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Research Article

Management of blast disease of finger millet (*Eleusine coracana* L. Gaertn) caused by *Pyricularia grisea* under field conditions in Dolakha, Nepal

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ABSTRACT

Lack of understanding regarding the choice of chemical fungicides or botanicals with their optimal doze and spraying schedule is one of the major problems concerning mid-hill farmers to control finger millet diseases in Nepal. In order to assess the effectiveness of the four fungicides, namely Bavistin 50 WP (Carbendazim 50%), SAAF (Carbendazim 12% + Mancozeb 63% WP), RIDOMIL-MZ 72 WP (Metalyxl 8% + Mancozeb 64% WP), BAAN 75 WP (Tricyclazole 75%), and two botanicals viz; *Lantana camara* and *Berberis vulgaris* fermented anaerobically in cattle urine, an artificial epiphytotic field. In the years 2018 and 2019, the experiment was run using a randomized complete block design with three replications. Carbendazim, one of the chosen treatments, had the greatest impact in lowering the AUDPC values for leaf blast (1818, 1191) as well as neck (4,53) and finger blast (10,45) incidence percentage in both 2018 and 2019 years. Tricyclazole, SAAF, RIDOMIL-MZ, and *Lantana camara* fermented in cow urine were also discovered to be beneficial throughout the year. So it is recommended to deploy fungicides in a controlled manner through rotation and mixed applications, which is advantageous for both grain and seed production even for minor and underutilized crops from an economic aspect.

Keywords: Blast, chemical, economic, fingermillet, management

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INTRODUCTION

Food instability and nutritional deficiencies have long been problems in developing and poor nations like Nepal. Major cereals like *Oryza sativa* L. (rice), *Zea mays* L. (maize), and *Triticum aestivum* L. (wheat) are all involved in some way in addressing these problems. Contrarily, finger millet (*Eleusine coracana* L. Gaertn), in addition to these cereals, is a good source of iron, calcium, and zinc. Despite having such advantageous nutritional qualities, it is regarded as a low status dish in Nepal. Recent patterns indicate that the nation's production and consumption of finger millet are similarly poor (Bhandari *et al*., 2010). It is the fourth cereal crop in terms of acreage and output in the nation, and it is a good source of revenue for the country's severely poor farmers as well as a highly affordable and widely accessible

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source of food for the poor living in distant highland areas (Prasad *et al*., 2010). Millions of people in tropical drylands depend mostly on millet, an annual drought-tolerant grain (Reynolds *et al*., 2015).

With a productivity of 0.98 t/ha, millet is grown on 31.65 million ha of land globally (FAOSTAT, 2021). Over 25 nations in Africa and Asia grow finger millet, which makes up roughly 12% of the world's millet acreage (Babu *et al*., 2015). It produces 314,225 Mt of millets across an area of 263,261 ha in Nepal with a productivity of 1.19 Mt/ha (MOALD, 2019). In Nepal, the crop is primarily grown in a mid-hill setting, and the Gandaki province has the most land that is used for finger millet farming. Finger millet is mostly grown in Sindhupalchok, Sindhuli, Kavre, Nuwakot, Gorkha, Lamjung, Kaski, Tanahun, Parbat, Baglung, Syangja, Dolakha, Khotang, Okhaldhunga, and Mugu (MOALD, 2019).

Although fingermillet is typically farmed in Nepal as a monoculture, in hilly areas farmers combine it with maize. Therefore, it is more crucial in subsistence farming systems, where it is grown on marginal ground without the use of outside resources and sustains a rural population's diet. People typically eat it as thick breads, pancakes, and porridge. , The one fourth of domestic production was utilized as beverage production. Since its other food products are not widely consumed in cities, the majority of imported fingermillet is utilized in cities primarily for the production of beverages.

The growth of finger millet is impeded by a number of biotic and abiotic factors that eventually limit yield. The most important biotic stressors impacting finger millet productivity worldwide are pests and diseases. Numerous diseases, including fungal ones like blast, cercospora leaf spot, sheath blight, brown spot disease, foot rot disease, green ear disease, smut disease, and damping off disease afflict finger millet crops (Preethi *et al*., 2020). Due to its disruptive existence under favorable conditions and its widespread distribution in Nepal and all finger millet-growing areas, finger millet blast, which is brought on by the filamentous fungus *Magnaporthe grisea* (Anamorph- *Pyricularia grisea*), is the disease that most negatively affects finger millet production and productivity. It overwinter in contaminated crop debris and is spread via seed (Manandhar *et al*., 2016; Yoshida *et al*., 2016). The parasitic illness that parasitizes rice is undoubtedly the most harmful one to rice. Blast affects many aerial components at all growth phases. Spindle-shaped patches with gray or whitish cores and brown or reddish-brown edges that first show as symptoms eventually enlarge and consolidate to give the leaf lamina a blasted appearance. In addition to the leaf, the disease frequently affects the nodal area, neck region, fingers, and developing grains (Bhatta *et al*., 2017). While infection after milking stage contributes to the reduction in seed size, number, and 1000 seed weight, infection prior to milking stage causes finger sterility and affects grain weight and number (Hunsigi and Krishna, 1998). Nearly all phases of a finger millet plant's growth are infected by *M. grisea*, which causes an up to 100% reduction in crop grain output and biomass (Takan *et al*., 2012; Dida *et al*., 2021). At Lumle, Kaski, it was stated that nursery beds lost 70–90% of their contents, necks lost 60%, and fingers lost 3-80%. (Ghimire and Pradhanag, 1994). There have been reports of up to 40% neck blast and 25% finger blast in farmer's fields in hilly places (Prasad, 2008).

