Application of logistic regression model for predicting the association of climate change resilient cultural practices with early blight of tomato (*Alternaria solani*) epidemics in the East Shewa, Central Ethiopia

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**ABSTRACT**

A field survey was conducted to determine the distribution and importance of early blight of tomato in East Shewa, Central Ethiopia. A total of 140 tomato fields were inspected in 4 districts (Adama, Lome, Dugda, and Bora). The associations of early blight incidence and severity with independent variables were evaluated. Disease incidence was found higher in Dugda (72.19%) and Bora (62.28%) districts. The highest mean disease severity was 31.39% in Dugda and 26.09% in Bora district, while the lowest was recorded in Adama (14.71%) district. In reduced multiple variable models, early blight percentage severity index >25% showed a high probability of association with all parameters. Logistic regression analyses of disease severity revealed that some traits were found among the most significant variables. Overall, proper weed management practices, crop rotation with non-solanoaceous hosts, and other related farm practices should be carried out to reduce the impact of early blight on tomatoes.

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*Alternaria solani; disease severity; Solanum lycopersicum; weed density*

**1. Introduction**

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family of Solanaceae. It is the second most important economically important vegetable in the World (Ibitoye et al. 2009; Muriel et al., 2019). In Ethiopia tomato is one of the most important and widely grown vegetable crops, both during the rainy and dry seasons for its fruit by smallholder farmers, commercial state, and private farms (Emana et al. 2014; Kibru et al. 2018). The total production of tomatoes in Ethiopia has shown a marked increase since it became the most profitable crop providing a higher income to small-scale farmers compared to other vegetable crops (Lemma 2002; Elms 2020). Most of the largest area of production is done in the rift valley, mainly along Awash River Valley and around the Rift Valley lakes. The national average yield of tomatoes in Ethiopia is very low which is around 9.3 tons/ha and less than 50% of the current world average yield of about 27 tons/ha (CSA 2017). Despite its importance, the crop is vulnerable to bacterial, viral, nematode, and fungal diseases. Among fungal diseases, early blight caused by *Alternaria solani* (Ellis and Martin) is the important foliage and fruit disease causing yield losses of about 79% in the World and 53% in Ethiopia (Chaerani et al. 2006; Desta and Yesuf 2015; Dey et al. 2019).

*Alternaria solani* is a soil-inhabiting air-borne pathogen responsible for leaf blight, collar, and fruit rot of tomato disseminated by fungal spores (Desta and Yesuf 2015). It is an important disease of tropical and subtropical areas. Distinctive bull-eye patterns of leaf spots with concentric rings of spores surrounded by a halo of chlorotic leaf area are common. The plant leaves become yellow and dry up when only a rare spot is existing (Datar et al. 1981; Riley et al. 2002; Dey et al. 2019). The pathogen causes infection on leaves, stem, petiole, twig, and fruits that leads to the defoliation, drying of twigs, and premature fruit drop thereby ultimately reducing the yield. The other important things that can play roles are various climatic factors. Under high temperature and humidity (crowded plantation, high rainfall, and extended period of leaf wetness from dew) the plants are more susceptible to blight infection during the fruiting period (Gleason et al. 2006; Meno et al. 2020). Diseases caused by *Alternaria solani* are controlled primarily through the use of chemical sprays with fungicides, and disease free or treated seeds, adequate nitrogen fertilizer were generally reduces the rate of infection by *Alternaria solani*. Crop rotation, removal and burning of crop debris (if infected), and eradication of weed hosts help in reducing the inoculum potential for subsequent plantings of susceptible crops (Agrios, 2005). In Ethiopia, control of early blight is largely dependent on fungicidal application. Because of the polycyclic nature of the disease, several applications of fungicides are required to offer an adequate protection of the tomatoes from early blight attacks. However, the application of fungicide is generally associated with issues of environmental pollution, high production costs, and the risk of fungicide resistance that may arise due to excessive application of fungicides (Rai et al. 2006; Meno et al. 2020). The use of resistant cultivars in the control of early blight offers an economical and environmentally friendly alternative consistent with the objective of integrated pest management (Abuley et al. 2018). Unfortunately, no tomato cultivar has been reported to be completely resistant to early blight in Ethiopia. Because of the continued cultivation of tomatoes in major growing areas of Ethiopia, early blight is a constant threat...
throughout the year. Therefore, it is important to quantitatively determine its distribution and associated factors affecting disease development. Indeed, sustainable management of the disease requires an understanding of the factors affecting early blight, which is lacking in Ethiopia. Hence, the objectives of this study were to determine: (i) distribution of early blight of tomato in major growing areas of East Shewa, Ethiopia, and (ii) association of the disease incidence and severity with climate change resilient cultural crop management practices.

