Indian J. Genet. Plant Breed., (2025); 85(3): 472-480

https://doi.org/10.31742/ISGPB.85.3.13

ISSN: 0975-6906

www.isgpb.org

RESEARCH ARTICLE

Functional diversity of Finger millet [*Eleusine coracana* L. Gaertn.] cultural composite for the management of blast [*Pyricularia grisea* (Cooke) Sacc.] disease

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Abstract

Combinations of cultivar mixtures with varying levels of disease resistance show promise in managing plant diseases under reduced fungicide application. Theoretically, canopy architecture influences the expansion of disease epidemics under field conditions. The objective of this study was to evaluate the effect of different combinations of cultivar composites on finger millet blast epidemics and yield sustainability. A composite of advanced pre-released cultures, TNEc 1285, TNEc 1294, and TNEc 1310, combined with the resistant check GE 4449, a leading variety, in a 1:1 ratio, was evaluated against tricyclazole 75% WP under field conditions for leaf blast reactions. Fungicide treatment with tricyclazole 75% WP recorded a lower incidence of leaf blast, with all the treatments tried performing at par with all the treatments across both years. Quantitative measurements of disease epidemics using the area under the disease progress curve indicated a consistent pattern of disease progression across all treatments. The benefit-cost (B:C) ratio, analysed through partial budgeting, identified the cultivar composite as the most effective among all treatments. This approach effectively reduced disease epidemics under field conditions and sustained yield over both years, even with minimal or no chemical/fungicidal inputs.

Keywords: AUDPC, Cultures, Finger millet, Composite, Resistance.

Introduction

Finger millet (*Eleusine coracana* L. Gaertn.) is known for its exceptional nutraceutical properties, long storage potential and unique adaptability to semi-arid and arid regions of South Asia and Eastern Africa. Despite being one of the hardiest crops, it is susceptible to several pathogens that cause major diseases such as blast, foot rot, smut, streak, and mottling virus (Govindu and Shivanandappa 1967). Among these, blast disease caused by *Pyricularia grisea* (Cooke) Sacc. (formerly *Pyricularia oryzae* Cavara), The anamorph of *Magnaporthe grisea* (Hebert) Barr (Rossman et al. 1990) is the most devastating. This heterothallic filamentous fungus is pathogenic to nearly 40 species across 30 genera within the Poaceae family, including *Eleusine*. It produces lesions on leaves, necks, and fingers, and discolors the grains. Early symptoms include spindle-shaped or elliptical spots on leaves with brown or reddish-brown margins and grey to whitish centres. These lesions may coalesce under favourable conditions, leading to complete leaf drying. Neck blast is characterized by initial browning, followed by blackening near the ear, often accompanied by olive-grey fungal growth. Finger blast presents as brown, chaffy fingers on the ear head, typically starting at the tip and progressing toward the base (Patro and Madhuri 2014). Among these, blast, caused by *P. grisea*, is particularly devastating, causing yield losses exceeding 50% in wet seasons and potentially

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How to cite this article: Rajesh M., Sudha A., Sharavanan P.T., Sivagamy K., Veeramani P., Ram S.R.R. and Nirmalakumari A. 2025. Functional diversity of Finger millet [*Eleusine coracana* L. Gaertn.] cultural composite for the management of blast [*Pyricularia grisea* (Cooke) Sacc.] disease. Indian J. Genet. Plant Breed., **85**(3): 472-480.

Source of support: Nil

Conflict of interest: None.

Received: Oct. 2024 **Revised:** July 2025 **Accepted:** July 2025

reaching 90% under congenial conditions (Bisht 1987; Ekwamu 1989). The rapid evolution of virulent pathogen strains necessitates judicious selection of resistance genes from diverse germplasm resources. Nagaraja et al. (2024) have suggested breeding strategies to select superior genotypes with high yield and resistance to blast. Identification of numerous resistant and moderately resistant germplasm lines within India has been done earlier (Babu et al. 2013; Manyasa et al. 2019) and globally (Dida et al. 2020).