Plant quarantine, the use of resistant varieties, the removal of pathogen inocula, the application of good agricultural practices such as intercropping and rotating crops, the understanding and combating of pathogen virulence mechanisms, the use of biological control methods, chemical fungicides, and biotechnological techniques to improve plant performance are all currently used to manage blast disease and improve crops (Margaret *et al*., 2020). In order to create parental lines and hybrids of finger millet that are resistant to

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blast, efforts should be undertaken to understand how *M. grisea* resistance is inherited and how the pathogen changes through time. Additionally, it has the capacity to produce novel pathogenic strains that quickly destroy resistance (Khadka *et al*., 2013). Therefore, employing fungicides to control blast disease in finger millet may be the best course of action. Although the most effective and affordable disease management technique to control blast in underutilized crops is host plant resistance (Subedi *et al*., 2022), the majority of the cultivars grown in Nepal are not suitable for all growing locations. It becomes more blast susceptible when grown with maize. Chemical fungicides are the most effective way to control the disease when blast-resistant cultivars are not available. Botanicals and other organic materials like cattle urine also play a beneficial part in the treatment of blast sickness. The incidence of neck blasts in rice has not been significantly decreased by cow urine, and seed production has only slightly increased (Govindaraju and Somasekhara, 2016). *Lantana camara* leaf extracts have antibacterial, fungicidal (Subedi *et al*., 2019), insecticidal, and nematicidal properties. It has been discovered to increase soil fertility and conserve water, which is advantageous for agriculture (Negi *et al*., 2019). Berberine, which may be found in several portions of the barberry plant, is one of the most significant functional compounds. Additionally, it possesses antioxidant, antifungal, and antibacterial effects (Sarraf *et al*., 2019). The control of finger millet blast under field conditions in Nepal, however, does not appear to have been the subject of any prior research activities. Botanical blast management is primarily limited to laboratories or screen houses. However, a lack of knowledge among farmers causes them to apply various fungicides carelessly and in large quantities, harming the crop's beneficial micro-flora and micro-fauna as well as causing soil, water, and air pollution. Additionally, these farmers frequently use pesticides as a preventative step to safeguard the crop against the illness even before the symptoms manifest and occasionally even in the absence of the disease. Even though cow urine and botanicals are readily available in Nepal's mid-hills, there hasn't been enough research done on them. The current study was therefore carried out aiming to explore the best fungicidal agents to control blast disease of fingermillet.

MATERIALS AND METHODS

Location of experiments

In the years 2018 and 2019, the experiment was carried out at the NARC's Hill Crop Research Program (HCRP) in Dolakha. Dolakha is situated in a south-facing topography at an altitude of 1650 meters above sea level with coordinates of 27^{o}38'7.09" north latitude, 86^o 8'23.73" east longitude. The soil type was sandy loam.

Collection of the inoculum, Isolation, and Purification of the pathogen culture

A sample of infected leaves from a farmer's crop in the Dolakha district that displayed the classic symptoms of blast in an earlier season was used to grow *P. grisea*. Upon arrival in the lab, the sick sample was chilled at 4°C in preparation for pathogen isolation. Using a sterile knife, diseased leaf samples were cut from the edge of the contaminated region into little pieces (approximately 2 mm). The parts were cleaned three times in succession with distilled water after being surface sterilized with 1% sodium hypochloride for one minute. Then, three layers of moistened blotting paper were placed in a clean, sterile petri dish. The samples were then incubated for 24 hours at 25 to 26°C. (Dida *et al*., 2021). A single spore (4%) was transported from the sporulating lesion to the water agar. Single spore was once more transferred from water agar to different culture tubes of oatmeal agar (OMA) slants under stereomicroscope after the spores had germinated after 24 hours, using an aseptic inoculating needle (Gashaw *et al*., 2014). Germinated conidia were transferred to the oatmeal agar plates. To obtain a pure monoconidial isolate, the plates were cultured in an incubator at 25° C for

10 days (Khadka *et al*., 2013).

Identification of the pathogen and Maintenance of pure culture

Isolates were kept in a 4°C refrigerator. The fungus was prepared on temporary slides, which were then carefully studied under a microscope. The conidial form and septation seen using a light compound microscope at a 40X magnification were used to identify the pathogen. In oatmeal agar medium, their colony color and morphology were also investigated.

Mass production, Inoculum preparation and Foliar inoculation

Each oatmeal agar plate's medium was directly in contact with the pure culture, which was cut into 5mm-diameter discs with the help of a cork borer to speed up spore growth.The plates were then sealed with parafilm sheet and stored for 10 days at 25^0C for incubation. After the medium's surface had been completely coated in fungal mycelium, it was scraped with sterile glass slides and 10 ml of distilled water (Khadka *et al*., 2013).

Furthermore, sorghum seeds were used in the mass production of inoculum. Seeds were cleaned four or five times with tap water before being half-boiled with an equivalent amount of water. For three days straight, each conical flask holding 100 g of seed was autoclaved at 121^0C for 20 minutes. The conical flask was then aseptically filled with 6–8 mycelial discs measuring 5 mm, placed inside a laminar flow chamber, and incubated for 12 days at 25^0C.

