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RESEARCH ARTICLE

Assessment of maize (*Zea mays* L.) turcicum leaf blight, morphological characterisation of *Exserohilum turcicum* and response of maize varieties to the disease in Wolaita Zone, Southern Ethiopia

Alemu Nega*, Dereje Biru, Mesfin Kebede & Lakew Getaneh

Department of Plant Sciences, College of Agriculture, Wolaita Sodo University, Sodo 138, Ethiopia

*Correspondence email - alemunega531@gmail.com

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Abstract

Turcicum leaf blight (TLB), caused by *Exserohilum turcicum*, is a major foliar disease limiting maize yields in Ethiopia, particularly in humid, moderate-temperature areas. This study aimed to assess the status of TLB, characterise pathogen diversity and evaluate varietal resistance in the Wolaita Zone, Southern Ethiopia. Comprehensive surveys in 4 districts revealed TLB to be widely prevalent, with Damot Sore and Humbo showing the highest incidence (over 90 %) and severity (nearly 73.9 %), underscoring environmental influence on disease distribution. Morphological evaluation of *E. turcicum* isolates demonstrated marked diversity in colony morphology and growth rates, indicating significant pathogen variability across locations. Field trials with 12 maize varieties under natural TLB infection indicated highly significant differences in disease response and yield. AMH-854 and AMH-851 were the most resistant, exhibiting the lowest final severity indices (19.1–30.6 %) and highest grain yields (up to 94.9 q ha^{-1}), while MH-140 and BH-546 were most susceptible. Disease progression fitted the Gompertz model, highlighting variation in epidemic development among varieties. Correlation analysis showed a negative relationship between disease parameters and yield attributes. The results highlight the urgent need for integrated management, prioritising resistant hybrids and ongoing surveillance to improve maize productivity and sustain disease control in TLB-prone areas.

Keywords: Ethiopia; *Exserohilum turcicum*; maize; resistance; turcicum leaf blight

Introduction

Maize (*Zea mays* L.) is the most widely produced cereal crop in Ethiopia, serving as a primary food and income source for millions of smallholder farmers (1, 2). Its cultivation spans a range of agroecological zones, with the greatest concentration in mid-altitude and sub-humid regions of southern Ethiopia, where maize plays a central role in both household nutrition and local economies (3, 4). National production exceeds 9.7 Mt annually from approximately 2.2 Mha, making maize the leading cereal by volume in the country (1). Despite this, average yield levels (4.4 t ha^{-1}) remain well below potential, constrained by a combination of abiotic stress and persistent diseases (5).

Among biotic threats, turcicum leaf blight (TLB), caused by *Exserohilum turcicum*, is recognised as a major foliar disease of maize in Ethiopia and across East Africa (6, 7). The TLB thrives in the humid, moderate-temperature highlands prevalent in the region, often resulting in extensive leaf necrosis and yield losses that can reach as high as 70 % in susceptible cultivars (4, 8). The disease is favoured by prolonged rainfall and high relative humidity, which commonly prevail in the maize-growing belts of Southern Ethiopia (5). While breeding for TLB resistance has been a priority in Ethiopia's maize improvement initiatives, numerous popular hybrids and open-pollinated varieties remain susceptible to the disease (3, 6). Effective resistance breeding and deployment depend on a nuanced understanding of the local diversity of *E. turcicum* populations, as well as the responses of available maize germplasm (4, 7). However, there is a clear gap in regional data regarding the morphological diversity of *E. turcicum* isolates and the resistance profiles of maize varieties, particularly in the Wolaita Zone, a major maize-producing area with climatic conditions that favour frequent TLB outbreaks.

Accordingly, the present study aimed to: (i) assess the incidence and severity of TLB in key maize-growing districts of the Wolaita Zone; (ii) characterise the morphological diversity of *E. turcicum* isolates collected from this region and (iii) evaluate the field resistance of improved maize varieties to TLB infection. It is hypothesised that significant variation exists in both pathogen isolate characteristics and varietal resistance within the Wolaita Zone and that certain improved maize hybrids possess robust resistance suitable for deployment in TLB-prone environments.

Materials and Methods

Survey of maize turcicum leaf blight

Description of the study area

This study was conducted in the Wolaita Zone of Southern Ethiopia, a region distinguished by its diverse agroecology and key role in national maize production. Field surveys were conducted during the main maize-growing season (July–August 2023) across 4 major maize-producing woredas: Damot Gale, Boloso Sore, Damot Sore and Humbo. A total of 40 maize fields (10 per woreda) were systematically selected at 5–10 km intervals along primary transport routes, ensuring broad spatial coverage and reduced sampling bias. Woreda selection was based on marked differences in altitude, climate, soil characteristics, agronomic practices and vegetation, factors known to influence maize yield and the epidemiology of TLB. Damot Gale (07°03′06″ N, 36°16′30″ E; 2288 m AMSL) is characterised by a cool, dry climate (1150 mm annual rainfall, 18 °C mean temperature). Boloso Sore (7°04′ N, 37°42′ E; 2000 m above mean sea level (AMSL)) experiences moderate rainfall (841–1400 mm) and has a mean temperature of 21 °C. Damot Sore (6°73′125″ N, 37°74′742″ E; 1955 m AMSL) receives 1295 mm of rainfall and averages 20 °C, while Humbo (6°73′125″N, 37°74′742″E; 1800 m AMSL) is the lowest and warmest (1025 mm rainfall, 22.5 °C mean temperature) (9) (Fig. 1). This environmental variation allowed for a comprehensive assessment of local factors influencing TLB prevalence and severity.