Despite extensive research, blast remains a major constraint to finger millet production, particularly in areas with favourable climates and the cultivation of susceptible varieties. Since finger millet is predominantly cultivated as a rainfed crop by small and marginal farmers, chemical control methods are often economically unviable. Therefore, leveraging the crop's inherent resistance is a practical and sustainable solution. Growing resistant varieties is not only cost-effective but also environmentally friendly. Host plant resistance is a cornerstone of integrated disease management (IDM) strategies and has been critical in maintaining crop productivity, especially against pathogens like *P. oryzae*, which exhibits multiple pathotypes. Using resistant varieties requires no additional input costs for farmers and is safe for the environment (Mew 1991). Moreover, resistant seeds are easily distributed, allowing widespread adoption (Bonman 1992). Varietal mixtures offer functional genetic diversity, which can reduce the intensity of pathogen epidemics and stabilize yields (Zhu et al. 2000). Wolfe and Barrett (1980), and many subsequent researchers, have emphasized the use of varietal mixtures, particularly in cereals, for managing airborne pathogens. Chin and Husin (1982) demonstrated that a rice mixture with 66% resistant components was sufficient to manage blast caused by *P. oryzae*. This concept of functional diversity underpins current research in finger millet as well.

In Uttarakhand, local finger millet varieties are widely cultivated due to farmer preference, despite their susceptibility to blast. VL 149, once resistant, is now losing its effectiveness due to the emergence of new pathogen races. To extend the lifespan of VL 149 and reduce blast incidence in the preferred local variety PRM 1, an experiment was conducted during the 2006 and 2007 cropping seasons. Varietal mixtures of PRM 1 (V1) and VL 149 (V2) in 1:1 and 2:1 ratios under field conditions were evaluated earlier. The 1:1 mixture was most effective, recording the lowest incidence of neck blast (0.84%) and finger blast (10.42%), compared to either variety grown alone (Kumar et al. 2022). Keeping in view these results, new combinations comprising mixtures of a different set of varieties were evaluated in different treatments under field conditions at different locations.

Materials and methods

Experiments were conducted under natural disease pressure during *rabi* seasons of 2020 and 2021 at the Centre of Excellence in Millets, Tamil Nadu Agricultural University, Athiyandal. A total of 11 treatments were constituted as released and leading variety (CO15) in farmers' field with resistant culture (GE4449), pre-released cultures with resistant culture (TNEc 1285, TNEc 1294, TNEc 1310, GE4449), sole crop for released and pre-released cultures, resistant and susceptible variety. Finally, cultural composite treatments were compared with fungicide recommendations (Two sprays of tricyclazole 75% WP @ 500 g/ha at maximum tillering and heading stages).

Treatment details

T_1	-	Released variety (CO15) + GE4449 (Resistant Check) 1:1 ratio
T_2	-	Released variety (CO15) + GE4449 (Resistant Check) 2:1 ratio
T_3	-	Pre-released cultures (TNEc 1285 + TNEc 1294 + TNEc 1310) + GE4449 1:1 ratio
T_4	-	Pre-released cultures (TNEc 1285 + TNEc 1294 + TNEc 1310) + GE4449 2:1 ratio
T_5	-	GE4449 sole crop (Resistant Check)
T_6	-	*Udurumallige* (Susceptible Check)
T_7	-	CO15 sole crop
T_8	-	TNEc 1285 sole crop
T_9	-	TNEc 1294 sole crop
T_{10}	-	TNEc 1310 sole crop
T_{11}	-	Two spray of fungicide tricyclazole75% WP @ 0.2%

A randomized block design was used with three replicates per treatment. Crops were sown during *rabi* 2020 and *rabi* 2021 with a spacing of 25x10 cm, which was comparable to common practices in the region. Nitrogen fertilization was adjusted according to the crop production guide 2020. A single nitrogen application took place at the beginning of tillering, around the vegetative growth stage. No fungicide treatment was applied during the entire crop growth period except comparison check.

Recording of data on disease incidence

The leaf blast incidence, PDI, was recorded in weekly intervals at the early stage (14–42 days after sowing), after the incidence occurrence, treatment with fungicide (Tricyclazole 75% WP) @ 0.2% spray was given at 25 DAS (Tillering stage). During the vegetative season, leaf blast incidence observations were done on 14, 21, 28, 35 and 42 days after sowing by using 1–9 scale (where 9 – fully susceptible and 1 – fully resistant) neck and finger blast/ panicle blast (Patro et al. 2020). The flowering phase, neck blast incidence observations were done on 70, 77, 84and 91 days after sowing, while finger/panicle blast incidences were recorded during maturity stages 91, 98 and 105 days after sowing. The following evaluation system (SES) was used to score leaf blast infection.