After that, sterile distilled water was poured into the flasks, and they were let to stand for five minutes. To remove the spores, they were scraped against a sterile glass rod. A haemocytometer was used to determine the concentration of the spore suspension after it had been filtered through two layers of muslin cloth. After that, sterile distilled water was used to dilute the spore suspension to the necessary concentration of 1×10^5 spores/ml (Babu *et al*., 2012).

After 25 days of transplanting, inoculum was sprayed using a Knapsack power sprayer in the evening at a concentration of 1×10^5 spores/ml with a drop of tween 20 for uniform dissemination on the foliage to create a uniform disease pressure. Sprinkler irrigation produced high humidity (>90% relative humidity) and leaf wetness to encourage the development of disease (Babu *et al*., 2015). After 10 days from the initial spray, a second inoculum was applied.

Field preparation and Experiment layout

The field tests were carried out on a research farm at HCRP, Dolakha, Nepal, during the rainy seasons of 2018 and 2019. A total of seven treatments replicated thrice in well managed piece of land with randomized complete block design. Each plot measured 6 m^2. The susceptible fingermillet variety Kabre Kodo 2 was selected for the study. Seedlings placed into the area had 10×10 cm spacing and were 25 days old. The finger millet cultivation recommendations provided by HCRP were followed.

Treatment details and fungicides spray schedule

Using a hand sprayer (Atomizer) with a 2-L capacity, four different kinds of fungicides were administered together with the fermented botanicals found in cow urine. Fermented botanicals in cattle urine are detailed in Table 2 while the specifics of the fungicide treatments are described in Table 1. To reduce differences caused by moisture, control plots were merely treated with water in the same way as fungicide-sprayed plots. As soon as lesions appeared on two or three of the susceptible variety's leaves, fungicides and fermented botanicals were sprayed three times at 10-day intervals.

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Table 1: Fungicides evaluated against *Pyricularia grisea* under field condition during 2018 and 2019

Treatment number	Common name	Trade name	Active ingredient (%)	Formulation	WHO class	Applied concentration
T1	No fungicides applied					
T2	Carbendazim 12% + Mancozeb 63%	SAAF	75	WP	NH	0.2%
T3	Metalyxl 8% + Mancozeb 64%	RIDOMIL-MZ	72	WP	NH	0.2%
T4	Tricyclazole	BAAN	75	WP	II	0.2%
T5	Carbendazim	BAVISTIN	50	WP	NH	0.2%

Table 2: Fermented botanicals in cattle urine evaluated against *Pyricularia grisea* under field condition during 2018 and 2019

Treatment number	Treatment details	Formulation procedures	Applied concentration
T6	Fermented cattle urine + *Lantana camara*	2 months of anaerobic fermentation of 15 liters of cattle urine with 5 kg small pieces of *Lantana camara* leaves	Dilution with water in the ratio of 1:10
T7	Fermented cattle urine + Barbery	2 months of anaerobic fermentation of 15 liters of cattle urine with 5 kg small pieces of barbery leaves	Dilution with water in the ratio of 1:5

Agronomic parameter

Following the finger millet descriptor, information was also gathered for agronomic traits such as plant height (cm), days to 50% heading, days to 75% maturity, bearing head/m^2, finger length (cm), number of fingers/head, seed weight/head, weight of head/head, 500 grain weight, grain yield, and straw yield (IBPGR, 1985).

Disease assessment and Statistical analysis

After 10 days of inoculation, 20 randomly selected plants from each plot were tagged, and leaf blast disease severity was evaluated using the following 1–9 rating scale provided by Babu *et al.* (2013).

Table3: Disease rating scale of leaf blast of finger millet

Scale	Leaf area percent covered
1	No lesions to small brown specks of pinhead size (0.1– 1.0 mm), less than 1 % leaf area affected
2	typical blast lesions covering 1–5 % leaf area covered with lesions
3	typical blast lesions covering 6–10 % leaf area covered with lesions
4	typical blast lesions covering 11–20 % leaf area covered with lesions
5	typical blast lesions covering 21–30 % leaf area covered with lesions
6	typical blast lesions covering 31–40 % leaf area covered with lesions
7	typical blast lesions covering 41–50 % leaf area covered with lesions
8	typical blast lesions covering 51–75 % leaf area covered with lesions and many leaves dead
9	typical blast lesions covering >75 % leaf area or all the leaves dead

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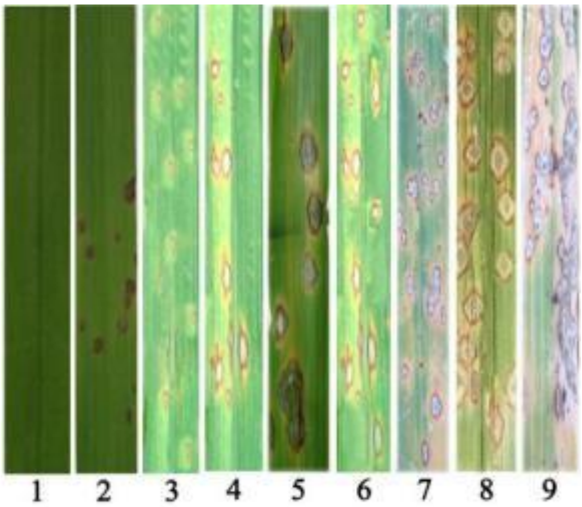