Sample collection and disease assessment

Sample collection: A total of 40 maize fields were systematically surveyed to assess the occurrence and impact of TLB. From each field, 6 symptomatic maize leaves exhibiting classic TLB lesions, characterised by grey-green margins, tan centers and frequent dark fungal sporulation were collected to capture representative disease phenotypes across all sites. The infected leaves were air-dried and pressed flat between newspaper sheets using a botanical press to produce high-quality herbarium specimens. Each specimen was labelled with essential metadata, including geographic zone, district, farm identifier, collector's name and collection date, following established traceability standards (10). Labelled specimens were transported to the Plant Pathology Laboratory at Wolaita Sodo University, where the samples were stored at 4 °C to preserve their integrity for subsequent morphological and cultural analyses for pathogen identification.

Assessment of disease severity

Disease prevalence was quantified by evaluating both incidence and severity in each field. Thirty maize plants per field were assessed at the crop's anthesis-silking stage (July–August 2023), a critical period for TLB impact on yield. Plants were selected using a randomised walk that followed a "W" transect pattern (11), to ensure unbiased sampling.

Disease severity: Disease severity was visually assessed using a widely recognised 1–5 scale (12).

Where, 1 = no visible symptoms or presence of chlorotic flecks; 2 = 1–10 % of leaf area covered with hypersensitive lesions without acervuli; 3 = 11–25 % of leaf area covered with hypersensitive and restricted lesions without acervuli; 4 = 26–50 % of leaf area covered with coalescing necrotic lesions with acervuli and 5 = >50 % of leaf area affected. Numerical severity scores assigned to individual plants were subsequently converted into a disease index (DI) using the following formula (13):

$$\text{Disease index (DI)} = \frac{\text{Sum of numerical rating} \times 100}{\text{Total number of plant observed} \times \text{Maximum rating}}$$

Isolation and characterisation of *Exserohilum turcicum* isolates

A rigorous protocol was employed to isolate, purify and characterise *E. turcicum*, the causal agent of TLB in maize. The methodology comprised two main stages: (i) isolation and purification of the fungus from infected tissue and (ii) morphological and cultural characterisation of the fungal isolates.

Isolation and identification of *Exserohilum turcicum*

Symptomatic maize leaves with characteristic TLB lesions were collected. Small sections (~2 cm^2) were cut from infected areas and surface sterilised in 3 % sodium hypochlorite for 15–30 sec to remove contaminants. After thorough rinsing with sterile distilled water and blotting dry, the segments were placed on potato dextrose agar (PDA) plates. Plates were sealed with parafilm and incubated at 27 °C for 7 days. Developing fungal growth was monitored and hyphal tips were aseptically transferred to fresh PDA to obtain pure *E. turcicum* cultures (14).

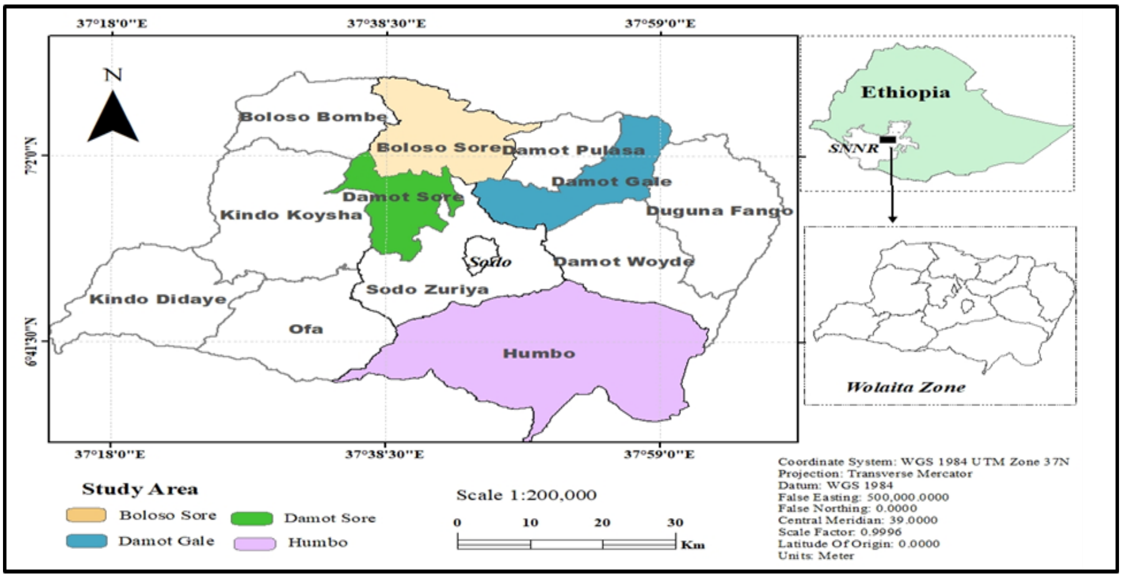

Fig. 1. Map of the study area.