2. Materials and methods

2.1. Description of the study area

A disease survey was conducted in the central rift valley areas in four districts (Adama, Bora, Lome, and Dugda) during the main cropping season (Figure 1). This research survey was conducted from July - August 2018. The timing of the survey was chosen to coincide with the time of fruit formation and flowering in the surveyed districts.

2.2. Survey methods and disease assessments

From each district, five Kebele (peasant association) were considered for the survey, and from each Kebele, seven crop fields were selected along the main roads and accessible rural areas. The survey was conducted by inspecting tomato fields and interviewing growers in the surveyed area. In each farmer’s field surveyed, a 4m² quadrant was used to sample plants along an X-shaped transect. The quadrant was thrown three times on sampling points that were at least 9 m apart, with the three throws representing three replications per field. Following each throw, the number of healthy and infected 10 plants within the field was recorded. Early blight of tomato incidence was rated as a mean percentage of diseased plants within the quadrant. Severity was rated by estimating the percentage of leaf area diseased from the same 10 representative plants in each quadrant, using a rating scale of Latha et al. (2009), where, 0 = no disease, 1 = 1-5%, 2 = 6-10, 3 = 11-25, 5 = 26-50, 7 = 51-75, and 9 ≥ 76, of the leaf area infected. The scores were converted into percentage severity index (PSI) using the formula of Ibrahim et al. (2004).

\[
\text{Percentage severity index (PSI)} = \frac{T}{N} \times 100
\]

Where, \(T\) = number of infected leaves per plant; \(N\) = total number of leaves per plant.

During the survey, altitude (m), cropping stage, weed density, and plant density were recorded for each sampled field. Growers were asked for information on the date of planting, previous crop, fertilization, and chemical applied for the early blight of tomato management.

2.3. Data analyses

Disease incidence and severity data were classified into distinct groups of binomial qualitative data. Thus, <50 and ≥50 were chosen for early blight incidence and ≥25 and <25 for early blight severity, yielding binary dependent variables (Table 1). Categorized independent variables that were used in the analysis are presented. Contingency tables of disease intensity and the independent variables were built to represent the bivariate distribution of fields according to two classifications (e.g. district by early blight severity). An entry in a cell of a contingency table represents the frequency of fields falling into that cell. Several contingency tables were combined into a single matrix. The association of early blight incidence and severity with independent variables was analyzed using logistic regression as described by Yuen et al. (1996) with the SAS Procedure GENMOD (2008). The logistic regression model allows evaluating the importance of multiple independent variables that affect the response variable. Similar analyses were also employed by previous studies to determine the association between independent variables with disease incidence and/or severity (Fininsa and Yuen 2001; Belete et al. 2013).

Logistic regression calculates the probability of a given binary outcome (response) as a function of the independent variables (McCullagh and Nelder 1989; Fullerton 2020). In this case, the binary outcome was the probability that early blight incidence exceeds 50% and severity exceeds 25% in a given tomato field. The GENMOD procedure gives parameter estimates and the standard error of the parameter estimates. Exponentiation of the parameter estimate yields the odds ratio, which is interpreted here as the relative risks (Kumar and Barnwal 2017). The importance of the independent variables was early blight evaluated in three ways. First, the association of an independent variable along with disease incidence or severity was tested. This consists of testing the deviance reduction attributed to a variable when it was first entered into the model. Second, the association of an independent variable with disease incidence or severity was tested when entered last into the model with all other independent variables. Third, variables with a high association to disease intensity when entered first and last into a model were added to reduced multiple variable models. A complete analysis of the deviance table was generated for the final reduced multiple variable models, where deviance reduction (DR) was calculated for each variable as it was added to the reduced model. The deviance (−2 \(x\) log-likelihood) was used to compare single and multiple variable models. The difference between the two models, known as a likelihood ratio test (LRT), was used to examine the importance of the variable and was tested against a \(\chi^2\)
3. Results