Figure 1: Disease rating scale for leaf blast of finger millet adopted from Babu et al. (2013)

Estimation of disease incidence percentage

The percentage for disease incidence was calculated by using the formula:

$$\text{Disease incidence }\% = \frac{\text{No. of infected plants}}{\text{Total no of observed plants}} \times 100\%$$

Estimation of disease severity percentage

The disease score was converted into the severity percentage by using the formula:

$$\text{Disease severity }\% = \frac{\text{(Sum of all numerical ratings)}}{\text{No.of plants observed X maximum reading of scale (i.e.9)}} \times 100\%$$

Estimation of Area under Disease Progress Curve (AUDPC)

The disease severity values at each recording were used to calculate the area under the disease progress curve (AUDPC). The AUDPC was calculated using the formula:

$$\text{AUDPC} = \sum_{i=1}^{n-1} \left(\frac{y_i + y_{i+1}}{2}\right)(t_{i+1} - t_i)$$

Where "t" is the time of each reading, "y" is percent disease severity at each reading and "n" is the number of readings.

Estimation of percent reduction of disease incidence over control

Disease incidence was recorded at physiological maturity (1 week before harvesting) for neck and finger blast to calculate percent disease incidence in the treatments over control using the formula:

$$\text{Percent reduction of disease incidence over control} = \frac{\text{Disease incidence in control} - \text{Disease incidence in treatment}}{\text{Disease incidence in control}} \times 100$$

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Three replications of the experiment were carried out in the field. The experiment's results were entered and saved in Microsoft Excel. Genstat 18th edition was used to calculate the analysis of variance (ANOVA). Based on the input and output prices on the local market, economic analyses were conducted for each treatment.

RESULTS AND DISCUSSION

Isolation and morphological identification of the pathogen

The pathogen's conidiophores were discovered to be slender, straight, gray, grayish black, or dark brown, smooth, and carrying clusters of conidia, often of the pyriform or obclavate shape with 2-3 septa. It is determined to be *Pyricularia grisea* based on these morphological features (Gashaw *et al*., 2014).

Yield attributing traits of fingermillet in different management strategies

The plant height was found maximum (71cm) in the plot sprayed with Metalaxyl 18% + Mancozeb 64% in the year 2018 but no significant differences among the treatments was observed in 2019. No differences was observed in days to 50% heading and days to 75% maturity in 2018 but Fermented cattle urine + barbery took longer days for 50% heading (100 days) and 75% maturity (152 days) in 2019. Fermented cattle urine + *Lantana camara* had great performed for bearing head/m^2 (191) in 2018 but in 2019, Carbendazim at par with fermented cattle urine + barbery performed well. None of the treatment have any effects on the number of fingers/head and finger length in both of the year. Plot treated with carbendazim at par with Tricyclazole had highest seed weight/finger in 2019 but there were not any differences in 2018. Carbendazim treated plot had highest weight of head/head in 2019 but there were not any differences in 2018. Similarly, 500 grain weight was highest in the plot with treatment fermented cattle urine + barbery (2.17g) in 2019 but there was not any differences in 2018 among the treatment (Table 5 and 6). Highest grain yield was observed in the plot sprayed with Carbendazim 12%+ mancozeb 63% in 2018 but with carbendazim only in 2019. Control plot at par with Metalaxyl 8% + Mancozeb 64% yielded highest straw in 2018.

Effect of different management strategies in finger millet blast

Over the course of two years, the efficacy of fungicides and botanicals that were fermented in cow urine was assessed in the field. Ten days following the inoculation, the untreated control had definite signs of the disease. Consequently, ten days after the vaccination, the first observation was made. Different sets of treatments showed significant differences ($P < 0.05$) for AUDPC for leaf blast over the control. This revealed variations in the efficiency of therapies used to combat blast.

In both years, as shown in Tables 5 and 6, the AUDPC values for the Carbendazim-treated plot were much lower than those for the untreated control and other management techniques. In 2018, Metalaxyl 8% + Mancozeb 64% reduced leaf blast by 54% compared to the control, whereas Carbendazim reduced disease by 63% compared to the control in 2019 (Figure 2).