Morphological and cultural characterisation

After 7 days of incubation, pure *E. turcicum* cultures were characterised based on both macroscopic and microscopic features. Colony morphology, including colour (determined using Munsell's color chart (15)), diameter, margin, form and elevation, was thoroughly documented. Colony diameter was measured daily to calculate average radial growth (mm day^{-1}), reflecting isolate variability. For microscopic analysis, sub-cultured isolates were suspended in sterile water, stained with lactophenol blue and examined using an Olympus CX23 light microscope at 400 × magnification. This allowed for detailed assessment of conidial and other diagnostic features, ensuring accurate identification and differentiation of *E. turcicum* isolates.

Response of maize varieties to turcicum leaf blight under field conditions

Description of experimental site

The field experiment was conducted during the main cropping season (March– April) in Humbo Woreda (Gututo Larena Kebele), Wolaita Zone, Southern Ethiopia. The site is located at 6°73'125" N latitude and 37°74'742" E longitude, at an altitude of 1800 m AMSL. Humbo receives an average annual rainfall of 1295 mm, with temperatures ranging from 14–26 °C throughout the year (9). Climate data, obtained from sub-stations of the Hawassa Meteorological Agency in 2023, provide essential context for the environmental conditions under which maize varieties were evaluated.

Field management and experimental design

Land preparation

The field was prepared by double ploughing before sowing to achieve a fine tilth suitable for maize germination. Shallow furrows were created for systematic sowing. Two fertilisers were used: blended NPSB (nitrogen, phosphorus, sulfur, boron) at 150 kg ha^{-1} applied at sowing and urea (46 % N) at 100 kg ha^{-1}, split equally between sowing and the knee-height stage. Standard agronomic practices, including timely weed control, were followed up to the anthesis-silking stage to ensure proper crop establishment and growth.

Experimental materials

Twelve improved maize varieties, MH-140, MH-141, BH-549, BH-661, AMH-852Q (Huluka), AMH-853 (Kolba), AMH-800, AMH-851 (Jibat), AMH-850 (Wenchi), AMBSYN-01 (Hora), AMH-854 and BH-546, were selected for their genetic diversity and varying resistance to TLB. This selection enabled a robust assessment of field response to natural TLB pressure in Humbo. Table 1 summarises each variety's pedigree, release year, recommended altitude and rainfall, TLB reaction and yield potential (16).

Treatments and experimental design

The experiment was conducted under natural TLB infection pressure. Each plot measured 3 × 4.5 m (13.5 m^2) and contained 6 rows with 30 cm intra-row and 75 cm inter-row spacing. Twelve maize varieties were arranged in a randomised complete block design (RCBD) with 3 replications to account for environmental variability. Plots were separated by 0.5 m, with 1 m between blocks, for a total area of 15.5 × 41.5 m (643.25 m^2). Seeds were sown at two per hole and thinned to one per stand 6 weeks after emergence, with 60 plants per plot (10 per row). This design enabled robust statistical analysis of varietal responses to TLB.

Data collection

Assessment of disease data and evaluation of yield components and yield

Disease assessments were performed 6 times at 10-day intervals, starting from the first appearance of TLB symptoms to physiological maturity. In each plot, 20 plants were randomly selected and tagged from the 4 central rows to ensure uniformity and minimise border effects. All subsequent disease evaluations were conducted on these plants (17). Disease severity was visually rated on a standardised 1–5 scale (12), allowing consistent quantification across varieties. Scores were converted to a percentage disease index for more intuitive comparisons (13). Disease progression was quantified using the area under the disease progress curve (AUDPC), integrating severity data from all 6 assessments and was calculated using the following formula (18):

$$AUDPC = \sum_{i-1}^{n-1} 0.5[(x_{i+1} + x_i)(t_{i+1} - t_i)]$$

Where, x_i is the percentage disease severity at the ith observation, t_i is the time (days after sowing) at the ith observation and n is the total number of observations. This approach yields a single value reflecting cumulative disease pressure over the entire assessment period, enabling robust comparisons of disease progression among maize varieties and treatments.

Thousand seed weight (TSW)

To determine the thousand-seed weight, a representative sample of 1000 kernels was collected from the harvested yield of each maize plot. The samples were counted using an electronic seed counter (Model: Yongjia SC-2000, counting accuracy ±1 seed, capacity up to 3000 seeds per batch), ensuring speed and precision in sample preparation. The seeds were then weighed using a precision digital balance (Model: Mettler Toledo ML204, readability 0.1 mg, maximum capacity 220 g), allowing

Table 1. Description of maize varieties with their different level of resistance to turcicum leaf blight

