

**INTEGRATED SEED TREATMENT AND FOLIAR FUNGICIDE APPLICATION
FOR THE MANAGEMENT OF BANDED LEAF AND SHEATH BLIGHT
(*Rhizoctonia solani* f. sp. *sasakii*) OF MAIZE**

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ABSTRACT

Banded leaf and sheath blight (BLSB), caused by *Rhizoctonia solani* f. sp. *sasakii*, is one of the major constraints to maize production in Nepal. This study evaluated the effectiveness of seed treatment and foliar fungicide application for managing BLSB and improving maize yield. The pathogen was isolated, identified, and mass-multiplied on barley grains at the Plant Pathology Laboratory of the Agriculture and Forestry University, Rampur, Chitwan. The experiment was conducted using a 3 × 10 factorial split-plot design with three seed treatments and ten foliar fungicide treatments. Artificial inoculation was performed at the knee-high stage to ensure uniform disease development. Disease incidence, percent disease severity (PDS), area under the disease progress curve (AUDPC), yield components, and grain yield were recorded. Seed treatments did not significantly affect disease incidence, PDS, or AUDPC, but significantly influenced grain yield and several yield-attributing traits. Among the foliar fungicides, propiconazole 25% at 0.1% recorded the lowest disease incidence (9.03%), PDS (4.94%), and AUDPC (312.35), while validamycin 3% at 0.2% produced the highest grain yield (3.42 t ha⁻¹). Carbendazim 50% seed treatment recorded the highest grain yield among seed treatments (2.99 t ha⁻¹). These findings indicate that appropriate foliar fungicide application can effectively suppress BLSB and improve maize productivity under Nepalese conditions.

Keywords: Effect on yield, efficacy of fungicides, Nepal

INTRODUCTION

Maize (*Zea mays* L.) is a versatile cereal crop grown for food, feed, and industrial purposes. It ranks third globally among cereal crops in terms of production (Basandrai et al., 2020). In Nepal, maize is the second most important cereal crop after rice in terms of cultivated area and production and plays a vital role in the livelihoods of farming communities, particularly in the mid-hills. It is widely grown for human consumption, livestock feed, and fodder, and its demand continues to increase by approximately 5% annually (KC et al., 2015).

Maize is cultivated on about 928,761 ha in Nepal and contributes nearly 24.93% of the country's total cereal production. Most of the production comes from the mid-hill region. However, the national average yield is only 2.46 t ha⁻¹, which is far below the potential yield of improved varieties (6.7 t

ha⁻¹). This yield gap is mainly attributed to diseases and inadequate crop management practices (Subedi, 2015). Several diseases, including northern leaf blight (*Exserohilum turcicum*), southern leaf blight (*Bipolaris maydis*), stalk rots, and banded leaf and sheath blight (BLSB) (*Rhizoctonia solani* f. sp. *sasakii*), are major constraints to maize production.

Among these diseases, BLSB is one of the most destructive diseases in maize-growing regions of Nepal (Phulara et al., 2025; KC et al., 2015). The pathogen survives in soil and infected crop residues as sclerotia, allowing it to persist between cropping seasons. Infection usually begins on the lower leaf sheaths and gradually spreads upward under favourable environmental conditions (G.C. & Bhusal, 2019). Yield losses ranging from 11% to 40% have been reported, while severe epidemics may result in complete crop failure (Chaudhary et al., 2016). Disease development is favoured by warm temperatures (25-30 °C), high humidity, prolonged rainfall, waterlogged soils, and intensive cropping systems (Rai & Singh, 2018). These conditions are common in Nepal's Inner Terai during the maize-growing season, making the region highly prone to disease outbreaks. BLSB was first reported in Nepal in 1977 and has since become a major disease in both the Inner Terai and mid-hill regions (Subedi, 2015). Most maize cultivars grown in Nepal are susceptible to the disease, although hybrids such as RML-76 and RL-105 have shown partial resistance (G.C. et al., 2019). Cultural practices, including removal of infected lower leaves, may help reduce disease but often provide limited control and may increase the risk of lodging.

Chemical control remains an important component of BLSB management. Carbendazim has been reported to reduce disease severity when used as either a seed treatment or foliar spray, and its effectiveness improves when integrated with appropriate cultural practices (Debbarma et al., 2021; Subedi et al., 2022). Fungicides suppress disease by interfering with essential physiological and biochemical processes of fungal pathogens, including spore germination, mycelial growth, respiration, cell wall formation, membrane integrity, and nucleic acid synthesis. These actions restrict pathogen development, resulting in healthier crops and improved yield (Shah et al., 2025). Among the available fungicides, triazole-based compounds have shown high efficacy against several fungal diseases while posing relatively low environmental risks (Thind, 2022; Kumar et al., 2018).