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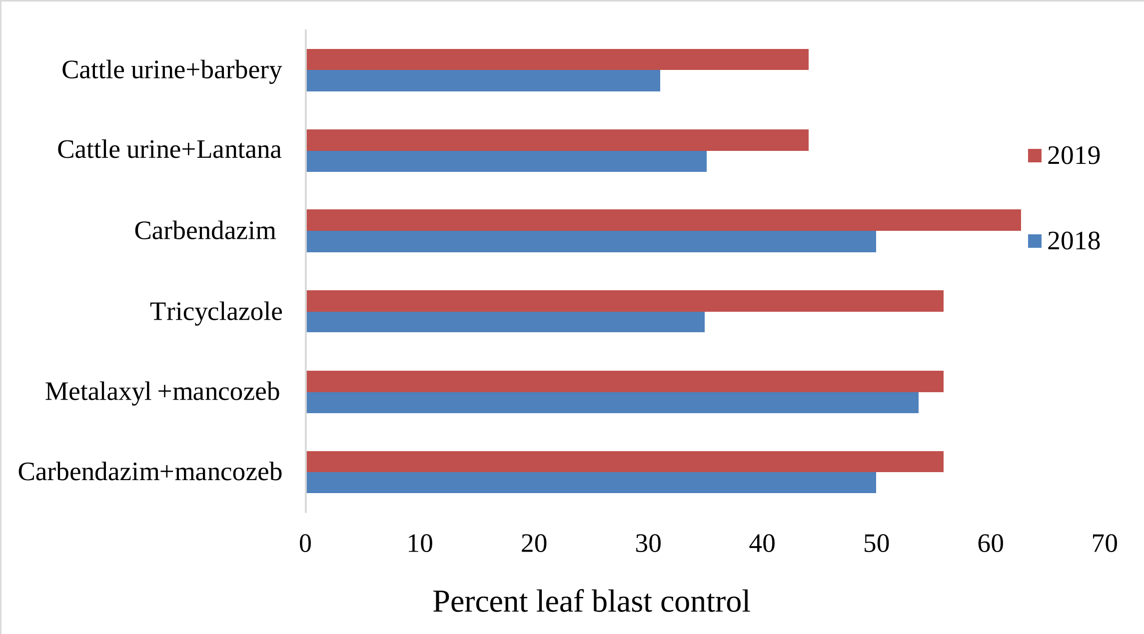

Figure 2: Percentage leaf blast control over the untreated plot in response to different management strategies during 2018 and 2019

The incidence of Finger and Neck blasts differs significantly between assigned treatments. However, Carbendazim and Metalaxyl 8% + Mancozeb 64% at par with Tricyclazole and Fermented Cattle Urine + *Lantana Camara* were best to treat finger blast in 2018. Carbendazim at par with Carbendazim 12% + Mancozeb 63% were reported to have produced decreased incidence of finger blast and lower the frequency of finger blasts in 2019. In a similar vein, carbendazim and tricyclazole will lessen the prevalence of neck blasts in 2018. In 2019, carbendazim, fermented cow urine with barbering at a level with carbendazim 12 percent plus mancozeb 63 percent and tricyclazole were effective at lowering the occurrence of neck blasts (Table 4 and Figure 3).

Table 4: Percent reduction of disease incidence over control during 2018 and 2019

Treatments	% reduction of finger blast over control			% reduction of neck blast over control		
	2018	2019	Mean	2018	2019	Mean
No fungicides applied	0	0	0	0	0	0
Carbendazim 12% + Mancozeb 63%	79	16	47	79	32	56
Metalyxl 8% + Mancozeb 64%	57	24	40	60	15	38
Tricyclazole	57	29	43	87	27	57
Carbendazim	76	29	52	92	38	65
Fermented cattle urine + *Lantana camara*	26	24	25	47	21	34
Fermented cattle urine + Barbery	17	14	15	19	38	28

After the first spray of all the treatments, the disease greatly worsened but then started to improve. Even though all forms of treatment shown an effective ability to slow the spread of the disease, carbendazim produced better outcomes than other types of chemical fungicides. Chemical fungicides were more effective in stopping the progression of the leaf blast in both years than botanical fungicides fermented with barbery and Lantana camara.

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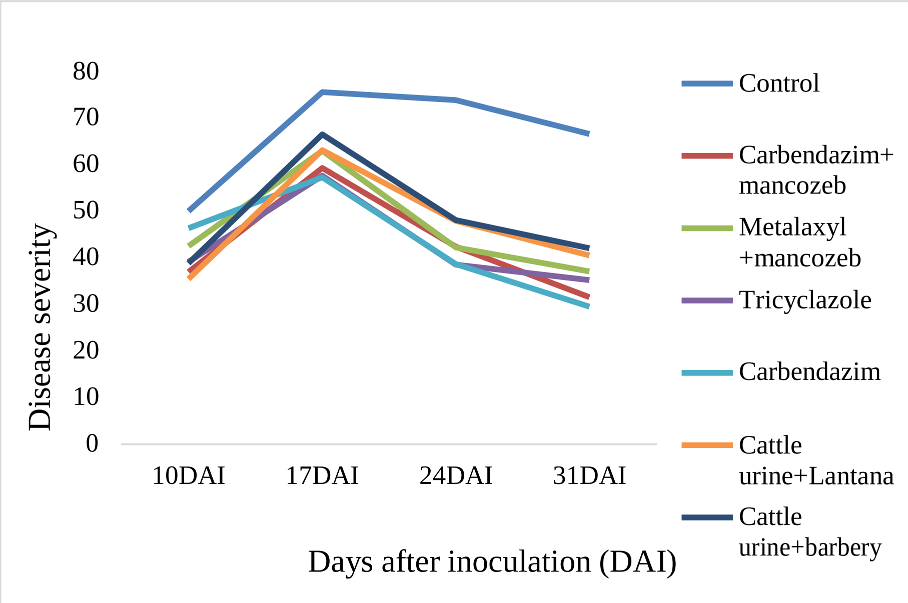

Figure 3: Leaf blast progression of different treatments of both year 2018 and 2019

Table 5: Effect of different blast management practices on the different agronomic parameters of finger millet in 2018