Varieties	Year of release	Altitude (m)	Rainfall (mm)	Reaction to TLB	Yield potential (t ha^{-1})
MH-140	2013	1000–1800	1000–1800	R	6.5–7.5
MH-141	N/A	N/A	N/A	N/A	N/A
BH-549	N/A	N/A	N/A	N/A	N/A
BH-546	2013	1000–2000	N/A	T	6.5–7.5
BH-661	2011	1600–2200	1000–1500	T	6.5–8.5
AMH-852Q	2016	1800–2400	1000–1200	N/A	N/A
AMH-853	2016	1800–2600	1000–1200	T	9–12
AMH-800	2005	N/A	N/A	N/A	N/A
AMH-851	2009	1800–2600	1000–1200	R	7–9
AMH-850	2008	1800–2600	1000–1200	MT	N/A
AMH-854	2005	1800–2600	1800–2600	T	6–8
AMBSYN-01	N/A	N/A	N/A	N/A	N/A

R: Resistant; T: Tolerant; MT: Moderately tolerant; S: Susceptible and N/A: Not available; TLB: Turcicum leaf blight.

for highly accurate mass determination. All weights were adjusted to a standard moisture content of 12.5 % to ensure accuracy and comparability among samples (19).

Grain yield (GY)

Grain yield was measured by harvesting all maize plants within each plot, shelling the ears and weighing the grain using an electronic balance. The moisture content of each sample was determined with a digital moisture tester and adjusted to the standard 12.5 % level (19). Adjusted GY (kg ha^{-1}) was calculated according to the formula presented below:

$$\text{GY (kg plot}^{-1}) = \frac{\text{Field weight of grains (kg)}}{100 - \text{Moisture content}} \times 100$$

This standardised procedure accounts for variations in grain moisture and plot size, ensuring reliable and comparable yield estimates across all maize varieties and experimental treatments.

Data analyses

Comprehensive statistical analyses were conducted to evaluate the distribution and impact of TLB across the Wolaita Zone. For each surveyed woreda, the mean incidence and severity of TLB were calculated to capture spatial patterns and disease intensity. Growth characteristics of *E. turcicum* isolates, including colony diameter and growth rate, were analysed using one-way analysis of variance (ANOVA) to detect significant differences among strains. All data analyses related to disease prevalence, severity and pathogen growth characteristics were conducted using Genstat statistical software, which is widely utilised in agricultural research for its robust statistical capabilities.

Field experiment data, including disease severity, i.e., percent severity index (PSI) and AUDPC, were compared among maize varieties using ANOVA within the generalised linear model (GLM) framework in Genstat (16th edition) (20). Significant differences were further analysed using Fisher's least significant difference (LSD) test at the 5 % probability level (21), providing a reliable basis for comparing varietal responses to TLB.

To assess disease progress, the progression of disease incidence and severity over time was evaluated by constructing disease progress curves (DPCs) for each crop variety. The disease progress rate was quantified using EPIMODEL software, developed in Java (22). This software facilitated the visualisation and simultaneous fitting of temporal disease data to 5 commonly utilised population growth models in plant epidemiology: linear, monomolecular, exponential, logistic and Gompertz models (22, 23). These models were applied in order of increasing complexity, from linear to Gompertz.

Model selection was guided by a set of criteria, including the number of data points, inspection of residual plots and assessment of goodness-of-fit through residual diagnostics (23). When necessary, appropriate transformations of the dependent variable were performed to linearise the models and transformed disease intensity values were regressed against time (days) to estimate the y-intercept (y) and apparent infection rate (r) parameters. Significant F-statistics prompted further evaluation using the coefficient of determination (R^2) and the standard error of the y estimate (SEEy) to determine the best-fit model.

The apparent infection rate (r), representing the slope of the regression line of transformed disease intensity versus time was estimated for each variety according to established methods (24, 25). For additional statistical rigor, the lme4 package in R-software package (26) was employed to calculate the infection rates across varieties, allowing for robust mixed-effects modeling. This approach provided a comprehensive assessment of disease progress and model fit, enabling accurate characterisation of disease dynamics in relation to crop variety.

Agronomic data (yield components and yield) were subjected to ANOVA via the GLM procedure in Genstat, with significant effects further examined using LSD at the 5 % level. Relationships among disease parameters (PSI, disease progress rate and AUDPC) and yield components or yield were evaluated using Pearson correlation analysis. All analyses were performed using Genstat, ensuring robust and precise statistical evaluation.

Results

Current status of maize turcicum leaf blight in surveyed areas

Turcicum leaf blight was detected in all surveyed districts of Wolaita Zone, but incidence and severity varied significantly by location (Table 2). The highest TLB incidence was observed in Damot Sore (92.3 %) and Humbo (92.0 %), while Boloso Sore recorded the lowest (72.3 %). Disease severity, expressed as the mean PSI, was highest in Damot Sore (73.9 %), followed by Humbo (66.3 %) and Damot Gale (41.3 %); while Boloso Sore recorded the lowest severity (30.0 %). Thus, TLB is endemic throughout the study area, although its intensity is spatially heterogeneous.

Morphological characteristics of *Exserohilum turcicum*

Isolates of *E. turcicum* exhibited marked morphological diversity in colony colour, form, margin and elevation (Table 3). Diverse colony colour types were observed, with grey and white being the most prevalent (Fig. 2). Colony morphology ranged from circular to rhizoid forms, with margins predominantly undulate or entire. Elevation was generally flat or raised. This morphological diversity was observed both within and among districts.