Although several studies have evaluated individual fungicides or single disease management practices, information on integrated approaches for managing BLSB under Nepalese conditions remains limited. Studies conducted in India have demonstrated the effectiveness of fungicides such as azoxystrobin and tebuconazole for managing BLSB through foliar application. However, research integrating seed treatment with foliar fungicide application in Nepal is scarce. Furthermore, information on optimum application schedules, consistency of fungicide performance across seasons, and economic feasibility remains limited (Raju et al., 2025; Subedi et al., 2022). Therefore, this study was undertaken to evaluate different seed treatments and foliar fungicides for the integrated management of BLSB under the Inner Terai agro-climatic conditions of Nepal

MATERIALS AND METHODS

Experimental site and design

The experiment was conducted at the research plot of the Agriculture and Forestry University, Rampur, Nepal, from June to September 2022. The experimental site is located at 27°34'60" N

latitude and 84°30'60" E longitude at an altitude of 197 m above sea level. The area lies within the central climatic zone of Nepal. The monsoon generally begins in mid-June and ends in late September, accounting for approximately 75% of the annual rainfall. The average annual rainfall is about 1,500 mm. Temperatures range from 2-3 °C during winter to 42-43 °C during summer. The experiment was laid out in a 3 × 10 factorial split-plot design, with seed treatment as the main-plot factor and foliar fungicide treatment as the sub-plot factor. The three seed treatments were Bavistin (carbendazim 50%), Vitavax (carboxin 37.5% + thiram 37.5%), and an untreated control. The sub-plot factor consisted of ten foliar fungicide treatments which is presented in Table 1. The specifications of the fungicides are presented in Table 2.

Each experimental plot measured 3 m × 1 m (3 m²). Maize was planted at a spacing of 75 cm × 25 cm. A buffer distance of 1 m between blocks and 0.5 m between adjacent plots was maintained to minimize treatment interference. The susceptible maize variety 'Rampur Composite' was used in the study. To control fall armyworm and other insect pests, Taffin (spinosad 45% SC) was applied at 0.2 ml/l at 20 days after sowing. The first fungicide spray was applied two days after the appearance of disease symptoms, followed by two additional sprays at 10-day intervals. Spraying was performed during the evening using a hand-held atomizer sprayer to minimize spray drift between plots. A commercial surfactant (ALLVIT) was added to improve spray coverage and reduce wash-off during rainfall. Fungicides were applied at their recommended concentrations: carbendazim 50% (0.25%), carboxin 37.5% + thiram 37.5% (0.05%), azoxystrobin 23% (0.1%), carbendazim 12% + mancozeb 63% (0.1%), tebuconazole 50% + trifloxystrobin 25% (0.05%), hexaconazole 5% (0.2%), propiconazole 25% (0.1%), thiophanate-methyl 45% (0.2%), and validamycin 3% (0.2%). Spraying was performed to ensure thorough coverage of all plant parts, especially the leaf sheaths where BLSB symptoms typically develop. The untreated control received no foliar fungicide spray.

Table 1. Details of seed treatments and foliar fungicide treatments evaluated for disease management

Main plot factor (seed treatment)		Sub-plot factor (foliar spray at 10 days interval)	
SN		SN	
1	Carbendazim 50% (2.5 g per kg of seed)	1	Carbendazim at 0.25%
		2	Carboxin 37.5% + Thiram 37.5% powder at 0.05%
		3	Azoxystrobin 23% at 0.1%
		4	Carbendazim 12% + Mancozeb 63% at 0.1%
2	Carboxin 37.5% + Thiram 37.5% (2.5 g per kg of seed)	5	Tebuconazole 50% + Trifloxystrobin 25% at 0.05%
		6	Hexaconazole 5% at 0.2%
		7	Propiconazole 25% at 0.1%
		8	Thiophanate methyl 45% at 0.2%
3	Control (No seed treatment)	9	Validamycin 3% at 0.2%
		10	Untreated control (No foliar spray)

Table 2. Detail information of the fungicides used in the seed treatment and foliar application

Trade name	Technical name	Chemical group	Formulation	Mode of action
Bavistin	Carbendazim 50%	Benzimidazole	WP	Systemic
Vitavax powder	Carboxin 37.5% + Thiram 37.5%	Oxathiins	WP	Systemic and contact
Amistar	Azoxystrobin 23%	Strobilurins	SC	Systemic
SAAF	Carbendazim 12% + Mancozeb 63%	Benzimidazole + Dithiocarbamate	WP	Systemic and contact
Nativo	Tebuconazole 50% + Trifloxystrobin 25%	Triazole + Strobilurins	WG	Systemic
Contaf Plus	Hexaconazole 5%	Triazole	EC	Systemic
Tilt	Propiconazole 25%	Triazole	EC	Systemic
Topsin M	Thiophanate-Methyl 45%	Dimethyl ester	WP	Protectant, systemic and curative
Sheathmar	Validamycin 3%	Aminoglycoside antibiotic	EC	Contact

WP = Wettable powder, SC = Suspension concentrate, WG = Wettable granule, EC = Emulsifiable concentrate

Collection of disease samples, isolation, identification, and inoculum production

Diseased maize plants showing typical BLSB symptoms were collected from the National Maize Research Program (NMRP), Rampur, Chitwan, in April 2022 and transported to the Plant Pathology Laboratory of the Agriculture and Forestry University, Rampur.