Treatments	PH (cm)	DTH	DTM	BH /m^2	FL (cm)	NF /head	SW /head	HW /head (g)	500 GW (g)
No fungicides applied	69^{ab}	90^{ab}	151^{ab}	183^{ab}	5^{a}	5^{a}	2.7^{a}	4.07^{a}	1.4^{a}
Carbendazim 12% + Mancozeb 63%	69^{ab}	88^{ab}	152^{a}	177^{ab}	4.8^{a}	4.7^{a}	2.5^{a}	3.43^{a}	1.4^{a}
Metalyxl 8% + Mancozeb 64%	71^{a}	87^{ab}	152^{ab}	155^{cd}	5^{a}	5.3^{a}	2.4^{a}	3.7^{a}	1.4^{a}
Tricyclazole	65^{ab}	88^{ab}	152^{a}	149^{d}	5.2^{a}	4.3^{a}	3.1^{a}	4.4^{a}	1.3^{a}
Carbendazim	69^{ab}	91^{a}	152^{a}	175^{b}	5.1^{a}	4.7^{a}	2.4^{a}	3.57^{a}	1.4^{a}
Fermented cattle urine + *Lantana camara*	58^{c}	85^{b}	151^{b}	191^{a}	4.8^{a}	4.7^{a}	2.5^{a}	3.53^{a}	1.5^{a}
Fermented cattle urine + Barbery	64^{bc}	91^{a}	151^{ab}	169^{bc}	4.9^{a}	4.3^{a}	2.5^{a}	3.77^{a}	1.3^{a}
Mean	67	88.8	152	171	4.95	4.71	2.58	3.78	1.38
P-Value	0.01	0.19	0.11	0.001	0.93	0.43	0.67	0.68	0.85
CV (%)	5.52	3.02	0.43	4.7	8.8	12.6	19.85	19.27	11.15
LSD (0.05)	6.54	4.78	1.18	14.45	0.78	1.06	0.91	1.29	0.27

Values in a column followed by different alphabets are significantly different at $P \leq 0.01$ according to Tukey's test. PH: Plant height, DTH: Days to 50% heading, DTM: Days to 75% maturity, BH/m^2: Bearing head/m^2, FL: Finger length, NF/head: Number of finger/head, SW/head: Seed weight/head, HW/head: Weight of head/head, 500 GW: 500 Grain weight, GY: Grain yield, SY: Straw yield. LSD (0.05): Least Significant difference, CV: Coefficient of variation

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Table 6: Effects of different blast management practices on pathological parameters of rice in 2018

Treatments	GY (t/ha)	SY (t/ha)	LB-AUDPC	% FB incidence	% NB incidence
No fungicides applied	4.1^{bcd}	12^{a}	2826^{a}	42^{a}	53^{a}
Carbendazim 12% + Mancozeb 63%	4.87^{a}	11.8^{ab}	1905^{bc}	9^{c}	11^{cd}
Metalyxl 8% + Mancozeb 64%	4.57^{abc}	12^{a}	2178^{b}	18^{bc}	21^{bc}
Tricyclazole	4.63^{ab}	11.2^{abc}	1724^{c}	18^{bc}	7^{d}
Carbendazim	4.03^{cd}	9.6^{bcd}	1828^{bc}	10^{c}	4^{d}
Fermented cattle urine + *Lantana camara*	3.7^{d}	8.2^{d}	2217^{b}	31^{ab}	28^{b}
Fermented cattle urine + Barbery	3.67^{d}	9.4^{cd}	2230^{b}	35^{a}	43^{a}
Mean	4.22	10.5	2129	23	24
P-Value	0.0026	0.01	0.0017	0.001	0.001
CV (%)	7.4	11.78	11.02	33.2	27.77
LSD (0.05)	0.55	2.21	417.63	13.86	11.9

Values in a column followed by different alphabets are significantly different at $P \leq 0.01$ according to Tukey's test.LB-AUDPC: Leaf blast- Area Under Disease Progress Curve, %FB: % Finger blast, %NB: % Neck blast. LSD (0.05): Least Significant difference, CV: Coefficient of variation

Table 7: Effect of different blast management practices on the different agronomic parameters of fingermillet in 2019

Treatments	PH (cm)	DTH	DTM	BH/m^{2}	FL (cm)	NF /Head	SW /head	HW/ head (g)	500 GW (g)
No fungicides applied	110^{a}	98^{cd}	148^{d}	167^{abc}	5^{ab}	6^{a}	5.2^{abc}	5.97^{cd}	1.73^{b}
Carbendazim 12% + Mancozeb 63%	114^{a}	97^{d}	150^{bcd}	154^{c}	4.93^{ab}	7^{a}	5.5^{abc}	6.47^{ab}	1.93^{ab}
Metalyxl 8% + Mancozeb 64%	115^{a}	99^{ab}	151^{ab}	170^{abc}	5.17^{ab}	7^{a}	5.07^{c}	6.23^{bc}	1.87^{ab}
Tricyclazole	117^{a}	99^{abc}	151^{abc}	158^{bc}	5.23^{a}	7^{a}	5.6^{ab}	6.53^{ab}	1.87^{ab}
Carbendazim	114^{a}	98^{bcd}	150^{abc}	177^{a}	4.8^{b}	6^{a}	5.7^{a}	6.67^{a}	2^{ab}
Fermented cattle urine + *Lantana camara*	110^{a}	97^{d}	149^{cd}	153^{c}	4.87^{ab}	7^{a}	5.27^{abc}	6.27^{bc}	1.97^{ab}
Fermented cattle urine + Barbery	114^{a}	100^{a}	152^{a}	173^{ab}	4.77^{b}	6^{a}	5.1^{bc}	5.83^{d}	2.17^{a}
Mean	114	98	150	165	4.96	7	5.34	6.28	1.93
P Value	0.78	0.0015	0.013	0.05	0.187	0.58	0.1	0.0032	0.177
CV (%)	5.15	0.57	0.66	5.85	4.67	10.84	5.43	3.29	8.94
LSD (0.05)	10.4	1	1.77	17.13	0.41	1.26	0.516	0.36	0.31