Mycelial growth of *Exserohilum turcicum*

A total of 12 numbers of *E. turcicum* isolated and demonstrated significant differences in mycelial growth rate on PDA at 27 °C ($p \leq 0.05$), ranging from 6.45 mm day^{-1} (H-102) to 12.86 mm day^{-1} (H-91, DG-52, H-23, H-82). Colony diameters after 7 days ranged from 45.17 mm to 90 mm, highlighting substantial variability among isolates (Table 4).

Table 2. Prevalence of maize turcicum leaf blight in four districts of Wolaita Zone, southern Ethiopia, during the 2023 crop season

District	Diseases incidence (%)		PSI	
	Mean	SD	Mean	SD
Humbo	92.00	6.77	66.30	13.42
Damot Gale	84.30	0.92	41.30	11.57
Damot Sore	92.30	7.07	73.90	21.02
Boloso Sore	72.30	12.29	30.00	22.87

SD: Standard deviation; PSI: Percent severity index.

Table 3. Morphological characteristics of different accessions of *Exserohilum turcicum*

Isolates	Macroscopic colony features			Colony colour	
	Colony form	**Colony elevation**	**Colony margin**	**Obverse colour**	**Reverse colour**
H-23	Irregular	Convex	Undulate	Light grey	White
H-72	Irregular	Raised	Undulate	White	Pinkish white
H-82	Circular	Raised	Entire	White	Pale brown
H-91	Circular	Flat	Entire	Grey	Greyish brown
H-102	Rhizoid	Flat	Undulate	Reddish yellow	Yellow
DG-52	Filamentous	Raised	Filiform	Light grey	Light grey
DG-92	Rhizoid	Flat	Lobate	Pinkish white	Pinkish white
DG-101	Filamentous	Raised	Filiform	Light grey	Pale brown
DS-71	Irregular	Flat	Undulate	Greyish white	Very dark brown
DS-92	Circular	Flat	Entire	Brown	Light yellowish Brown
BS-32	Irregular	Flat	Undulate	Brown greyish	Dark brown
BS-91	Circular	Raised	Entire	White	Pinkish white

Isolates H-23, H-82, H-91, H-72 and H-102 were obtained from Humbo; DG-52, DG-101 and DG-92 from Damot Gale; DS-71 and DS-92 from Damot Sore; and BS-32 and BS-91 from Boloso Sore.

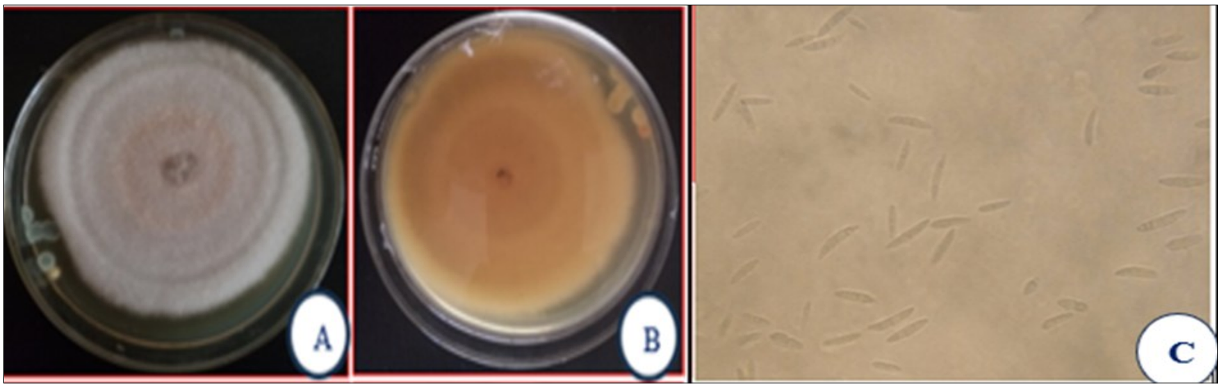

Fig. 2. (A & B) Front and reverse side of the colony; (C) Conidia of *Exserohilum turcicum*.

Table 4. Mycelial growth diameter and culture growth rate of *Exserohilum turcicum* isolates on potato dextrose agar

Isolate	Growth rate (mm day^{-1})	Mycelial growth (mm) after 7 days of incubation
H-23	12.86^{a}	90.00^{a}
DG-52	12.86^{a}	90.00^{a}
H-82	12.86^{a}	90.00^{a}
H-91	12.86^{a}	90.00^{a}
DS-92	12.81^{a}	89.67^{a}
DG-101	12.76^{a}	89.33^{a}
BS-91	12.31^{b}	86.17^{b}
DS-71	12.21^{b}	85.50^{b}
BS-32	10.24^{c}	71.67^{c}
DG-92	8.93^{d}	62.50^{d}
H-72	6.71^{e}	47.00^{e}
H-102	6.45^{e}	45.17^{e}
LSD (0.05)	0.20**	1.40**
CV (%)	1.10	1.10

Isolates H-23, H-82, H-91, H-72 and H-102 were obtained from Humbo; DG-52, DG-101 and DG-92 from Damot Gale; DS-71 and DS-92 from Damot Sore; and BS-32 and BS-91 from Boloso Sore. Means within a column followed by the same letter are not significantly different according to LSD at a 5 % probability level. LSD: Least significant difference; CV = Coefficient of variation.