Score	Description
1	Small brown specks of pinhead size without sporulating centre.
2	Small roundish to slightly elongated, necrotic grey spots, about 1-2 mm 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, 3 mm 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.
9	More than 75% leaf area affected

$$\text{Neck blast (\%)} = \frac{\text{Number of infected panicles}}{\text{Total number of panicles}} \times 100$$

$$\text{Finger blast (\%)} = \frac{\text{Number of infected panicles}}{\text{Average no. of fingers/plant x Total number of panicles}} \times 100$$

Economic appraisal (B:C ratio) of treatments

Economic analyses were worked out for costs and returns to each treatment, in order to assess the treatment impacts. The total returns were the value of the marketable grain and fodder yields obtained in each treatment. The increase in yield over control was assumed to be solely due to the treatment's effect. Therefore, partial budgeting was used to estimate profit per hectare for each treatment. As per Jackson et al. (2020), the costs of land preparation, sowing, weeding, fertilizer application, irrigation and harvesting were included in the partial budgeting. Benefit-cost ratio was calculated as:

$$\text{Benefit – Cost ratio} = \frac{\text{Net Return (Rs.)}}{\text{Total variable cost (Rs.)}} \times 100$$

Statistical analysis

Statistical analysis was carried out by adopting the standard method (Gomez and Gomez 1984). The treatment effects were examined by analysis of variance (ANOVA) of a randomized block design (RBD). Data for leaf blast, neck blast and finger blast were arcsine transformed before analysis. In order to compare the disease levels on different culture composites in pure stands and on their mixtures combined with standard fungicide treatment, the area under the disease progress curve (AUDPC) was evaluated as described by Finckh et al. (1997). Correlation coefficients between leaf blast, neck blast, finger blast, and grain and fodder yields during the *rabi* seasons of 2020 and 2021 were analysed. A two-factor randomized block design was employed to test for significant differences among treatments, and the data were analysed using both MS Excel and OPSTAT software.

Results and discussion

Blast epidemics incidence during rabi 2020 and 2021

Leaf blast incidence was initially observed at the 2 to 3 leaf stage of the crop and reached its peak by the fourth week (28 days after sowing). Typical symptoms included spindle-shaped lesions with greyish or whitish centres and reddish-brown or brown margins (Fig. 1). As the disease progressed, neck blast symptoms appeared as dark brown lesions on the panicle, often leading to panicle breakage. In severe cases, nodes turned from brown to black. Finger blast, which developed later, caused shrivelled and deformed grains (Fig. 1). Among the tested treatments, the advanced pre-released cultures TNEc 1285, TNEc 1294, and TNEc 1310, when combined with the resistant line GE 4449 in a 1:1 ratio (T_3), recorded the lowest leaf blast incidence. This was followed by the 2:1 ratio combination (T_4). The Area Under Disease Progress Curve (AUDPC) values for leaf blast ranged from 1564 to 2340 across the treatments, which included susceptible checks, resistant checks, and chemical control measures (Tables 1 and 3; Fig. 2). Similarly, for neck and finger blast, the AUDPC values during *rabi* 2020 ranged from a minimum of 210 to a maximum of 1330, while during *rabi* 2021 they ranged from 217 to 1692 under the respective treatments (Tables 2 and 4; Fig. 3).

The effectiveness of cultivar mixtures in suppressing blast incidence can be attributed to four major mechanisms: density effect, barrier effect, induced resistance, and alteration of the microclimate (Vidal et al. 2017a). The barrier effect, in particular, plays a key role, resistant cultivars act as physical or biological barriers, intercepting pathogen spores and preventing their spread to susceptible plants (Schoeny et al. 2008). In rice, Koizumi (2001) reported that a multiline composition comprising 75% resistant cultivars significantly reduced blast severity to levels comparable to those achieved by fungicide applications.

Grain and fodder yield

Based on the mean of two trials, the highest grain yield (2304 kg/ha) was recorded in the treatment involving two sprays of Tricyclazole 75% WP (T_{11}), followed closely by the combination of pre-released cultures (TNEc 1285, TNEc 1294, and TNEc 1310) with the resistant line GE 4449 in a 2:1 ratio, which yielded 2291 kg/ha. These two treatments were statistically at par (Table 5; Fig. 4). Similarly, Upamanya et al. (2019) reported that Tricyclazole was more effective than other fungicides in reducing the incidence of all three types of blast in finger millet.