Values in a column followed by different alphabets are significantly different at $P \leq 0.01$ according to Tukey's test.PH: Plant height, DTH: Days to 50% heading, DTM: Days to 75% maturity, BH/m^{2}: Bearing head/m^{2}, FL: Finger length, NF/head: Number of finger/head, SW/head: Seed weight/head, HW/head: Weight of head/head, 500 GW: 500 Grain weight. LSD (0.05): Least Significant difference, CV: Coefficient of variation

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Table 8: Effect of different blast management practices on the different pathological parameters of finger millet in 2019

Treatments	GY (t/ha)	SY (t/ha)	LB-AUDPC	% FB incidence	%NB incidence
No fungicides applied	3.6[d]	11[d]	1434[a]	63[a]	85[a]
Carbendazim 12% + Mancozeb 63%	4.5[c]	15.7[a]	1343[abc]	53[ab]	58[b]
Metalyxl 8% + Mancozeb 64%	4.7[bc]	15.5[a]	1245[cd]	48[b]	72[ab]
Tricyclazole	4.9[ab]	14.6[ab]	1309[bc]	45[b]	62[b]
Carbendazim	5.2[a]	15.7[a]	1191[d]	45[b]	53[b]
Fermented cattle urine + *Lantana camara*	4.6[bc]	12[cd]	1376[ab]	48[b]	67[ab]
Fermented cattle urine + Barbery	4.6[bc]	12.8[bc]	1361[ab]	54[ab]	53[b]
Mean	4.6	13.89	1322	50.85	64
P Value	0.001	0.001	0.0049	0.16	0.046
CV (%)	4.2	7.15	4.48	15.7	17.43
LSD (0.05)	0.34	1.76	105.62	14.2	19.93

Values in a column followed by different alphabets are significantly different at $P \leq 0.01$ according to Tukey's test. GY: Grain yield, SY: Straw yield. LB-AUDPC: Leaf blast- Area Under Disease Progress Curve, %FB : % Finger blast, %NB: % Neck blast. LSD (0.05): Least Significant difference, CV: Coefficient of variation

Economic analysis of blast management practice in finger millet in Nepalese hill condition

Seed production is found more beneficial than grain production with the BC ratio of 2.2 and 1.3 respectively (Table 9 and 10).

Table 9: Cost details of grain and seed production of fingermillet in semi-mechanized cultivation

SN	Items	Unit	Per unit price	Requirements	Cost- Grain production	Cost- Seed production
1	Carbendazim	Kg	1600	0.5	800	800
2	Saaf	Kg	1600	0.75	1200	1200
3	Ridomil	Kg	2200	2	4400	4400
4	Tricyclazole	Kg	4400	0.4	1760	1760
5	Drums	Number	200	2	400	400
6	Compost	Ton	1500	6	9000	9000
7	Urea	Kg	20	92	1834	1834
8	DAP	Kg	40	43	1739	1739
9	MoP	Kg	30	33	1000	1000
10	Tillage-1-Mini tiler charge	Hour	800	10	8000	8000
11	Tillage-2-Mini tiler charge	Hour	800	10	8000	8000
12	Compost- transportation	Truck trip	5000	1	5000	5000
13	Seed	Kg	90	10	900	900
14	sowing Labor	Numbers	600	2	1200	1200
15	Transplanting Labor	Numbers	600	30	18000	18000
16	Weeding Labor	Numbers	600	15	9000	9000
17	Sprayers	Numbers	5000	2	10000	10000
18	Spraying Labor	Numbers	600	6	3600	3600
19	Tents	Numbers	1500	2	3000	3000

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20	Buckets	Numbers	250	4	1000	1000
21	Harvesting Labors	Numbers	600	40	24000	24000
22	Threshing Labors	Numbers	600	6	3600	3600
23	Threshing Machine	Hours	1000	8	8000	8000
24	Cleaning, Grading Labors	Numbers	600	5	3000	10000
25	Truthful label	Numbers	100	10	-	1000
26	Monitoring costs	Times	5000	2	-	10000
27	Plastic sacs	Numbers	50	80	4000	4000
28	Packaging Labor	Numbers	600	4	2400	2400
29	Straw harvesting labor	Numbers	600	15	9000	9000
30	Land rent				5000	5000
31	Miscellaneous				5000	5000
	Total cost				153833	171833

Table 10: Benefit cost analysis of fingermillet grain and seed production in Nepalese hill condition

Output	**Trial verage Production (kg ha^{-1})**	**Price NRS/Kg**	**Revenue**	**Total Revenue**	**Total cost**	**Profit**	**BC Ratio**
Grain	4220	35	147700	197700	153833	43867	1.3
Straw	10,000	5	50000				
Seed	3376	90	303840	383380	171833	211547	2.2
Mix (20%)	844	35	29540				

Two years average data showed that highest grain yield of 4.8 and 4.7 t /ha in the BAAN and SAAF treated plots with same BC ratio of 1.5. Likewise, both of them were also had highest BC ratio in seed production (table 11).