3.1. Disease incidence and severity

Different levels of early blight tomato incidence and severity were recorded among the districts. The mean disease incidence was higher in Dugda (72.19%) and Bora (62.28%) districts (Table 2). The highest mean disease severity ranged from 31.39% (Dugda) to 26.09% (Bora), while the lowest was recorded in Adama (14.71%) district. Weeding in general was not done in tomato fields (Figure 2). A higher mean disease severity of early blight (27.68%) was observed in fields with a higher weed population compared with a lower weed population (18.82%). The weeds commonly observed during the survey were Solanum nigrum, Amaranthus hybri dus, Datura stramonium, Commelina bengalensis, Cypereus esculentus, Ipomea arciocarpa, and Chenopodium procurner. Similarly, the highest disease severity was observed in crops at high density (22.95%), while the lowest was observed in fields at low crop density (24.06%). Disease incidence and severity varied significantly with the date of planting. Early planting had higher disease severity (24.06%), while late planting had lower disease severity (19.28%). Disease incidence was also higher in early planting (65.69%) when compared to late planting (52.89%).

3.1.1. Association of climate changes resilient cultural practices with the disease intensity

The association of all independent variables with early blight incidence and PSI is presented in Table 3. The independent variables varied in their association with early blight. All the variables except fertilization, fungicides, and crop density were significantly associated with early blight incidence when entered first into a logistic regression model as a single variable (Table 3). However, when all variables entered last into the regression model, fungicides and crop density showed significant association with early blight incidence in addition to other variables. All the variables except fertilization, fungicides, crop density, and previous crop were significantly associated with early blight severity when entered first into a logistic regression model as a single variable. However, when all variables entered last into the regression model previous crop, fungicides, and crop density gained importance when entered last into the model with the addition of other variables (Table 3).

Analysis of deviance for the variables, parameter estimates, standard error, and odds ratio was given in (Table 4). The probability of high early blight incidence was highly associated with Dugda district and altitude ≥1600. Low early blight incidence had a high probability of association to Adama district, weed density <65, late planting date, during flowering, and in non-solanum hosts. In Dugda district and altitude ≥1600, there was three times the greater probability that early blight incidence will exceed 50% (Table 4). Similarly, the highest early blight severity had shown that a high probability of association when altitude exceeds1600 m.a.s.l, dense weed population (≥65), and Dugda district (Table 5). The probability of low early blight severity was highly associated with Adama, flowering stage, weed density <65, and late planting.

4. Discussion

Early blight of tomato was found to be widely distributed in all the surveyed districts. The weather conditions during the survey were conducive to early blight attacks (Table 6). Relatively, higher rainfall was noted in Dugda and Bora districts
during the growth period, whereas lower rainfall in Lome and Adama districts. Many workers have studied various weather factors for the disease development of *A. solani* (Chothihani et al. 2017; Kumar and Barnwal 2017). In humid areas with frequent rains followed by hot and dry weather, the disease imposes considerable reductions in yield (Yazici et al. 2011). *A. solani* in severe cases, can lead to complete defoliation of plants. The disease is most damaging on tomatoes in regions with heavy rainfall, high humidity, and high temperatures (22–29 °C). However, epidemics of early blight can also occur in semi-arid climates, where frequent and prolonged nightly dews occur (Chaerani and Voorips 2006; Selim 2015). Furthermore, as the rain splash, spores are dispersed from one place to another place and start initiation pathogen infection. According to Dessie (2017), heavy rainfall and cloud cover interfered with light penetration thereby affecting metabolic activity of the crop and favor disease development, and restrict plant growth of tomato plants.

The present study showed that higher disease severity was observed in fields cultivated with Solanaceous families the previous year. *A. solani* indeed survives from season to season on decaying plant material in the soil. Since early blight can infect all the solanaceous crops, it is expected to be higher in fields preceded by solanaceous crops and a rotation with non-solanaceous crops spaced three to five years helps in controlling the disease (Foolad et al. 2008; AFE 2021). Volunteer tomatoes and potatoes can serve as a source of inoculums and it overwinters as thick-walled survival spores, chlamydospores (Windham et al. 2008). Early blight survives between crops in or on the residue from diseased plants, so it is important to remove diseased plants or destroy them immediately after harvest. Alternatively, burying diseased crop debris by deep plowing reduces spore levels available for infection of new plants.