The above results indicate a consistent association between disease epidemics and treatment responses

Table 1. Effect of finger millet leaf blast disease epidemics on cultural composite under field trial during *rabi*2020

Treatments	Leaf blast PDI					AUDPC
	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	
T1	52.50 (46.41)	68.33 (55.73)	70.00 (56.77)	69.29 (56.32)	59.17 (50.26)	1844.17
T2	52.50 (46.41)	70.00 (56.77)	77.50 (61.66)	74.29 (59.51)	61.67 (51.73)	1952.08
T3	46.25 (42.83)	64.17 (53.21)	73.75 (59.16)	67.86 (55.44)	55.00 (47.85)	1794.79
T4	47.50 (43.55)	65.00 (53.71)	74.38 (59.56)	68.57 (55.88)	55.83 (48.33)	1817.29
T5	51.25 (45.70)	67.50 (55.22)	76.25 (60.81)	72.14 (58.12)	65.00 (53.71)	1918.13
T6	72.50 (58.35)	82.50 (65.24)	88.33 (70.00)	86.88 (68.73)	80.71 (63.92)	2340.21
T7	57.00 (49.00)	70.71 (57.21)	84.38 (66.69)	81.43 (64.45)	72.50 (58.35)	2108.88
T8	59.00 (50.16)	73.57 (59.04)	86.88 (68.73)	85.71 (67.77)	80.00 (63.41)	2209.63
T9	57.00 (49.00)	72.14 (58.12)	87.50 (69.27)	82.14 (64.98)	77.50 (61.66)	2163.25
T10	59.00 (50.16)	73.57 (59.04)	87.50 (69.27)	82.86 (65.51)	79.17 (62.82)	2191.08
T11	59.00 (50.16)	75.00 (59.98)	61.67 (51.73)	40.00 (39.22)	38.33 (38.24)	1577.33

Figures in the parentheses are arcsine transformed values

Table 2. Effect of finger millet neck and finger blast disease epidemics on cultural composite under field trial during *rabi* 2020

Treatments	Neck blast PDI				AUDPC	Finger blast PDI			AUDPC
	70 DAS	77 DAS	84 DAS	91 DAS		91 DAS	98 DAS	105 DAS	
T1	10.00 (18.43)	13.33 (21.41)	16.67 (24.09)	20.00 (26.55)	1761.52	7.50 (15.89)	16.50 (23.96)	22.50 (28.31)	278.25
T2	13.33 (21.41)	16.67 (24.09)	20.00 (26.55)	23.33 (28.87)	2193.49	9.00 (17.45)	17.00 (24.34)	23.00 (28.65)	290.50
T3	6.67 (14.96)	10.00 (18.43)	13.33 (21.41)	16.67 (24.09)	1330.00	5.00 (12.92)	12.50 (20.70)	17.50 (24.72)	210.00
T4	6.67 (14.96)	10.00 (18.43)	13.33 (21.41)	16.67 (24.09)	1330.00	5.00 (12.92)	14.00 (21.96)	19.00 (25.83)	231.00
T5	6.67 (14.96)	13.33 (21.41)	23.33 (28.87)	26.67 (31.08)	1889.76	6.50 (14.76)	15.00 (22.78)	20.50 (26.91)	252.00
T6	20.00 (26.55)	26.67 (31.08)	40.00 (39.22)	46.67 (43.07)	3733.59	15.00 (22.78)	27.50 (31.62)	38.00 (38.04)	474.25
T7	6.67 (14.96)	13.33 (21.41)	20.00 (26.55)	23.33 (28.87)	1784.83	7.50 (15.89)	16.00 (23.57)	22.00 (27.96)	271.25
T8	10.00 (18.43)	16.67 (24.09)	23.33 (28.87)	26.67 (31.08)	2216.83	9.00 (17.45)	17.50 (24.72)	24.00 (29.32)	299.25
T9	10.00 (18.43)	16.67 (24.09)	20.00 (26.55)	26.67 (31.08)	2123.59	8.00 (16.42)	18.00 (25.09)	23.00 (28.65)	297.50
T10	10.00 (18.43)	20.00 (26.55)	23.33 (28.87)	30.00 (33.20)	2473.24	9.00 (17.45)	20.00 (26.55)	24.50 (29.66)	327.25
T11	6.67 (14.96)	13.33 (21.41)	20.00 (26.55)	16.67 (24.09)	1761.52	9.00 (17.45)	19.00 (25.83)	25.00 (29.99)	318.50