The infected plant tissues were washed under running water and cut into approximately 5 mm pieces. The tissue pieces were surface sterilized in 1% sodium hypochlorite (NaOCl) for one minute, followed by three rinses with sterile distilled water to remove residual disinfectant. Excess moisture was removed by blotting the pieces on sterile filter paper before placing the pieces on 2% water agar (WA) medium plates. The plates were incubated at 25 °C for 2-3 days to promote fungal growth. The pathogen was identified based on its cultural and morphological characteristics. Pure cultures were maintained on potato dextrose agar (PDA) slants and stored at 4 ± 1 °C (Phulara et al., 2025).

The inoculum of *Rhizoctonia solani* was mass-multiplied on barley grains following the method described by Ahuja and Payak (1978). The grains were washed three times with tap water and soaked overnight in 2% sucrose solution. After draining excess water, 40 g of soaked grains were placed in a 250 ml Erlenmeyer flask. The flask was plugged with cotton and sterilized in an autoclave at 121 °C (15 psi) for two consecutive days. Each flask was inoculated with 5 ml of homogenized 3-day-old fungal culture and incubated at 26 ± 2 °C for 10 days. The flask was shaken periodically to ensure uniform colonization of the barley grains.

Plant growing and artificial inoculation

The susceptible maize variety ‘Rampur Composite’ was grown following the recommended agronomic practices. The field was ploughed one month before sowing and subsequently pulverized and levelled. Well-decomposed farmyard manure (FYM) was incorporated into the soil at 8 t ha⁻¹ fifteen days before sowing. Chemical fertilizers were applied at 120:60:40 kg N:P₂O₅:K₂O/ha through urea, di-ammonium phosphate (DAP), and muriate of potash (MOP). The entire doses of DAP and MOP, along with half of the nitrogen, were applied as basal fertilizer at sowing. The remaining nitrogen was top-dressed in two equal splits: the first during earthing-up and the second at the flowering stage. Thinning was completed 15 days after sowing to maintain the recommended plant population. Weeding and earthing-up were carried out at the knee-high stage and again before tasseling. Irrigation was provided at critical growth stages, specifically during the knee-high and tasseling stages.

Artificial inoculation was performed at the knee-high stage (32 days after sowing) by inserting four pathogen-colonized barley grains between the leaf sheath and stem of each plant. High humidity was maintained through frequent water misting to facilitate disease development (Phulara et al., 2025).

Disease assessment and statistical analysis

Before inoculation, ten plants were randomly selected and tagged in each plot for disease assessment. The first observation was made five days after the first foliar spray, followed by subsequent observations at 10-day intervals. Disease severity was assessed using a 1–9 scale (Ahuja & Payak, 1983), as presented in Table 3.

Table 3. Disease rating scale of banded leaf and sheath blight of maize

Scale	Degree of infection
1	Disease on one leaf sheath only; few small, non-coalescent lesions present.
2	Disease on two sheaths; lesions are large and coalescent
3	Disease up to four sheaths, lesions many and always coalescent.
4	As in scale 3 + rind discolored with small lesions.
5	Disease on all sheaths except two internodes below the ear.
6	Disease up to one internode below the ear shoot; rind discoloration on many internodes with large depressed lesions
7	Disease up to internode bearing the ear shoot but shank not affected.
8	Disease on the ear; husk leaves show bleaching, bands and caking among them-selves as also of silk fibers; abundant fungal growth between and on kernel rows; kernel formation normal except their being lusterless; ear size less than normal; some plant prematurely dead.
9	In addition to scale 8, shrinkage of stalk; reduced ear dimensions; wet rot and disorganization of ear; kernel formation absents or rudimentary; premature dead plants common; abundant sclerotia production on husk leaves, kernels, ear tips or silk.

Disease incidence (DI)

Disease incidence (DI) was calculated based on the proportion of plants showing visible BLSB symptoms by using the formula of Wheeler (1969).

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Percent disease severity (PDS)

Disease severity was quantified using the disease scores assigned to the individual plants based on the 1-9 disease rating scale. It was calculated by using the following formula given by Wheeler (1969).

$$\text{Disease severity (\%)} = \frac{\text{Sum of all numerical rating} \times 100}{\text{Total number of samples observed} \times \text{maximum rating}}$$

Area under disease progress curve (AUDPC)

AUDPC was calculated by using the following formula given by Shaner and Finney (1977).

$$\begin{aligned} i &= n-1 \\ \text{AUDPC} &= \sum_{i=1}^{n-1} \left[\frac{(Y_i + Y_{i+1})}{2} \times (t_{i+1} - t_i) \right] \end{aligned}$$

Where, Y_i = disease severity on the i^{th} date
 Y_{i+1} = disease severity on the $i+1^{\text{th}}$ date and
 n = number of dates
 t_i = time of the i^{th} assessment
 t_{i+1} = time of the $(i+1)^{\text{th}}$ assessment

Yield and yield attributing assessment of maize

Yield and yield-attributing traits were recorded at different stages of crop growth. The number of cobs per plant (CN) was counted at harvest. Cob length (CL) was measured using a ruler, while cob diameter (CD) was measured using a digital Vernier caliper. For thousand-grain weight, 1000 seeds were counted manually and weighed accurately.

