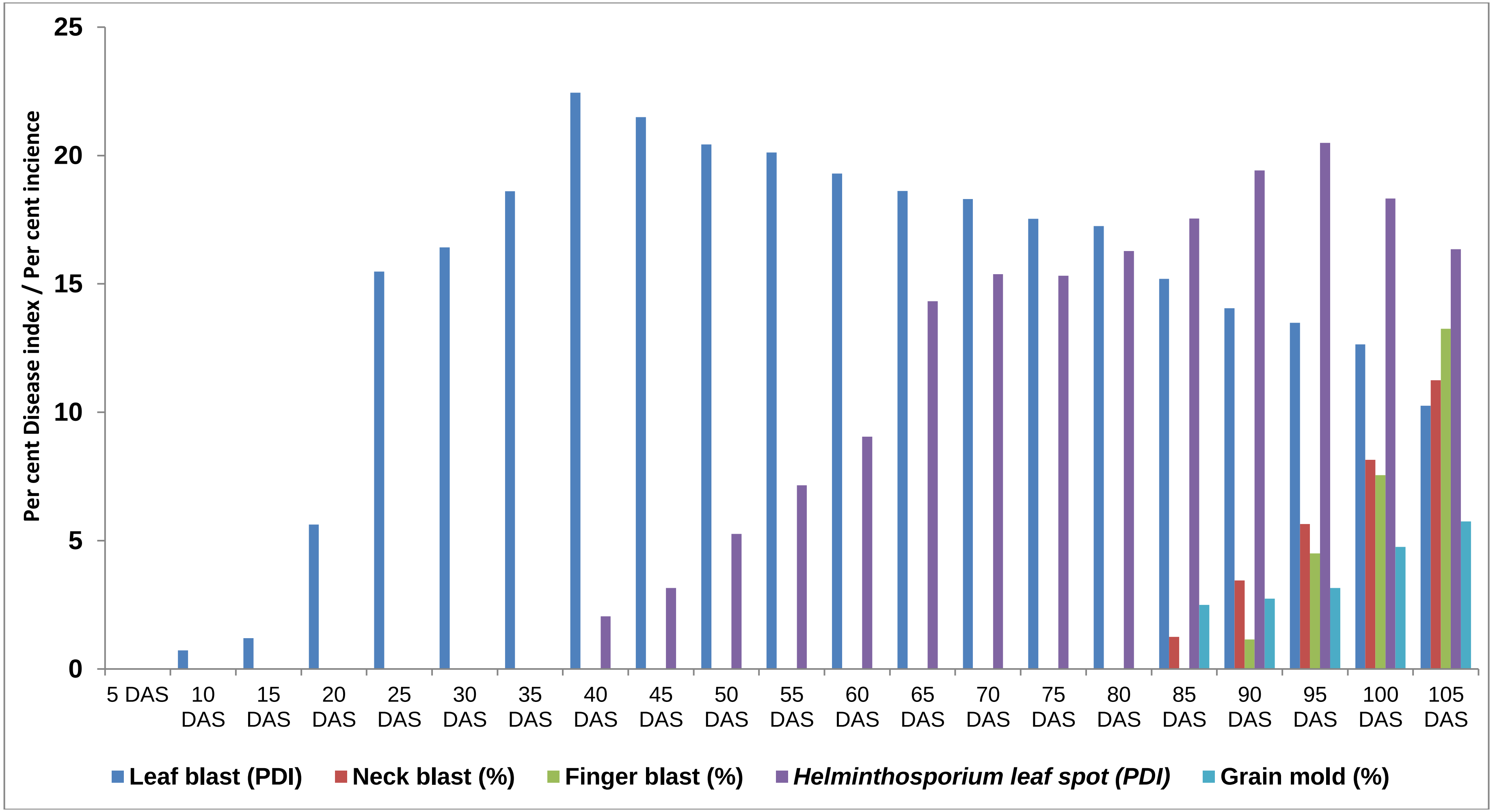

Fig. 1. Occurrence of major diseases of finger millet during *kharif*, 2021-22

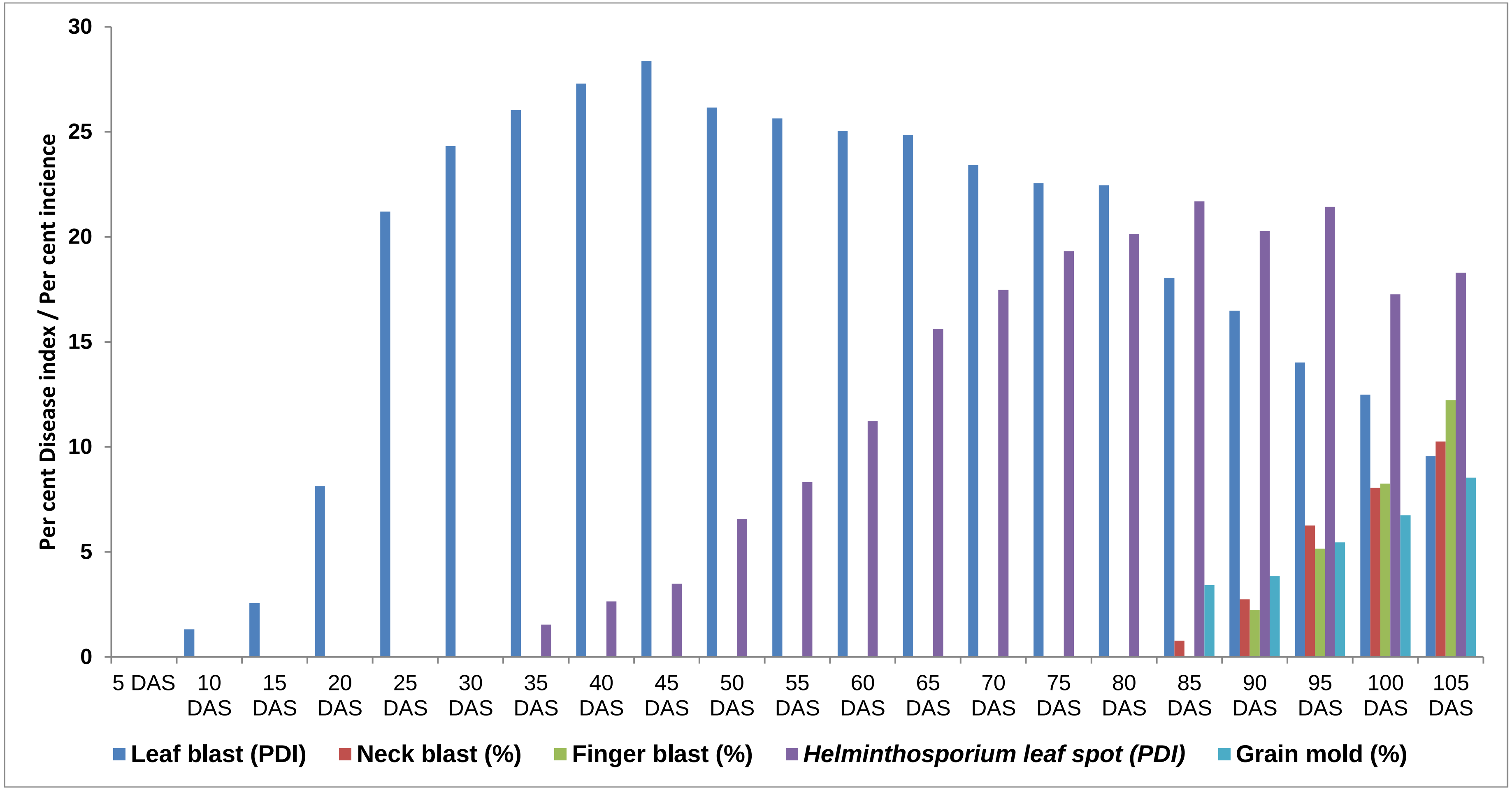

Fig. 2. Occurrence of major diseases of finger millet during *kharif*, 2022-23

Table 1. Combined effect of biocontrol agents and fungicides on major diseases of finger millet