Figures in the parentheses are arcsine transformed values

across both trials. To identify the most cost-effective approach, the benefit-cost (B:C) ratio was analysed using the partial budgeting method. The two-spray application of Tricyclazole 75% WP effectively suppressed disease epidemics under field conditions and recorded a B:C ratio of 1:1.47. In contrast, the cultural composite treatments exhibited a slower disease progression curve from the early stages through the epidemic period, and despite incurring no additional input costs, they achieved sustainable yields with higher B:C ratios of 1:1.51 and 1:1.52 over both trial

Table 3. Effect of finger millet leaf blast disease epidemics on cultural composite under field trial during *rabi* 2021

Treatments	Leaf blast PDI					AUDPC
	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	
T1	51.25 (45.70)	66.67 (54.71)	71.25 (57.55)	67.86 (55.44)	57.50 (49.29)	1821.04
T2	53.75 (47.13)	69.17 (56.25)	75.63 (60.39)	72.14 (58.12)	60.83 (51.24)	1919.58
T3	47.50 (43.55)	63.33 (52.71)	72.50 (58.35)	65.71 (54.14)	52.50 (46.41)	1760.83
T4	48.75 (44.27)	64.17 (53.21)	73.13 (58.75)	66.43 (54.57)	54.17 (47.37)	1786.25
T5	52.50 (46.41)	68.33 (55.73)	75.00 (59.98)	69.29 (56.32)	63.33 (52.71)	1893.75
T6	71.67 (57.82)	81.88 (64.78)	89.44 (71.01)	86.25 (68.21)	79.29 (62.90)	2331.32
T7	58.00 (49.58)	71.43 (57.67)	81.25 (64.32)	77.14 (61.41)	70.83 (57.29)	2059.67
T8	60.00 (50.75)	72.14 (58.12)	83.75 (66.20)	81.43 (64.45)	75.00 (59.98)	2133.75
T9	59.00 (50.16)	71.43 (57.67)	84.38 (66.69)	80.71 (63.92)	73.33 (58.89)	2118.79
T10	60.00 (50.75)	72.86 (58.58)	85.00 (67.19)	79.29 (62.90)	75.83 (60.53)	2135.42
T11	61.00 (51.33)	74.29 (59.51)	63.33 (52.71)	37.00 (37.45)	36.67 (37.25)	1564.17

Figures in the parentheses are arcsine transformed values

Table 4. Effect of finger millet neck and finger blast disease epidemics on cultural composite under field trial during *rabi* 2021

Treatments	Neck blast PDI				AUDPC	Finger blast PDI			AUDPC
	70 DAS	77 DAS	84 DAS	91 DAS		91 DAS	98 DAS	105 DAS	
T1	13.33 (21.41)	20.00 (26.55)	23.33 (28.87)	26.67 (31.08)	2543.17	9.00 (17.45)	16.50 (23.96)	22.50 (28.31)	283.50
T2	10.00 (18.43)	16.67 (24.09)	23.33 (28.87)	26.67 (31.08)	2216.83	8.50 (16.94)	17.00 (24.34)	23.00 (28.65)	288.75
T3	10.00 (18.43)	13.33 (21.41)	16.67 (24.09)	20.00 (26.55)	1761.52	7.00 (15.34)	12.50 (20.70)	17.50 (24.72)	217.00
T4	6.67 (14.96)	13.33 (21.41)	16.67 (24.09)	23.33 (28.87)	1691.59	7.00 (15.34)	15.00 (22.78)	19.00 (25.83)	248.50
T5	10.00 (18.43)	16.67 (24.09)	20.00 (26.55)	26.67 (31.08)	2123.59	8.50 (16.94)	15.00 (22.78)	21.00 (27.26)	260.75
T6	16.67 (24.09)	26.67 (31.08)	36.67 (37.25)	46.67 (43.07)	3558.77	12.50 (20.70)	27.50 (31.62)	40.00 (39.22)	472.50
T7	10.00 (18.43)	16.67 (24.09)	20.00 (26.55)	23.33 (28.87)	2111.90	7.50 (15.89)	16.00 (23.57)	22.00 (27.96)	271.25
T8	6.67 (14.96)	16.67 (24.09)	23.33 (28.87)	26.67 (31.08)	2135.25	8.50 (16.94)	17.50 (24.72)	24.00 (29.32)	297.50
T9	10.00 (18.43)	16.67 (24.09)	20.00 (26.55)	26.67 (31.08)	2123.59	8.00 (16.42)	18.00 (25.09)	23.00 (28.65)	297.50
T10	10.00 (18.43)	16.67 (24.09)	23.33 (28.87)	30.00 (33.20)	2228.49	9.00 (17.45)	20.00 (26.55)	24.50 (29.66)	327.25
T11	13.33 (21.41)	16.67 (24.09)	20.00 (26.55)	16.67 (24.09)	2170.18	9.00 (17.45)	19.00 (25.83)	25.00 (29.99)	318.50