Grain yield was calculated using the formula described by Tandzi and Mutengwa (2020).

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{FEW (kg/plot)} \times (100 - \text{HMC}) \times S \times 10000}{(100 - \text{DMC}) \times \text{NPA} \times 1000}$$

In this case,

FEW = Fresh ear weight, HMC = Moisture content at harvest, DMC = Desired moisture content i.e., 12.5%, S = Shelling coefficient i.e., 0.8 and NPA = Net plot area in m^2

Statistical data analysis

The field experiment was laid out in a split-plot design. The collected data were first compiled and organized in Microsoft Excel. Analysis of variance (ANOVA) was performed using R version 4.0.2 with the Agricolae package to determine treatment effects. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

RESULTS

Confirmation of *Rhizoctonia solani*

Morphological and cultural characteristics

After isolation, the fungus was characterized based on its cultural and morphological characteristics. *Rhizoctonia solani* was identified by its pale-to-brown mycelium, which branched toward the distal septum and showed constriction and septum formation at the points of branching. The fungus lacked clamp connections and produced undifferentiated sclerotia. The hyphal cells were multinucleate and hyaline, with prominent septal pores. On PDA, colonies grew rapidly and were initially silky white, gradually becoming dull with age. These characteristics were consistent with those reported by Hooda et al. (2015).

Pathogenicity test

Pathogenicity was tested using pure fungal cultures on tagged plants. Typical BLSB symptoms, characterized by concentric brown, tan, or grey bands on the leaf sheaths, appeared within seven days after inoculation. The pathogen was subsequently re-isolated from infected tissues onto PDA, thereby fulfilling Koch's postulates and confirming *R. solani* as the causal agent.

Effects of seed treatment and foliar fungicide application on DI, PDS, and AUDPC

Seed treatments did not significantly affect disease incidence (DI), percent disease severity (PDS), or area under the disease progress curve (AUDPC). The mean DI ranged from 39.17% in the untreated seed control to 47.08% with carbendazim 50% seed treatment. Similarly, PDS ranged from 26.30% in the carboxin 37.5% + thiram 37.5% treatment and the untreated seed control to 27.11% with carbendazim 50%. AUDPC ranged from 855.56 in the untreated seed control to 865.93 with carbendazim 50% seed treatment. However, these differences were not statistically significant.

Foliar fungicide treatments significantly affected DI, PDS, and AUDPC ($p < 0.001$). The untreated foliar control recorded the highest DI (69.44%), whereas propiconazole 25% recorded the lowest DI (9.03%), followed by validamycin 3% (11.81%). The untreated foliar control also recorded the highest PDS (49.88%), while propiconazole 25% recorded the lowest PDS (4.94%), followed by validamycin 3% (7.90%). Propiconazole 25% recorded the lowest AUDPC (312.35), followed by validamycin 3% (350.62), whereas the untreated foliar control recorded the highest AUDPC (1479.01). The results are presented in Table 4.

Table 4. Effect of seed treatment and foliar spray of fungicides on DI, PDS and AUDPC of banded leaf and sheath blight (*Rhizoctonia solani* f. sp. *sasakii*) of maize cv. Rampur Composite at Rampur, Chitwan, 2022

Treatments	DI (%)	PDS (%)	AUDPC
Main plot: Seed treatment			
Carbendazim 50% @2.5 g/kg seed)	47.08 ± 2.23 ^a	27.11 ± 0.61 ^a	865.93 ± 9.96 ^a
Carboxin 37.5% + Thiram 37.5% @2.5 g/kg seed	45.83 ± 2.23 ^{ab}	26.30 ± 0.61 ^{ab}	860.74 ± 9.96 ^{ab}
Untreated control	39.17 ± 2.23 ^{abc}	26.30 ± 0.61 ^{abc}	855.56 ± 9.96 ^{abc}
SEm (±)	2.228	0.608	9.962
LSD (p<0.05)	8.747	2.387	39.116
F-test	NS	NS	NS
CV (%)	27.71	12.53	6.34
Sub-plot: Foliar spray			
Carbendazim 50% WP @0.25%	51.39 ± 3.58 ^{c-f}	27.90 ± 2.09 ^{c-f}	927.16 ± 41.48 ^{c-f}
Carboxin 37.5% + Thiram 37.5% @0.05%	50.00 ± 3.58 ^{c-g}	26.17 ± 2.09 ^{d-g}	848.15 ± 41.48 ^{fg}
Azoxystrobin 23% @0.1%	54.86 ± 3.58 ^{bc}	33.58 ± 2.09 ^c	1034.57 ± 41.48 ^{bc}
Carbendazim 12% + Mancozeb 63% @0.1%	63.19 ± 3.58 ^{ab}	39.75 ± 2.09 ^b	1096.30 ± 41.48 ^b
Tebuconazole 50% + Trifloxystrobin 25% @0.05%	25.69 ± 3.58 ^h	15.31 ± 2.09 ^h	561.73 ± 41.48 ^h
Hexaconazole 5% @0.2%	52.08 ± 3.58 ^{c-c}	29.63 ± 2.09 ^{c-c}	987.65 ± 41.48 ^{b-c}
Propiconazole 25% @0.1%	9.03 ± 3.58 ^{ij}	4.94 ± 2.09 ^{ij}	312.35 ± 41.48 ^{ij}
Thiophanate-methyl 45% @0.2%	52.78 ± 3.58 ^{b-d}	30.62 ± 2.09 ^{cd}	1009.88 ± 41.48 ^{b-d}
Validamycin 3% @0.2%	11.81 ± 3.58 ⁱ	7.90 ± 2.09 ⁱ	350.62 ± 41.48 ⁱ
Untreated control	69.44 ± 3.58 ^a	49.88 ± 2.09 ^a	1479.01 ± 41.48 ^a
SEm (±)	3.582	2.090	41.479
LSD (p < 0.05)	10.155	5.925	117.605
F-test	***	***	***
CV (%)	24.40	23.60	14.46
Grand mean	44.03	26.57	860.74