Disease development of turcicum leaf blight

Field evaluation in 2023 showed statistically significant variation in TLB response among maize varieties.

Initial disease severity

Initial TLB severity (PSI) differed significantly among varieties ($p \leq 0.05$) (Table 5). The highest initial PSI was recorded in maize variety MH-140 (22.83 %), whereas BH-549, AMH-853, AMH-854, AMH-852Q, AMH-8500 and AMBSYN-01 exhibited minimal initial severity, ranging from 1.66 to 3.85 %.

Final disease severity

Final PSI varied significantly ($p \leq 0.05$), with maize variety MH-140 being the most susceptible at 68.75 %, followed by BH-661 (56.53 %), BH-546 (54.95 %) and MH-141 (52.50 %). The most resistant varieties were AMH-851, AMH-852Q, AMH-853 and AMH-800 (19.11–25.00 %).

Area under disease progress curve

Maize varieties differed significantly in AUDPC values ($p \leq 0.05$), ranging from 505–2496 % days (Fig. 3). Variety MH-140 recorded the highest AUDPC (2496 % days), indicating the greatest susceptibility, whereas AMH-851, BH-549 and AMH-853 had the lowest values suggesting resistance to TLB.

Best-fit model and disease progress rate

The Gompertz model best described TLB disease progress, as indicated by the highest R^2 and lowest mean squared error (MSE) (Table 6). The apparent epidemic rate estimated using the Gompertz model ranged from 0.0047 gompit day^{1} in AMH-852Q to 0.023 gompit day^{1} in BH-549, indicating significant variation in disease progression among maize varieties.

Table 5. Mean initial and final severity indices and parameter estimates for TLB in 12 maize varieties during the 2023 cropping season in Humbo, Wolaita Zone

Variety	PSI$_{Initial}$	PSI$_{Final}$
MH-140	22.83^{a}	68.75^{a}
BH-661	10.66^{b}	56.53^{b}
BH-546	8.85^{b}	54.95^{b}
AMH-800	4.91^{c}	25.00^{cd}
MH-141	4.58^{c}	52.50^{b}
AMBSYN-01	3.85^{cd}	27.65^{c}
AMH-850	3.77^{cd}	30.29^{c}
AMH-852Q	3.58^{cd}	23.09^{cd}
AMH-854	3.50^{cd}	30.58^{c}
AMH-853	3.21^{cd}	24.07^{cd}
AMH-851	2.64^{cd}	19.11^{d}
BH-549	1.66^{d}	23.27^{cd}
LSD (0.05)	2.290	8.201
CV (%)	21.9	13.3

Means within a column followed by the same letter are not significantly different according to LSD at the 5 % probability level. PSI$_{Initial}$: Initial percent severity index; PSI$_{Final:}$ Final percent severity index.

Disease progress curve (DPC)

The onset of TLB was observed 60 days after sowing. Disease progression was observed in all varieties; however, both the speed and severity of disease development differed among them (Fig. 4). The steepest disease progress curves and highest severity were observed in varieties MH-141 and BH-546. However, BH-549 maintained relatively low severity despite an initially rapid increase, indicating partial resistance. MH-140 showed gradual disease development but reached the highest final severity.

Agronomic performance

Thousand-seed weight and grain yield

Thousand seed weight varied significantly among the maize varieties ($p \leq 0.05$), with the highest values recorded in AMH-854 (433.5 g) and AMH-851 (405.6 g), whereas the lowest were observed in MH-141 (297.3 g) and BH-546 (315.3 g). Grain yield also differed significantly among varieties ($p \leq 0.05$) (Table 7). The highest GY was observed in AMH-851 (94.9 q ha^{-1}), followed by AMH-854 (89.1 q ha^{-1})

Table 7. Thousand seed weight and grain yield of 12 maize varieties tested at Humbo, Wolaita Zone, during the 2023 main cropping

Variety	TSW/g	GY (q ha^{-1})
AMH-854	433.5^{a}	89.1^{ab}
AMH-851	405.6^{ab}	94.94^{a}
BH-661	397.5ab^{abc}	88.83^{ab}
AMH-800	385.1^{bcd}	71.22^{bcd}
AMH-853	382.2^{bcd}	78.15^{abc}
MH-140	374.6^{bcde}	57.26^{d}
AMBSYN-01	368.1^{bcde}	79.26^{abc}
AMH-850	366.6^{cde}	77.29^{abc}
AMH-852Q	357.7^{de}	71.88^{bcd}
BH-6549	343.1^{ef}	81.44^{abc}
BH-546	315.3^{fg}	82.66^{abc}
MH-141	297.1^{g}	63.48^{cd}
LSD (0.05)	38.07**	19348.4*
CV (%)	6.11	14.70

Means within a column followed by the same letter are not significantly different at $p<0.05$ according to the LSD. LSD: Least significant difference; CV = Coefficient of variation; TSW: Thousand seed weight; GY: Grain yield.