Table 11: Economic impact of different blast management practices (average of two years)

Treatments	FB%	NB%	Average GY (t/ha)	Average seed yield (t/ha)	Average SY (t/ha)	Grain production BC ratio	Seed production BC ratio
SAAF	31	34.5	4.7	3.75	13.75	1.5	2.6
RIDOMIL-MZ	33	46.5	4.6	3.71	13.75	1.5	2.5
BAAN	31.5	34.5	4.8	3.81	12.9	1.5	2.6
BAVISTIN	27.5	28.5	4.6	3.69	12.65	1.5	2.5
Fermented cattle urine + *Lantana camara*	39.5	47.5	4.2	3.32	10.1	1.3	2.2
Fermented cattle urine + Barbery	44.5	48	4.1	3.31	11.1	1.3	2.2

The main disease that can affect finger millet at any stage and result in losses of up to 80% is blast (Mgonja *et al*., 2007). Fungicides act as a potential means of managing plant diseases during the absence of resistant germplasm and can be regarded as an effective measure in addition to being cost-beneficial and environmentally safe because there are no 100% environmentally friendly and cost-effective ways to combat plant diseases (Jamil and Ashraf, 2020). The effectiveness of four fungicides and two botanicals fermented in cow urine against

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Pyricularia grisea was examined in the current investigation. In 2018, Metalaxyl 8% + Mancozeb 64% caused a 54% decrease in leaf blast over the control, whilst Carbendazim caused a 63% decrease in illness over the control in 2019. The AUDPC values for the plots treated with carbendazim in both years were significantly lower than those for the untreated control and other treatments. The findings by Ramappa *et al.* (2002), who claimed that two sprays of SAAF were successful in lowering the blast disease, are consistent with the conclusion that carbendazim at par with carbendazim 12% + mancozeb 63% were shown to have caused lower incidence of finger blast in 2018. According to this study, Patro et al. (2020) also recommended using fungicides like carbendazim and carbendazim + mancozeb to manage finger millet blast. However, Tricyclazole, Fermented Cattle Urine, and *Lantana Camara* followed by Carbendazim and Metalaxyl 8% + Mancozeb 64% were successful in lowering the prevalence of finger blasts in 2019. In a similar vein, carbendazim and tricyclazole will lessen the prevalence of neck blasts in 2018. In 2019, tricyclazole, carbendazim at par with carbendazim at 12% +, and mancozeb at 63% were successful at lowering the occurrence of neck blasts. Carbendazim is proven to be particularly beneficial against neck and finger blast disease, according to Nagaraja *et al.* (2007), which supports this study as well. Tricyclazole, according to Upamanya *et al.* (2019), outperformed other fungicides in terms of lowering the incidence of leaf blast. However, carbendazim also performed better in terms of eradicating the illness. Tricyclazole was reported to be stable and to accumulate in water-soil systems for 11 months after application by Jeong *et al.* (2012). Tricyclazole offers rice plants long-term protection up till the reproductive stage as a result of two administrations. This study confirms our findings because tricyclazole was successful in 2019 at reducing finger blast.

In 2019, *Lantana camara* fermented in cow urine has also demonstrated effective results in lowering the prevalence of finger blasts. *Lantana camara* combined with fermented cow urine produced excellent results for head/m^2 (191) in 2018. It might be because *Lantana camara* has fungicidal qualities (Negi *et al*., 2019). Cow urine can marginally boost seed output but has little impact on reducing the occurrence of neck blasts (Govindaraju and Somasekhara, 2016). It might be because cow pee contains a lot of nitrogen. Increased crop density, decreases in phenol, and changes in canopy structure have all been linked to increased vulnerability to disease, which may create a favorable microclimate for the growth of pathogens (Sharma, 2020).

The rice blast fungus M. grisea has been found to develop resistance to carbendazim. As a result, M. grisea's investigation into the pearl millet's varied sensitivity to carbendazim. Similar to this, tricyclazole, another fungicide that has been shown to be quite efficient in Gujarat against pearl millet blast and rice blast, was ineffective as well. Differential susceptibility to tricyclazole has also been seen in rice blast isolates obtained from various Chinese regions (Sharma *et al*., 2018).

CONCLUSION

Fungicides carbendazim, carbendazim 12%+ mancozeb 63%, metalaxyl 8%+ mancozeb 64%, and tricyclazole, were effective to control leaf, finger and neck blast of fingermillet. It's conceivable that fungicide resistance among pathogen populations has not yet developed since chemical fungicides are not often treated on neglected crops like finger millet in Nepal.It has been recommended that fungicides be used in rotation and combined with fungicides from groups with different modes of action or with botanicals or plant extracts to lessen the emergence of fungicide resistance in the population of pathogens.

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Authors' contribution

SB Gurung was involved in conducting the experiments, data analysis and interpretation, and drafting of the manuscript. NB Dhami was involved in field monitoring and managing manpower. J Shrestha and S Subedi were involved in critical revision and final shape of the manuscript. All authors listed have made a substantial, direct and intellectual contribution to the study, and approved it for publication.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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