*** denotes significance at $p < 0.001$, NS = Non-significant, CV = Coefficient of variation, SEm (±) = Standard error of mean, LSD = Least significant difference, Treatment mean ± SE within a column followed by the different letters were significantly different at $p = 0.05$ level by Duncan's multiple range test (DMRT)

Effects of seed treatment and foliar fungicide application on grain yield and yield attributing traits

Seed treatments significantly affected grain yield, thousand-grain weight (TGW), cob diameter, and number of cobs per plant ($p < 0.001$), while their effect on cob length was significant at $p < 0.05$. Carbendazim 50% seed treatment recorded the highest grain yield (2.99 t/ha), TGW (185.92 g), cob length (14.33 cm), cob diameter (4.491 cm), and number of cobs per plant (1.232). The untreated seed control recorded the lowest grain yield (2.76 t/ha), TGW (183.70 g), cob diameter (4.395 cm), and number of cobs per plant (1.130). For cob length, the untreated seed control recorded 14.22 cm, and it was statistically at par with the carboxin 37.5% + thiram 37.5% treatment.

Foliar fungicide treatments significantly affected all measured yield and yield-attributing traits ($p < 0.001$). Validamycin 3% recorded the highest grain yield (3.42 t/ha), TGW (188.76 g), cob length (14.62 cm), cob diameter (4.661 cm), and number of cobs per plant (1.623). The untreated foliar control recorded the lowest grain yield (1.18 t/ha), TGW (172.12 g), cob length (13.68 cm), cob diameter (4.206 cm), and number of cobs per plant (0.800). Propiconazole 25% also performed well, recording 3.32 t/ha grain yield, 187.94 g TGW, 14.55 cm cob length, 4.629 cm cob diameter, and 1.400 cobs per plant. The results are presented in Table 5.

Table 5. Effects of seed treatment and foliar fungicide application on grain yield, thousand-grain weight (TGW), and yield-attributing traits of maize affected by banded leaf and sheath blight at Rampur, Chitwan, Nepal, 2022

Treatments	Yield (t/ha)	TGW (g)	Cob length (cm)	Cob diameter (cm)	Number of cobs/plant
Main plot: Seed treatment					
Carbendazim 50% WP @2.5 g/kg seed	2.99 ± 0.01 ^a	185.92 ± 0.03 ^a	14.33 ± 0.02 ^a	4.491 ± 0.001 ^a	1.232 ± 0.001 ^a
Carboxin 37.5% + Thiram 37.5% @2.5 g/kg seed	2.87 ± 0.01 ^b	184.81 ± 0.03 ^b	14.25 ± 0.02 ^b	4.443 ± 0.001 ^b	1.180 ± 0.001 ^b
Untreated control	2.76 ± 0.01 ^c	183.70 ± 0.03 ^c	14.22 ± 0.02 ^{bc}	4.395 ± 0.001 ^c	1.130 ± 0.001 ^c
SEm (±)	0.008	0.030	0.017	0.0009	0.0013
LSD ($p < 0.05$)	0.031	0.117	0.067	0.0035	0.0050
F-test	***	***	*	***	***
CV (%)	1.49	0.09	0.66	0.11	0.60
Sub-plot: Foliar spray					
Carbendazim 50% @0.25%	2.86 ± 0.02 ^f	184.47 ± 0.04 ^f	14.24 ± 0.03 ^{cf}	4.409 ± 0.004 ^f	1.113 ± 0.003
Carboxin 37.5% + Thiram 37.5% @0.05%	2.75 ± 0.02 ^h	184.18 ± 0.04 ^{gh}	14.18 ± 0.03 ^{gh}	4.307 ± 0.004 ^h	1.080 ± 0.003 ^h

contd...