Figures in the parentheses are arcsine transformed values

years (Table 6). Rajesh et al. (2022) similarly reported that Tricyclazole 75% WP, applied twice (first spray at initial blast incidence, followed by a second spray 10–15 days later at 1 g/litre), significantly reduced the incidence of leaf, neck, and finger blast, achieving a B:C ratio of 1:2.

However, the economic justification for fungicide application is strongly influenced by the use of cultivar mixtures compared to pure stands. Across six trial sites over two seasons, 67% of the cultivar mixtures required fewer fungicide applications than their corresponding pure stands. These findings have significant implications for intensive cropping systems. Incorporating within-field genetic diversity through cultivar mixtures can reduce dependence on fungicides, lower the risk of fungicide

Table 5. Effect of treatment on grain and fodder yield of finger millet under field conditions during *rabi* 2020 and *rabi* 2021

Trt. No.	Rabi 2020		Rabi 2021		Mean		Yield increase over susceptible check (%)
	Grain yield (kg/ha)	Fodder yield (kg/ha)	Grain yield (kg/ha)	Fodder yield (kg/ha)	Grain yield (kg/ha)	Fodder yield (kg/ha)	
T_1	2340	4721	2135	4412	2238	4567	18.26(25.29)
T_2	2355	4710	2075	4316	2215	4513	17.07(24.40)
T_3	2410	4913	2150	4437	2280	4675	20.51(26.92)
T_4	2398	4896	2184	4465	2291	4681	21.09(27.33)
T_5	2230	4640	2026	4192	2128	4416	12.47(20.67)
T_6	1980	4121	1804	4015	1892	4068	00.00(0.77)
T_7	2195	4574	2019	4246	2107	4410	11.36(19.69)
T_8	2295	4676	2108	4197	2202	4437	16.36(23.85)
T_9	2285	4670	2087	4208	2186	4439	15.54(23.21)
T_{10}	2290	4650	2149	4215	2220	4433	17.31(24.58)
T_{11}	2418	4930	2189	4505	2304	4718	21.75(27.79)
S. Em					84.50	168	01.68
CD at 5%					179.00	351	3.52

Figures in the parentheses are arcsine transformed values

Table 6. Calculation of cost-benefit ratio of treatments (Partial budgeting method)

Treatment	Fixed cost (Rs.)	Treatment (Chemical + Spray) cost (Rs.)	Total cost (Rs.)	Grain Yield (kg/ha)	Straw Yield (kg/ha)	Gross Return (Rs.)	Net Return (Rs.)	B:C ratio
T_1	47500	-	47500	2238	4567	70550	23050	1:1.48
T_2	47500	-	47500	2215	4513	69835	22335	1:1.47
T_3	47500	-	47500	2280	4675	71906	24406	1:1.51
T_4	47500	-	47500	2291	4681	72240	24740	1:1.52
T_5	47500	-	47500	2128	4416	67152	19652	1:1.41
T_6	47500	-	47500	1892	4068	59811	12311	1:1.25
T_7	47500	-	47500	2107	4410	66518	19018	1:1.40
T_8	47500	-	47500	2202	4437	69372	21872	1:1.46
T_9	47500	-	47500	2186	4439	68909	21409	1:1.45
T_{10}	47500	-	47500	2220	4433	69909	22409	1:1.47
T_{11}	47500	1625	49125	2304	4718	72643	23518	1:1.47

resistance, and support a more sustainable production system by maintaining high yields with reduced chemical inputs (Kristoffersen et al. 2020).