Tomato early blight severity and incidence were higher in fields with dense weed populations. Solanaceous weeds like *Solanium nigrum*, should be eliminated as they may harbor pathogen inoculum. Sahile et al. (2008) and Adhikari et al. (2017) reported that high weed density in non-weeded fields increased more favorable for *Botrytis fabae* infection and the development of chocolate spot disease epidemics. This might be due to the pathogen is not exposed to direct sunlight and humidity is high as compared to weeded tomato fields. Bravo et al. (2012) reported shade improved the microclimate for the foliar disease of coffee development in the warm region of the study. Besides, high weed invasion could reduce plant

![Figure 2](image-url)

**Figure 2.** Linear regression relating early blight Percentage severity index (PSI) disease severity with weed population in tomato fields during 2018 cropping season (source: 2018 survey).

Table 3. Independent variables used in logistic regression modeling of early blight of tomato incidence and percentage severity index (PSI) and likelihood ratio test (LRT) for nine variables entered first and last into a model.

| Independent Variable | Df | Incidence LRT | Type 1 analysis | Type 3 analysis | PSI LRT | Type 1 analysis | Type 3 analysis |
|----------------------|----|---------------|----------------|----------------|--------|----------------|----------------|
|                      |    |               | DR  | Pr > χ² | DR  | Pr > χ² | DR  | Pr > χ² |
| District             | 3  | 66.8          | <.0001 | 80.13 | <.0001 | 49.97 | <.0001 | 58.6 | <.0001 |
| Altitude             | 1  | 7.35          | 0.006 | 6.52  | 0.01  | 9.36  | 0.0022 | 7.9  | 0.0049 |
| Crop density         | 1  | 1.79          | 0.181 | 5.15  | 0.0232 | 1.16  | 0.2806 | 5.44 | 0.0196 |
| Fertilization        | 1  | 0.99          | 0.32  | 0.49  | 0.483 | 0.33  | 0.5647 | 0.05 | 0.8199 |
| Fungicides           | 1  | 0.9           | 0.343 | 11.07 | 0.0009 | 0.8   | 0.3696 | 9.13 | 0.0025 |
| Growth stage         | 1  | 21.35         | <.0001 | 7.13  | 0.0076 | 32.9  | <.0001 | 10.98 | 0.0009 |
| Planting date        | 1  | 13.07         | 0.0003 | 6.09  | 0.0136 | 20.91 | <.0001 | 6.21  | 0.0127 |
| Previous crop        | 5  | 12.77         | 0.025 | 18.61 | 0.002 | 7.71  | 0.1733 | 12.21 | 0.032 |
| Weed density         | 1  | 5.52          | 0.018 | 9.9   | 0.0016 | 6.57  | 0.0104 | 10.89 | 0.001 |

Type 1 analysis, variable entered first; Type 3 analysis, variable entered last; Df, degrees of freedom; DR, deviance reduction; Pr, probability of a value χ² exceeding the deviance reduction.
was more severe when the altitude was above 1600, it had canopy which promotes disease development. The disease infestation also, increases the humidity within the crop. Previous crop effects of disease intensity is more severe during fruit formation as the age of plants increased (Ngoc 2011). A. solani indicated that tomatoes became increasingly susceptible to disease as the age of the host.

Table 4. Analysis of deviance, natural logarithms of odds ratio and standard error of added variables in a reduced model analyzing early blight of tomato incidence.

| Added Variable | Df | Residual Deviance | DR  | Pr > χ² | Variable Class | Estimate Loga | SEb | Odds ratio⁵ |
|---------------|----|-------------------|-----|---------|----------------|---------------|-----|------------|
| Intercept     |    |                   |     |         |                | 1.06          | 0.38 | 2.89       |
| District      | 3  | 193.6             | 66.8| <0.0001 | Adama          | -0.99         | 0.90 | 0.36       |
|               |    |                   |     |         | Bora           | -1.79         | 0.54 | 1.10       |
|               |    |                   |     |         | Dugda          | 1.21          | 0.69 | 3.35       |
| Altitude      | 1  | 186.61            | 7.35| 0.0067  | ≥1600          | 0.95          | 0.36 | 2.59       |
|               |    |                   |     |         | <1600          | 0*            | 1.00 |            |
| Planting date | 1  | 180.89            | 13.07| 0.0003 | Early          | 0*            | 1.00 |            |
| Growth stage  | 1  | 172.61            | 21.35| <0.0001 | Flowering      | -1.63         | 0.37 | 0.20       |
| Weed density  | 1  | 188.44            | 5.52| 0.0188  | Fruiting       | 0*            | 1.00 |            |
| Previous crop | 5  | 181.19            | 12.77| 0.0256 | Allium         | -0.62         | 0.64 | 0.53       |
|               |    |                   |     |         | Cereal         | -1.67         | 0.53 | 0.19       |
|               |    |                   |     |         | Legume         | -0.608        | 0.74 | 0.54       |
|               |    |                   |     |         | Mustard        | -0.41         | 0.65 | 0.67       |
|               |    |                   |     |         | Solanum        | 0*            | 1.00 |            |
|               |    |                   |     |         | Other          | -1.05         | 0.64 | 0.35       |