Treatments	Yield (t/ha)	TGW (g)	Cob length (cm)	Cob diameter (cm)	Number of cobs/plant
Azoxystrobin 23% @0.1%	3.22 ± 0.02 ^{cd}	187.41 ± 0.04 ^{cd}	14.35 ± 0.03 ^{cd}	4.510 ± 0.004 ^d	1.159 ± 0.003 ^d
Carbendazim 12% + Mancozeb 63% @0.1%	2.73 ± 0.02 ^{hi}	184.14 ± 0.04 ^{ghi}	14.15 ± 0.03 ^{ghi}	4.293 ± 0.004 ⁱ	1.077 ± 0.003 ^{hi}
Tebuconazole 50% + Trifloxystrobin 25% @0.05%	3.25 ± 0.02 ^c	187.51 ± 0.04 ^c	14.42 ± 0.03 ^c	4.572 ± 0.004 ^c	1.322 ± 0.003 ^c
Hexaconazole 5% @0.2%	2.80 ± 0.02 ^g	184.26 ± 0.04 ^g	14.21 ± 0.03 ^{efg}	4.363 ± 0.004 ^g	1.100 ± 0.003 ^g
Propiconazole 25% @0.1%	3.32 ± 0.02 ^b	187.94 ± 0.0 ^b	14.55 ± 0.03 ^{ab}	4.629 ± 0.004 ^b	1.400 ± 0.003 ^b
Thiophanate-methyl 45% @0.2%	3.16 ± 0.02 ^e	187.29 ± 0.04 ^e	14.27 ± 0.03 ^{de}	4.478 ± 0.004 ^e	1.133 ± 0.003 ^e
Validamycin 3% @0.2%	3.42 ± 0.02 ^a	188.76 ± 0.04 ^a	14.62 ± 0.03 ^a	4.661 ± 0.004 ^a	1.623 ± 0.003 ^a
Untreated control	1.18 ± 0.02 ^j	172.12 ± 0.04 ^j	13.68 ± 0.03 ^j	4.206 ± 0.004 ^j	0.800 ± 0.003 ^j
SEm (±)	0.017	0.041	0.027	0.0043	0.0027
LSD (p < 0.05)	0.048	0.115	0.077	0.0123	0.0075
F-test	***	***	***	***	***
CV (%)	1.78	0.07	0.57	0.29	0.68
Grand mean	2.87	184.81	14.27	4.443	1.181

*** denotes significance at $p < 0.001$, CV = Coefficient of variation, SEm (±) = Standard error of mean, LSD = Least significant difference, Treatment *mean* ± *SE* within a column followed by different letters were significantly different at $p = 0.05$ level by Duncan's multiple range test (DMRT)

DISCUSSION

Banded leaf and sheath blight (BLSB) of maize is managed through fungicides and integrated disease management practices. In the present study, seed treatments did not significantly affect disease incidence (DI), percent disease severity (PDS), or area under the disease progress curve (AUDPC). Although numerical differences were observed, the untreated seed control recorded comparatively lower DI (39.17%), PDS (26.30%), and AUDPC (855.56) than carbendazim 50%, which recorded 47.08%, 27.11%, and 865.93, respectively. Thus, under the conditions of the present study, seed treatment alone did not significantly suppress BLSB disease development. However, seed treatments significantly affected grain yield, thousand-grain weight, cob diameter, and number of cobs per plant, while cob length was also affected at the 5% significance level. Carbendazim 50% recorded the highest grain yield (2.99 t/ha), followed by carboxin 37.5% + thiram 37.5% (2.87 t/ha), whereas the

untreated control recorded the lowest yield (2.76 t/ha). Similar benefits of carbendazim seed treatment on maize performance have been reported by Devlash et al. (2011) and Bunker et al. (2012). Sandhya et al. (2018) also reported that fungicide seed treatments could inhibit the viability of *Rhizoctonia solani* sclerotia and protect seedlings from infection, indicating the potential role of seed treatment in early disease protection. However, such an effect was not reflected in the disease parameters measured in the present study.

In contrast, foliar fungicide treatments significantly affected DI, PDS, and AUDPC ($p < 0.001$). The untreated foliar control recorded the highest DI (69.44%), PDS (49.88%), and AUDPC (1479.01), whereas propiconazole 25% at 0.1% recorded the lowest DI (9.03%), PDS (4.94%), and AUDPC (312.35). Validamycin 3% at 0.2% was the next most effective treatment, with DI, PDS, and AUDPC values of 11.81%, 7.90%, and 350.62, respectively. The effectiveness of validamycin observed in the present study agrees with Singh and Singh (2011), Pujari et al. (1998), and Malik et al. (2018), who reported validamycin as an effective fungicide against BLSB. Similarly, the effectiveness of propiconazole is supported by Rajput and Harlapur (2015), who reported reduced disease severity following propiconazole application.

Validamycin 3% recorded the highest grain yield (3.42 t/ha), followed by propiconazole 25% (3.32 t/ha), while the untreated foliar control recorded the lowest grain yield (1.18 t/ha). Validamycin also recorded the highest TGW (188.76 g), cob length (14.62 cm), cob diameter (4.661 cm), and number of cobs per plant (1.623). Propiconazole similarly produced high values for these yield-attributing traits. These results indicate that effective suppression of BLSB by foliar fungicides was associated with improved crop productivity. The positive effect of validamycin on yield is consistent with Singh and Singh (2011), who reported higher grain yield with validamycin application.