Correlation analysis

Correlation defines the degree and direction of association between two or more traits. In the present study, correlation coefficients were calculated between the Area Under Disease Progress Curve (AUDPC) values for all three types of blast epidemics (leaf, neck, and finger) and the yield components (grain and fodder yields) during the *rabi* 2020 and *rabi* 2021 seasons. The results are presented in Table 7. Leaf blast (AUDPC) exhibited a significant negative correlation with both grain and fodder yields across both seasons, with correlation coefficients of –0.7665, –0.8038 (*Rabi* 2020), and –0.7048, –0.9287 (*Rabi* 2021), respectively. Similar trends were observed for neck and finger blast, which also showed significant negative correlations with yield components in both seasons (Fig. 5). These findings are consistent with those reported by Rajesh et al. (2022), who observed that the AUDPC of rice brown spot disease was negatively correlated with grain yield and yield-attributing traits.

The rice blast epidemic in upland rice was significantly reduced when a susceptible cultivar was grown alongside a resistant cultivar in a two-component mixture, compared to the same susceptible cultivar grown in a pure stand (Raboin et al. 2012). Similarly, in winter barley, varietal mixtures have been shown to enhance crop genetic diversity without requiring extensive breeding efforts. These mixtures can improve resilience to environmental stresses and are

Table 7, Correlation studies between epidemics curve and yield parameters

Treatment	Rabi 2020			Rabi 2021			Rabi 2020		Rabi 2021	
	Leaf blast	Neck blast	Finger blast	Leaf blast	Neck blast	Finger blast	Grain (kg/ha)	Fodder (kg/ha)	Grain (kg/ha)	Fodder (kg/ha)
T_1	1844.17	1761.52	278.25	1821.04	2543.17	283.50	2340	4721	2135	4412
T_2	1952.08	2193.49	290.50	1919.58	2216.83	288.75	2355	4710	2075	4316
T_3	1794.79	1330.00	210.00	1760.83	1761.52	217.00	2410	4913	2150	4437
T_4	1817.29	1330.00	231.00	1786.25	1691.59	248.50	2398	4896	2184	4465
T_5	1918.13	1889.76	252.00	1893.75	2123.59	260.75	2230	4640	2026	4192
T_6	2340.21	3733.59	474.25	2331.32	3558.77	472.50	1980	4121	1804	4015
T_7	2108.88	1784.83	271.25	2059.67	2111.9	271.25	2195	4574	2019	4246
T_8	2209.63	2216.83	299.25	2133.75	2135.25	297.50	2295	4676	2108	4197
T_9	2163.25	2123.59	297.50	2118.79	2123.59	297.50	2285	4670	2087	4208
T_{10}	2191.08	2473.24	327.25	2135.42	2228.49	327.25	2290	4650	2149	4215
T_{11}	1577.33	1761.52	318.50	1564.17	2170.18	318.50	2418	4930	2189	4505

AUDPC	*Rabi* 2020		*Rabi* 2021	
	Grain yield	Fodder yield	Grain yield	Fodder yield
Leaf blast	-0.7665*	-0.8038**	-0.7048*	-0.9287***
Neck blast	-0.8343**	-0.9028***	-0.8126**	-0.6415
Finger blast	-0.7593*	-0.8186**	-0.7245*	-0.6481

*, **, ***: Significant at 5%, 1% and 0.1% probability levels, respectively.

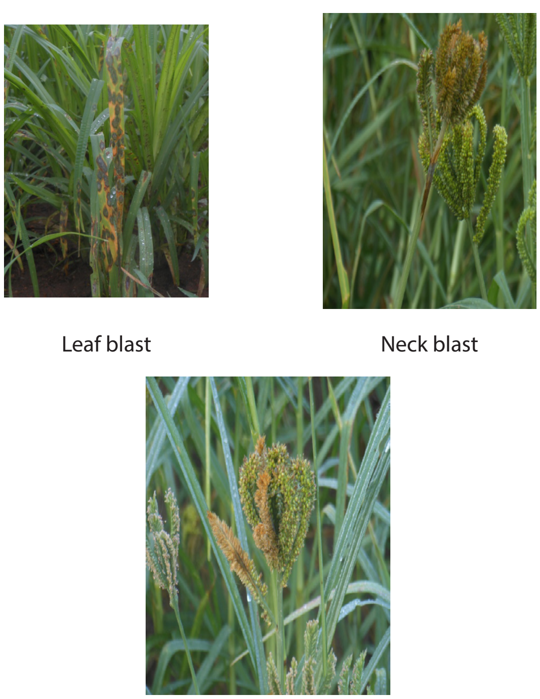

Fig. 1. Finger millet leaf, neck and finger/panicle blast symptoms under field condition