*, Reference group; Df, degrees of freedom; LRT, likelihood ratio test; DR, deviance reduction; Pr, probability of a χ² value exceeding the deviance reduction; aEstimate are from the model with all independent variables added; bStandard error of the estimate; cExponentiation the estimates

Table 5. Analysis of deviance, natural logarithms of odds ratio and standard error of added variables in a reduced model analyzing early blight of tomato percentage severity index (PSI).

| Added Variable | Df | Residual Deviance | DR  | Pr > χ² | Variable Class | Estimate Loga | SEb | Odds ratio⁵ |
|---------------|----|-------------------|-----|---------|----------------|---------------|-----|------------|
| Intercept     |    | 193.8             | 49.71| <0.0001 | Adama          | 0.799         | 0.36 | 2.18       |
| District      | 3  | 144.1             | 4.91|         | Bora           | -3.0478       | 0.86 | 0.047      |
|               |    |                   |     |         | Dugda          | 0.61          | 0.56 | 1.83       |
| Altitude      | 1  | 186.285           | 7.54| 0.006   | ≥1600          | 0.97          | 36.16| 2.65       |
|               |    |                   |     |         | <1600          | 0*            | 1    |            |
| Weed Density  | 1  | 188.5092          | 5.31| 0.0211  | ≥65           | 0             | 0    | 1          |
| Growth Stage  | 1  | 163.2764          | 30.55| <0.0001 | Flowering      | -1.79         | 0.35 | 0.17       |
| Planting Date | 1  | 174.253           | 19.57| <0.0001 | Early          | 0*            | 1    |            |
|               |    |                   |     |         | Late           | -1.56         | 0.36 | 0.21       |

*, Reference group; Df, degrees of freedom; LRT, likelihood ratio test; DR, deviance reduction; Pr, probability of a χ² value exceeding the deviance reduction; aEstimate are from the model with all independent variables added; bStandard error of the estimate; cExponentiation the estimates

Table 6. Summary of monthly weather conditions of surveyed districts in East Shewa, Central Ethiopia during 2018 cropping season.

| Districts | Weather variable | May | June | July | August | September |
|-----------|------------------|-----|------|------|--------|-----------|
| Adama     | T<sub>max</sub> (°C) | 34.9| 27.5| 26.5| 32.2   | 30.7      |
|           | T<sub>min</sub> (°C) | 12.5| 9.8 | 8.1 | 7.7    | 15.5      |
|           | T<sub>avg</sub> (°C) | 23.7| 18.7| 17.3| 20.0   | 23.1      |
| Bora      | T<sub>max</sub> (°C) | 35.3| 32.2| 27.7| 27.9   | 35.2      |
|           | T<sub>min</sub> (°C) | 16.7| 14.1| 9.8 | 10.0   | 19.8      |
|           | T<sub>avg</sub> (°C) | 26.0| 23.2| 18.8| 19.0   | 27.5      |
|           | R<sub>f (mm)</r | 75.2| 292.1| 325.8| 345.3 | 161.6      |
| Dugda     | T<sub>max</sub> (°C) | 35.3| 32.5| 27.8| 28.2   | 35.4      |
|           | T<sub>min</sub> (°C) | 16.9| 14.4| 10.0| 10.0   | 19.8      |
|           | T<sub>avg</sub> (°C) | 23.6| 23.5| 18.9| 19.1   | 27.6      |
|           | R<sub>f (mm)</r | 56.6| 365.3| 432.6| 448.1 | 170.8      |
| Lome      | T<sub>max</sub> (°C) | 30.8| 31.8| 26.7| 27.7   | 35.1      |
|           | T<sub>min</sub> (°C) | 12.6| 14.1| 8.3 | 7.5    | 10.3      |
|           | T<sub>avg</sub> (°C) | 21.7| 23.0| 17.5| 17.6   | 22.7      |
|           | R<sub>f (mm)</r | 38.8| 245.9| 247.8| 263.1 | 41.4       |