The tebuconazole 50% formulation combined with trifloxystrobin 25% (0.05%) was another foliar treatment that provided good disease suppression with DI of 25.69%, PDS of 15.31% and AUDPC of 561.73. It also showed a relatively high yield of grain of 3.25 t/ha. These findings agree with Malik et al. (2018) who found trifloxystrobin 25% + tebuconazole 50% to be effective against BLSB. However, the combination of carbendazim 12% + mancozeb 63% and azoxystrobin 23% proved to be less effective in reducing disease when compared to the other treatments used in the present study.

Although seed treatment had no significant effect on DI, PDS, or AUDPC, it significantly affected grain yield and several yield-attributing traits, indicating a potential benefit of seed treatment on crop performance. Hence, the present investigation revealed that the application of effective fungicides to the foliage, specifically 3% validamycin and 25% propiconazole was effective in controlling BLSB and enhancing grain yield. Therefore, under the conditions of this study, foliar fungicide application was more effective for BLSB suppression, whereas seed treatment was associated with improved grain yield and several yield-attributing traits. Further research is required to test the efficacy of combining seed treatment with foliar fungicides for BLSB control in various disease situations and environmental conditions.

CONCLUSIONS

The experiment demonstrated that foliar fungicide application was effective in managing banded leaf and sheath blight (BLSB) of maize under the conditions of the study. Seed treatments did not significantly affect disease incidence, percent disease severity, or AUDPC, but significantly influenced grain yield and several yield-attributing traits. Among the foliar fungicides, propiconazole 25% at 0.1% recorded the lowest disease incidence, PDS, and AUDPC, indicating its superior effectiveness among the tested foliar fungicides for suppressing disease development. However, validamycin 3% at 0.2% produced the highest grain yield and the highest values for all measured yield-attributing traits. These findings indicate that appropriate foliar fungicide application can substantially suppress BLSB and improve maize productivity. Further multi-location and multi-year studies are needed to validate the consistency, economic feasibility, and practical applicability of these management strategies.

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REFERENCES

- Ahuja, S.C., & Payak, M.M. (1978). A field inoculation technique for evaluating maize germplasm to banded leaf and sheath blight. *Indian Phytopathology*, 31(4), 517-520.
- Ahuja, S.C., & Payak, M.M. (1983). A rating scale for banded leaf and sheath blight of maize. *Indian Phytopathology*, 36, 338-340.
- Basandrai, A.K., Rathee, V.K., Mehta, A., & Basandrai, D. (2020). Efficacy and economics of some fungicides for the management of banded leaf and sheath blight in maize. *Journal of Plant Disease Sciences*, 12(2), 137-141.
- Bunker, R.N., Trivedi, A., & Mathur, K. (2012). Integrated management of banded leaf and sheath blight of maize caused by *Rhizoctonia solani* f. sp. *sasakii*. *Journal of Mycology and Plant Pathology*, 42(3), 367-371.
- Campbell, C.L., & Madden, L.V. (1990). *Introduction to Plant Disease Epidemiology*. New York, NY: John Wiley & Sons.
- Chaudhary, S., Sagar, S., Tomar, A., Sengar, R.S., & Kumar, M. (2016). Banded leaf and sheath blight: A menacing disease of maize (*Zea mays* L.) and its management. *Journal of Applied and Natural Science*, 8(3), 1720-1730. <https://doi.org/10.31018/jans.v8i3.1030>
- Debbarma, M., Rajesh, T., & Devi, R.K.T. (2021). In vitro efficacy of fungicides against *Rhizoctonia solani* causing banded leaf and sheath blight of maize. *International Journal of Plant and Soil Science*, 33(16), 232-236. <https://doi.org/10.9734/IJPSS/2021/v33i1630540>