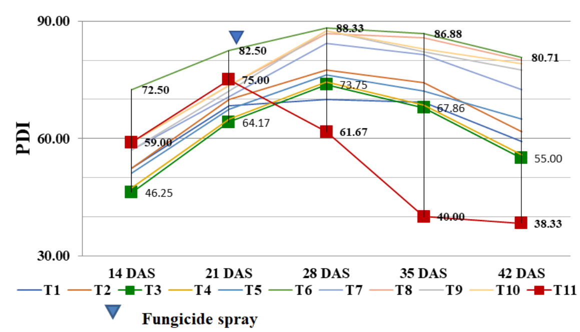

Fig. 2, Ragi leaf blast disease epidemics on cultural composite under field trial (*rabi* 2020)

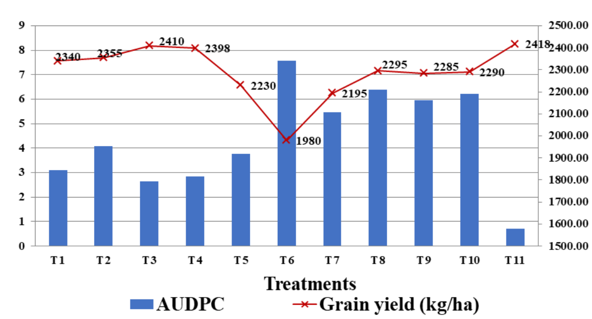

Fig. 3. Ragi leaf blast disease epidemics curves on cultural composite under field trial (*rabi* 2020)

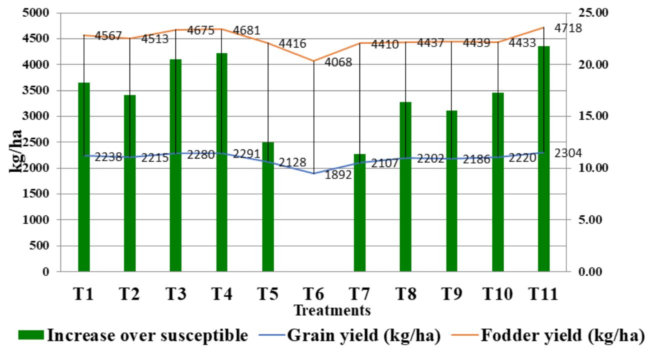

Fig. 4. Effect of treatment on grain and fodder mean yield of Ragi (*rabi* 2020 and 2021)

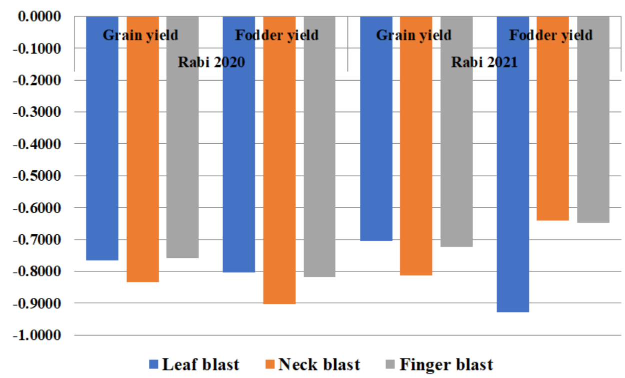

Fig. 5. Correlation between blast epidemics curve and yield parameters

considered a promising component of sustainable arable farming systems (Creissen et al. 2016).

In the present study, finger millet blast epidemics were notably slowed in cultivar mixtures, although disease severity reached its peak before harvest in the control (pure stand). Field experimental results support the concept that intra-specific crop diversification offers an eco-friendly and effective disease management strategy, particularly over large cultivation areas. Disease incidence in susceptible plants was significantly lower in heterogeneous mixtures than in monocultures. Interestingly, in monocultures, even highly resistant varieties developed dense canopies, creating microclimatic conditions favourable to disease development. In contrast, composite mixtures had comparatively lower canopy density and reduced spore dispersal compared to homogeneous stands. Regarding yield performance, cultivar mixtures generally resulted in more stable and buffered grain yields compared to pure stands, demonstrating their advantage in yield consistency under variable conditions.

Authors' contribution

Conceptualization of research (MR); Designing of the experiments (PTS, PV); Contribution of experimental materials (AN, SRRR); Execution of field experiments and data collection (MR, AS, KS); Analysis of data and interpretation (MR, AS); Preparation of the manuscript (MR).

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