Sl.No	Treatments	Leaf blast Incidence (PDI)		Neck Blast (%)		Finger blast (%)		*Helminthosporium* leaf spot (PDI)		Grain mold (%)	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
1	Seed treatment with *Bacillus subtilis* @ 10g/kg of seed	15.63	17.20	9.02	10.05	11.05	12.24	10.20	11.26	12.25	13.50
2	Foliar spray of *B.subtilis* @ 0.1 % at 25 and 40 DAS	11.05	11.47	7.55	8.05	10.54	11.02	10.05	9.45	10.45	11.57
3	Seed treatment with *B. subtilis* @ 10g/kg of seed + Foliar spray of *B.subtilis* @ 0.1 % at 25 and 40 DAS	10.25	13.25	8.52	9.05	10.25	9.30	8.65	7.55	10.25	11.48
4	Seed treatment with *B. subtilis* @ 10g/kg of seed + Spray of Azoxystrobin 25 SC @ 200 ml/ac at 25 and 40 DAS	4.20	6.32	3.25	4.20	3.25	2.75	2.01	1.85	3.65	4.84
5	Seed treatment with *B. subtilis* @ 10g/kg of seed + Spray of Tricyclazole 75 WP @ 500 g/ha at 25 and 40 DAS	7.95	8.25	6.20	8.29	4.02	3.75	3.65	4.05	4.75	5.52
6	Spray of Carbendazim 50 WP @ 500 g/ha at 25 and 40 DAS	6.38	7.62	5.02	6.93	6.5	5.75	3.75	3.25	6.05	6.15
7	Untreated control	18.36	21.35	10.20	12.05	13.25	12.55	12.34	15.27	13.50	14.25
	CD (0.05 % level)	0.96	0.85	1.02	1.20	0.96	0.82	0.85	0.91	0.84	0.67

Table 2. Combined effect of biocontrol agents and fungicides on yield of finger millet

Sl.No	Treatments	Grain yield (Kg/ha)		Straw yield (kg/ha)		Cost benefit ratio	
		2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
1	Seed treatment with *Bacillus subtilis* @ 10g/kg of seed	2632.5	2513.0	4756.3	4765.9	2.92	2.80
2	Foliar spray of *B.subtilis* @ 0.1 % at 25 and 40 DAS	2653.0	2761.3	4825.9	4762.5	2.94	3.05
3	Seed treatment with *B. subtilis* @ 10g/kg of seed + Foliar spray of *B.subtilis* @ 0.1 % at 25 and 40 DAS	2756.9	2831.0	4926.4	4852.0	3.06	3.13
4	Seed treatment with *B. subtilis* @ 10g/kg of seed + Spray of Azoxystrobin 25 SC @ 200 ml/ac at 25 and 40 DAS	2805.7	2921.3	4963.5	4925.1	3.11	3.23
5	Seed treatment with *B. subtilis* @ 10g/kg of seed + Spray of Tricyclazole 75 WP @ 500 g/ha at 25 and 40 DAS	2950.4	3059.0	5012.0	4956.9	3.26	3.37
6	Spray of Carbendazim 50 WP @ 500 g/ha at 25 and 40 DAS	2869.2	2863.0	4952.0	4859.4	3.17	3.16
7	Untreated control	2356.0	2410.6	4652.1	4526.7	2.74	2.79
	CD (0.05 % level)	32.20	41.56	39.62	41.30	0.07	0.08

The effect of the treatments on yield of the crop was recorded and the results are given in Table 2. The results indicated that seed treatment with *B. subtilis* at 10g/kg of seed + spray of Azoxystrobin25 SC @ 200 ml/ac at 25 DAS and 40 DAS has recorded the maximum yield and high cost benefit ratio followed by seed treatment with *B. subtilis* at 10g/kg of seed + spray of Tricyclazole 75 WP @ 500 g/ha at 25 DAS and 40 DAS.