- Devlash, R., Guleria, S.K., & Thakur, D.R. (2011). Evaluation of seed dressing fungicides for the management of banded leaf and sheath blight of maize. *Plant Disease Research*, 26(2), 169.
- G.C., S., & Bhusal, K. (2019). Banded leaf and sheath bight (BLSB) of maize, its introduction, losses and management. *Journal of Soil Science and Plant Physiology*, 1(2), 1-6. <https://doi.org/10.36266/JSSPP/106>
- G.C., S., Manandhar, H.K., Rijal, T.R., & Bhusal, K. (2019). Screening of maize genotypes/hybrids for identifying resistant sources against banded leaf and sheath blight (BLSB) in Rampur, Chitwan, Nepal. *International Journal of Agricultural Education and Extension*, 5(2), 260-264.
- Hooda, K.S., Khokhar, M.K., Parmar, H., Gogoi, R., Joshi, D., Sharma, S.S., & Yadav, O.P. (2015). Banded leaf and sheath blight of maize: Historical perspectives, current status and future directions. In *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*. <https://doi.org/10.1007/s40011-015-0688-5>
- KC, G., Karki, T.B., Shrestha, J., & Achhami, B.B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, 1(1), 1-9. <https://doi.org/10.5281/zenodo.34284>
- Kumar, P., Ahlawat, S., Chauhan, R., Kumar, A., Singh, R., & Kumar, A. (2018). Bio-efficacy and post-harvest residual toxicity of new fungicides against sheath blight (*Rhizoctonia solani*) of rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences*, 88(10), 1587-1592. <https://doi.org/10.56093/ijas.v88i10.84228>
- Malik, V.K., Singh, M., Hooda, K.S., Yadav, N.K., & Chauhan, P.K. (2018). Efficacy of newer molecules, bioagents and botanicals against maydis leaf blight and banded leaf and sheath blight of maize. *The Plant Pathology Journal*, 34(2), 121-125. <https://doi.org/10.5423/PPJ.OA.11.2017.0251>
- Malviya, D., Singh, S., Singh, R.K., Rai, J.P., Singh, U.B.S., & Saxena, A.K. (2022). First report of *Rhizoctonia solani* causing banded leaf and sheath blight disease in sugarcane (*Saccharum officinarum*) from Ghazipur district of Uttar Pradesh, India. *Indian Journal of Agricultural Sciences*, 92(3), 408-412. <https://doi.org/10.56093/ijas.v92i3.122728>
- Omar, I., O'Neill, T.M., & Rossall, S. (2006). Biological control of *Fusarium* crown and root rot of tomato with antagonistic bacteria and integrated control when combined with the fungicide carbendazim. *Plant Pathology*, 55(1), 92-99. <https://doi.org/10.1111/j.1365-3059.2005.01315.x>
- Phulara, B., Sharma, S., Gurung, S.B., Acharya, B., & Khati, H. (2025). Assessing resistance in maize genotypes to banded leaf and sheath blight (*Rhizoctonia solani* f. sp. *sasakii*) under artificial epiphytotic condition. *Turkish Journal of Agriculture–Food Science and Technology*, 13(S1), 2373-2379. <https://doi.org/10.24925/turjaf.v13is1.2373-2379.7921>
- Pujari, K.C., Saikia, U.N., & Bhattacharyya, A. (1998). Management of banded leaf and sheath blight of maize with chemicals. *Indian Phytopathology*, 51(1), 78-80.

- Rai, D., & Singh, S.K. (2018). Is banded leaf and sheath blight a potential threat to maize cultivation in Bihar? *International Journal of Current Microbiology and Applied Sciences*, 7(11), 671-683. <https://doi.org/10.20546/ijcmas.2018.711.080>
- Rajput, L., & Harlapur, S.I. (2015). Evaluation of fungicides and biocontrol agents for suppression of banded leaf and sheath blight of maize (*Zea mays*). *Indian Phytopathology*, 68(2), 149-155.
- Raju, M.R., Parime, B.C., Sujatha, V., & Deepthi Priya, B. (2025). Evaluation of fungicides for management of maize banded leaf and sheath blight disease caused by *Rhizoctonia solani* f. sp. *sasakii* and impact on economics of maize cultivation. *Journal of Advances in Biology & Biotechnology*, 28(6), 1473-1482. <https://doi.org/10.9734/jabb/2025/v28i62502>
- Sandhya, Y., Rajan, C.P.D., Kumar, M.R., & Rani, A.R. (2018). Efficacy of seed treatment with fungicides on the viability of sclerotia of *Rhizoctonia solani* admixed with the rice seed. *Journal of Pharmacognosy and Phytochemistry*, 7(3), 3443-3449.
- Shah, S.N., Jatoti, A.A., Khoso, M.A., Moiza, M., Paryal, P., & Ali, Y. (2025). Effect and role of fungicides and botanical extracts on late blight of tomato disease caused by *Phytophthora infestans*: A review. *Frontiers in Plant Protection*, 1(1), 9-16. <https://doi.org/10.38211/fpp.2025.01.176>
- Shivankar, S.K., & Wangikar, P.D. (1993). Effect of different fungicides on the control of gray mildew disease of cotton. *Indian Phytopathology*, 46(3), 230-235.
- Singh, A., & Singh, D. (2011). Integrated disease management strategy of banded leaf and sheath blight of maize. *Indian Society of Plant Pathologists*, 26(2), 192.
- Subedi, S. (2015). A review on important maize diseases and their management in Nepal. *Journal of Maize Research and Development*, 1, 28-52. <https://doi.org/10.5281/zenodo.34292>
- Subedi, S., Neupane, S., Oli, L., & Shrestha, J. (2022). Field efficacy of phytoextracts, antagonists and chemical fungicides with native approach for controlling banded leaf and sheath blight in maize. *Journal of Agriculture and Natural Resources*, 5(1), 73-78. <https://doi.org/10.3126/janr.v5i1.50534>
- Tandzi, L.N., & Mutengwa, C.S. (2020). Estimation of maize (*Zea mays* L.) yield per harvest area: Appropriate methods. *Agronomy*, 10(1), 10-29. <https://doi.org/10.3390/agronomy10010029>
- Thind, T.S. (2022). Fungicides in managing phyto fungal diseases: The changing scenario. *Journal of Mycology and Plant Pathology*, 52(1), 1-11.
- Wheeler, B.E.J. (1969). *An Introduction to Plant Diseases*. London: John Wiley and Sons Limited.