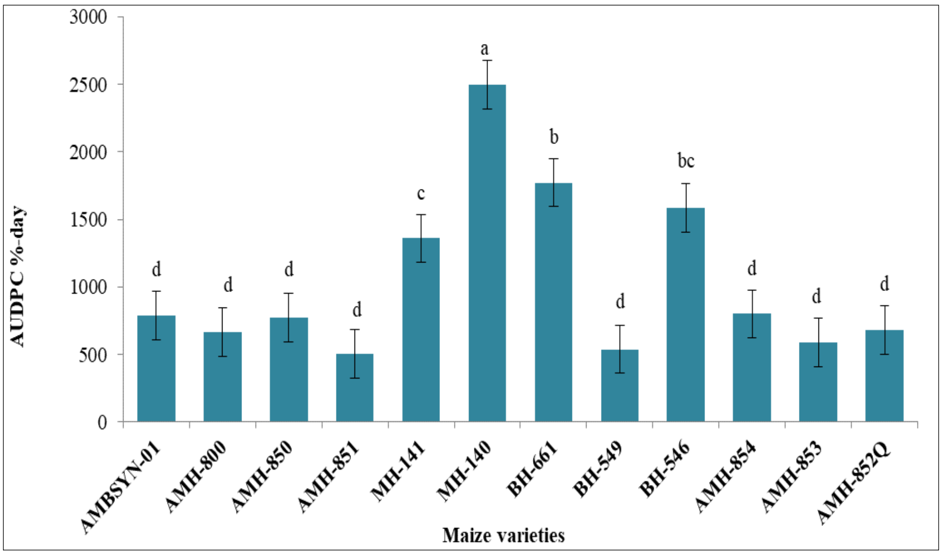

Fig. 3. Area under the disease progress curve for turcicum leaf blight on 12 maize varieties.

Table 6. The epimodel result of the best-fit model for turcicum leaf blight disease progress on 12 maize varieties

Variety	Best fit model	Intercept	Slope rate (day^{-1})	R^{2}	SEEy
AMBSYN-01	Monomolecular	-0.32	0.0049	0.991	0.01
AMH-800	Gompertz	-2	0.01	0.95	0.075
AMH-850	Gompertz	-2.31	0.01	0.994	0.03
AMH-851	Gompertz	-2.19	0.01	0.994	0.023
AMH-852Q	Linear	-0.2	0.0047	0.996	0.004
AMH-853	Gompertz	-2.37	0.018	0.9905	0.037
AMH-854	Gompertz	-2.4	0.021	0.992	0.038
BH-546	Linear	-0.48	0.009	0.992	0.017
BH-549	Gompertz	-2.9	0.023	0.956	0.1
BH-661	Monomolecular	-0.78	0.014	0.995	0.21
MH-140	Monomolecular	-0.85	0.018	0.97	0.06
MH-141	Linear	-0.58	0.01	0.98	0.08

SEEy : Standard error of the parameter estimates.

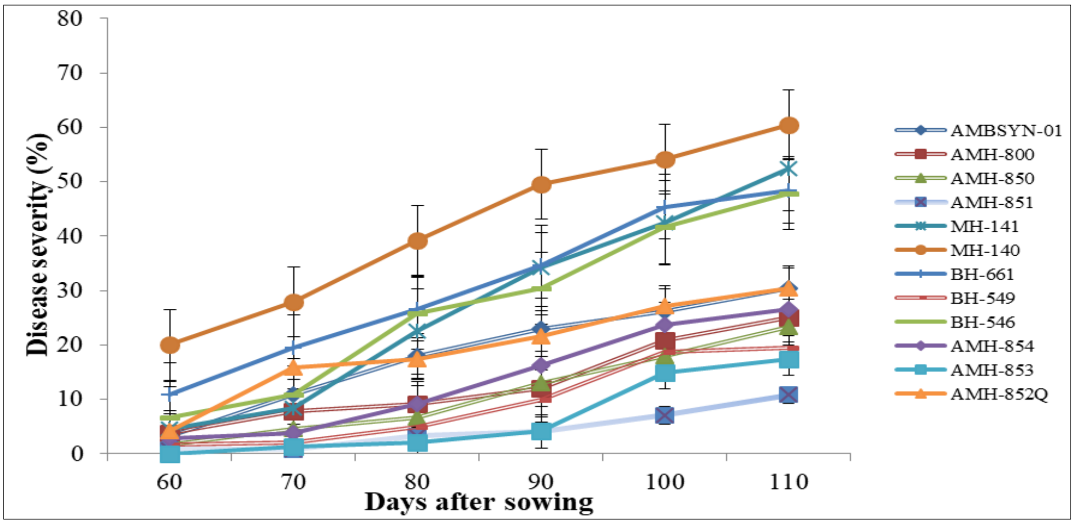

Fig. 4. Disease progression curves of turcicum leaf blight in 12 maize varieties.

and BH-661 (88.8 q ha^{-1}); while MH-140 (57.26 q ha^{-1}) and MH-141 (63.48 q ha^{-1}) produced the lowest yields.