Several researchers have screened various fungicides against blast pathogen. Actually, the seed may carry pathogens *viz*. *Pyricularia* and *Helminthosporium* and pathogens responsible for mold infection. It is necessary to go for seed treatment of finger millet with biocontrol agents or fungicides before sowing. Our experimental results are corroborated with other findings in this area of work. Earlier, Carbendazim has proven as the most effective for blast disease management (Nagaraja et al., 2007). Later, Tricyclazole also confirmed as an effective one for the management in water soil ecosystems and provides long lasting effect especially in rice (Jeong et al.,2012; Upamanya et al., 2019; Singh et al., 2000). Carbendazim and Tricyclazole showed effective control against pearl millet blast under field conditions (Lukose et al., 2007; Joshi & Gohel, 2015).

Palanna et al. (2021) stated that integrated approach is needed to manage all the diseases of small millets especially finger millet. Recently, Prajapati et al. (2020) reported that seed treatment with Carbendazim (2 g/kg of seed) + two times spray of Tricyclazole or Tebuconazole and seed treatment with *Pseudomonas fluorescens* (10g/kg of seed) + two times spray of *P. fuorescens* have significantly reduced the blast incidence in finger millet and they also enhanced the grain and fodder yield. Madhukeshwara et al., (2005) also reported that seed treatment with Carbendazim @ 2 g/kg seed and Tricyclazole @ 2 g/kg seed recorded the lowest level of all three blast symptoms and improved the yield of finger millet. Patro et al. (2020) concluded that Propiconazole @ 1mL/L was effective in managing all the three blasts *i e*., the leaf blast, neck blast and finger blast disease under *in vivo* conditions in finger millet. Gurung et al. (2022) reported that Carbendazim, Carbendazim 12% + Mancozeb 63%, Metalaxyl 8% + Mancozeb 64% and Tricyclazole were effective control all blast symptoms and they also identified that no fungicide resistance was noticed in the study. Native strains of *Pseudomonas* sp MSSRFD41 had shown inhibitory action of blast fungus *in vitro* and enhanced the growth of finger millet (Sekar et al., 2018). Similarly, *Bacillus tequilensis* effectively inhibited the growth of *Magnoporthe oryzae* of rice (Li et al., 2018). The biocontrol agent *B. subtilis* have demonstrated its effectiveness on disease management by secreting secondary metabolites (Harish et al., 2009) and the agent also promoting plant growth by ability to colonize rapidly and adapted wide range of soil condition. In rice crop, the strain of *B. methylotrophicus* strain BC79 and *B. subtilis* strain T429 was demonstrated its ability to suppress the growth of *M. oryzae* (Meng et al., 2015; Shan et al., 2013). So, the combinations of biocontrol agents and fungicides are effective to manage occurrence of major diseases of finger millet.

4. CONCLUSION

In finger millet, leaf blast disease was observed from 15 days after sowing (DAS) and showing an increasing trend up to 52 DAS. Whereas, *Helminthosporium* leaf spot was observed from 37 DAS till harvesting of the crop. The seed treatment with *B. subtilis* at 10g/kg of seed + spray of Azoxystrobin 25 SC @ 200 ml/ac at 25 and 40 days after sowing was found to be very effective in controlling all blast symptoms, *Helminthosporium* leaf spot and grain mold incidence and recording the maximum yield followed by seed treatment with *B. subtilis* at 10g/kg of seed + Tricyclazole 75 WP @ 500 g/ha at 25 days after sowing.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as large language models (CHATGPT, COPILOT etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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