Rainfall (R<sub>f</sub>), maximum temperature (T<sub>max</sub>), minimum temperature (T<sub>min</sub>) and average temperature (T<sub>avg</sub>)

vigor through competition for space and nutrients (Bravo et al. 2012; Getachew 2017; Tamirat 2020). High weed infestation also, increases the humidity within the crop canopy which promotes disease development. The disease was more severe when the altitude was above 1600, it had a significant effect on the disease development. Both disease incidence and severity were relatively higher above 1600 m.a.s.l. This might be due to the relative humidity is higher and the climate is moist at higher altitudes. Previous findings indicated that disease intensity was relatively higher above 2000m.a.s.l. for the early blight of tomato (Belay 2009; Sanouba and Barbanti 2017).

Throughout the survey, it was observed that there were higher disease incidence and severity on early planted tomatoes than late planted. Leaf wetness is one of the most crucial aspects that promote infection. Previous findings by Kumar and Barnwa (2017) and, Yanar et al. (2011) indicated that the effects of different planting dates were found to play a significant role in the development of early blight of tomatoes. Disease intensity is more severe during fruit formation as compared to the flowering stage. Previous research work indicated that tomatoes became increasingly susceptible to A. solani infection as the age of plants increased (Ngoc 2013). Early blight is most severe on plants stressed by a heavy fruit load. Shilpakumari (2008) and Adhikari et al. (2017) also reported that disease incidence of onion purple blotch was low when the plants were young and there was a progressive increase in disease severity with the increase in the age of the host.
The present findings showed that fungicides were used widely in the surveyed areas. The protectant fungicides mancozeb and chlorothalonil have been used extensively by farmers in Ethiopia to manage early blight on tomatoes. Despite the frequent application of these fungicides, a significant difference was not detected in early blight severity. This might suggest that Alternaria solani may develop a reduced sensitivity to these fungicides. Reduced sensitivity to mancozeb and chlorothalonil in A. solani isolates has been reported by Holm et al. (Holm et al. 2003) and Semen et al. (2016) where changes in A. solani population sensitivity were observed within and among growing seasons. These changes in sensitivity may provide evidence on some pathological fitness penalties associated with acquiring resistance against these fungicides.

Logistic regression analyses indicated that higher early blight epidemics during fruit formation, tomato plated early, at high altitude, and high weed density. The regression model quantified the relative importance of the multiple explanatory variables, indicating the variation of the disease epidemic either singly or in combination. Some independent variables were more important for increasing the disease than other variables. Both the qualitative and quantitative survey data generated from different agro-ecologies and agronomic practices could be easily analyzed by this model to identify factors that promote disease development (Zewde et al. 2007; Belay 2009; Belete et al. 2013; Reincke et al. 2018).

5. Conclusions

Early blight of tomato is the most economically important disease was found widely distributed in all the surveyed areas. The findings of the present study indicated that early blight of tomato incidence and severity varies among districts, date of planting, crop density, weed management, and environmental factors. The present study revealed that proper weeding practices, optimum plant density, crop rotation with other plants, and other related farm practices should be carried out to reduce the yield loss of tomatoes due to early blight in the surveyed area. Therefore, proper weeding management, late planting, proper crop density and other related farm practices should be carried out to reduce early blight impact until resistant tomato genotypes are developed and distributed to major tomato production regions of the country. Moreover, extensive studies are required to investigate whether Amaranthus hybribudas, Datura stramonium, Commelina benghalensis, Cyperus esculentus, Ipomea ariocarpa, and Chenopodium procerum weeds are alternative hosts for the early blight of tomato.

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Authors’ contributions

Meseret Tadelo conceived and designed the research, collected and analyzed the data, and wrote the manuscript. Meseret Tadelo did this work under the supervision of Dr. Hassen Shifa (major supervisor) and Dr. Addisu Assefa (co-supervisor) at Madda Walabu University. As supervisors, they participated in conception, design and interpretation of the results. They also provided guidance on developing the manuscript.

Data availability

All relevant data are within the paper and supporting information file.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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