Correlation analysis

Pearson correlation analysis revealed that most disease parameters were negatively associated with both GY and TSW, however, only the correlation between disease progress rate and TSW was statistically significant ($r = -0.585$, $p = 0.046$). Associations between PSI, AUDPC and yield or TSW were weak or not statistically significant (all $p>0.10$), suggesting that these factors had little to no direct effect on the agronomic traits measured in this study (Table 8).

Overall, AMH-851 and AMH-854 were the most resistant and highest-yielding varieties, whereas MH-140 and BH-546 were the most susceptible and lowest-yielding.

Table 8. Relationship between disease variables and yield parameters

	TSW	GY
TSW	1	
GY	0.47^{NS}	1
$PSI_{Initial}$	-0.0062^{NS}	-0.494^{NS}
PSI_{Final}	-0.32^{NS}	-0.425^{NS}
DPR	-0.585*	0.040^{NS}
AUDPC	-0.202^{NS}	-0.450^{NS}

NS: non-significant; * indicate correlation significance at the 0.05 levels; DPR: Disease progressive rate; TSW: Thousand seed weight; GY: Grain yield.

Discussion

Disease distribution and environmental factors

The spatial heterogeneity of TLB incidence and severity observed in the Wolaita Zone reflects the influence of local environmental and agronomic factors such as humidity, temperature, varietal selection and crop management. High disease pressure in districts like Damot Sore and Humbo likely results from favourable microclimates and the prevalence of susceptible maize varieties. These findings agree with prior Ethiopian and regional studies, which consistently report that warm, humid environments and poor residue management increase TLB risk (3, 4). Notably, the need for site-specific, integrated disease management remains clear, as environmental variability significantly shapes epidemic outcomes.

Morphological diversity of *Exserohilum turcicum*

The study confirms substantial morphological diversity among *E. turcicum* isolates, manifesting in variations in colony colour, form, margin and elevation. This plasticity, driven by both genetic and environmental factors, supports previous reports from Ethiopia and the broader area (4, 6). Such diversity has practical implications: it may signal underlying variation in pathogenicity or resistance to fungicides, thus complicating management and breeding efforts. Characterising this diversity is vital for resistance screening and the design of integrated disease management strategies.

Varietal response and resistance mechanisms

Marked varietal differences in TLB severity and epidemic development (as measured by AUDPC) highlight the central role of genetic resistance. Specifically, resistant maize varieties such as BH-546 and Melkassa-2 showed both delayed onset of TLB symptoms and reduced final disease severity compared to susceptible varieties like Local and BH-660. This pattern is consistent with previous national and regional findings, underscoring the effectiveness of deploying genetically resistant varieties to manage TLB in maize (3, 5, 6). The use of the Gompertz model facilitated robust assessment of resistance by quantifying apparent infection rates and disease progress. While technically informative, the practical value of this approach lies in its ability to distinguish among resistance levels and support breeding programs. The strong negative correlation between disease severity and both yield and seed weight underscores the economic benefit of deploying resistant cultivars.

Implications for disease management and breeding

The findings reinforce the need for a holistic, adaptive approach to TLB management in Ethiopia. The integration of resistant varieties improved agronomic practices and ongoing surveillance is essential to reduce reliance on fungicides and maintain yield stability. Continuous monitoring of pathogen diversity and disease dynamics will support the deployment of durable resistance and timely interventions. Multi-location and multi-year trials remain crucial for identifying varieties with stable resistance across diverse environments.

Comparison with previous Ethiopian studies

The present results largely concur with earlier Ethiopian research, confirming the central roles of environmental factors, pathogen diversity and host resistance in shaping TLB epidemics (3, 4). However, the observed diversity in both pathogen morphology and varietal responses suggests ongoing evolution and adaptation within the pathosystem, highlighting the importance of continued research and surveillance.

Conclusion

This study demonstrates that turcicum leaf blight, caused by a morphologically diverse population of *Exserohilum turcicum*, is prevalent and poses a significant threat to maize production in the Wolaita Zone. Disease incidence and severity were highest in Damot Sore and Humbo, with substantial pathogen diversity observed across the region. Among 12 improved maize varieties evaluated, AMH-851 and AMH-854 hybrids showed robust resistance to TLB, while MH-140, BH-546 and MH-141 were highly susceptible. The strong negative impact of TLB on grain yield and thousand seed weight underscores the urgent need for integrated management.

Practical recommendations include prioritising the adoption of resistant hybrids, particularly AMH-851 and AMH-854, in disease-prone areas and validating their performance through multi-location field trials. Ongoing farmer education in disease identification and integrated management is essential for effective control. Future research should focus on molecular characterisation of *E. turcicum* populations and on understanding genotype-by-environment interactions to support breeding for durable resistance. Advancing these research priorities will enhance the resilience of maize production systems in Ethiopia and similar agroecological zones.

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Authors' contributions

AN and DB contributed to the design of the research proposal, fieldwork, data collection, analysis and interpretation of the data using SAS software version 9.20, in addition to manuscript preparation. MK and LG assisted in the analysis and interpretation of the data, along with writing the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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