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Evaluation of Fungicide Efficacy for the Management of Tomato Late Blight (*Phytopthora infestans* (Mont) Debary) at Rama Northern Ethiopia

Nahom Weldu [a++*] and Gebretsadkan Zereabruk [a#]

[a] *Axum Agricultural Research Center, Tigray Agricultural Research Institute, P.O. Box 230, Axum, Ethiopia.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Tomato (*Lycopersicon esculentum* Mill) is an annual shrubby member of the solonaceae family which also include potato and peppers. It is an important vegetable crop grown around the world and is second to potato. Its fruit is an essential component of human diet for the supply of vitamins, minerals and certain types of hormones precursors in addition to protein and energy. It is one of the most important vegetable crops and is widely grown in Ethiopia, ranking 5th in the annual national production of vegetables and its productivity was 4.37 t/ha which is very low. To solve such serious production problem, an experiment was conducted at Rama in 2018 and 2019 irrigation seasons with the objective of to evaluate efficacy of fungicides chemical for the management of

[++] *Plant Pathology Researcher;*
[#] *Plant Entomology Researcher;*
**Corresponding author: E-mail: nahomweldu373@yahoo.com; nahomka1114@gmail.com;*

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tomato late blight. Five fungicide chemicals of Redomill Gold 68WG, Honor, Carbenchor, Agro laxylMz 63.5WP, Curzate M 68 WP and one control treatment was used and treatments were randomly arranged in factorial RCBD with three replications and the spacing between plots and blocks were 1.5m and 2m respectively and the spacing between plants and rows were 0.3m and 0.8m respectively per the recommendation of AxARC. All the necessary data were collected and analysed using SAS computer software. Statistically significant difference was observed in disease severity and AUDPC parameters among fungicide treated and untreated check. The highest severity and AUDPC were scored (5.28) and 21.12 respectively in 2018 as well as 2.91 and 17.84 in 2019.Similarly significantly highest 28.48 tha-1marketable yield of tomato was obtained from the fungicide chemical treated plots as compared to the non-treated control plots except plots treated with fungicide chemical of Curzate. Highest (4.85) tha -1and (4.04) tha-1 weight of unmarketable tomato yield was obtained from the un treated plots respectively in 2018 and 2019 irrigation season respectively followed by 3.06tha-1 in 2018 from Redomil gold treated plots and 2.90tha-1 from Carbenchlor and 2.69tha-1 from honor treated in 2019 irrigation seasons. Farmers have to use the evaluated fungicide chemicals interchangeably one after the other but not at the same time to control tomato late blight diseases effectively as each fungicide chemicals have their own specific active ingredient and system of inhibiting disease causing pathogens although there was no significant difference among the evaluated chemicals on the control of tomato late blight.

Keywords: Tomato; late blight; fungicide chemicals; incidence; severity.

1. INTRODUCTION

"Tomato (*Lycopersicon esculentum* Mill) is an annual shrubby member of the *solanaceae* family which also includes other well-known species, such as potato, tobacco, peppers and egg- plant" [1]. "It is an important vegetable crop grown around the world and is second to potato. It is grown for its commercially important fruit. Tomato is a warm-season crop, killed by freezing temperatures and injured by light frosts. The optimum range of day temperatures for growth is 21-24^{0}c. The minimum soil temperature for germination is 10^{0}C with an optimum of 30^{0}C and a maximum of 32.22^{0}C. From planting of seed or transplanted to harvest requires 60-90 days depending on the cultivar and growing condition" [2].

"Tomato (*Lycospersicon esculentum* Mill) fruit is an essential component of human diet for the supply of vitamins, minerals and certain types of hormones precursors in addition to protein and energy" [3].

"Its importance is increasing in Ethiopia and it is widely accepted and commonly used in a variety of dishes as row, cooked or processed products more than any other vegetables" [4]. "The tomato cultivars currently produced in Ethiopia vary in growth habit as determinate, semi determinate and indeterminate types. The indeterminate types are high in stature, produce fruits for extended period, need plant support and produce high fruit yield. Determinate cultivars are bush like, compact and fruits mature in a relatively short time as compared to indeterminate ones. It is favorable for concentrated fruit production for early market and for processing industries" [4].

There is no definite time recorded regarding the introduction of cultivated tomato to Ethiopia. However, cherry type has been growing for long period of time around big cities and in small gardens. Recently, the crop has expanded to commercial production for daily diet, export and processing industries. Small horticultural farms produce the bulk of fresh market tomatoes. Farmers are interested in tomato production more than any other vegetables for its multiple harvests, which result in high profit per unit area.

"Like in many other countries, it is also becoming important vegetable crop in Ethiopia in a variety of dishes. The fresh produces are sliced and used as salad. It is cooked for making local sauce "wot". The processed products such as tomato paste, tomato juice, tomato ketchup and whole peel tomato are produced for local market and export. It is an important cash-generating crop to small-scale farmers and provides employment in the production and processing industries. It also important source of vitamin A and C as well as minerals. Such diverse uses make tomato an important vegetable in irrigated agriculture in the country" [4]. "Tomato fruit quality for fresh consumption is determined by appearance (color, shape, size, free from physiological disorders and decay) firmness, texture, dry matter and organoleptic (flavor) and neutraceptic (health benefit) properties" [5].

“Tomato is the most widely cultivated vegetable crop in Ethiopia in particular and in the world in general. It is one of the most important vegetable crops and is widely grown in Ethiopia, ranking 5th in the annual national production of vegetables” [6]. “The importance of tomato is increasing from time to time as the crop is a high value commodity and gives higher yield per plot of lands. To advance the its production it has been given top priority in vegetable research too in Ethiopia” [7]. “Tomato is an important vegetable in irrigated agriculture in the country and production is also rapidly increasing in many parts of the country” [8]. “Small-scale and commercial growers could grow the crop for its fruits in different regions of the country. It is produced both during the rainy and dry seasons under supplemental irrigation” [4].

According to [6], tomato production was covered an area of 7,710.16hectares with a production of 33,655.84 tons. The report from [6] showed that the national productivity of tomato was 4.37 t/ha. However, the productivity of tomato is very low due to several biotic and abiotic factors among which diseases are the major ones [9,10,9] reported that early blight (Alternaria solani), late blight (*Phytophthora infestans*), fruit spot (*Xanthomonas campestris* pv. vesicatoria), Septoria leaf spot (*Septoria lycopersici*), powdery mildew (Leveillula taurica), bacterial wilt [Ralstonia (Pseudomonas) solanacearum or Clavibacter michiganense subsp. michganense], tomato leaf curl (Tobacco virus 16 or Nicotiana virus 10) and plant-parasitic nematodes (genera: Pratylenchus, Meloidogyne, Helicotylenchus, and Longidorus) are the major and economically important tomato diseases in Ethiopia. The major tomato disease is caused by fungal pathogen and out of these diseases late blight (phytophthora infestans) is the most common one.

Late blight is an extremely important and damaging disease of tomatoes and can be found nearly everywhere the crops is produced. IT is a potentially destructive disease of tomato and potato caused by the fungal organism called *Phytophthora infestans*. This pathogen is referred to as a ‘water mold’ since it thrives under wet conditions. Symptoms of tomato late blight include leaf lesions beginning as pale green or olive green areas that quickly enlarge to become brown-black, water-soaked, and oily in appearance. Lesions on leaves can also produce pathogen sporulation which looks like white-gray fuzzy growth. Stems can also exhibit dark brown to black lesions with sporulation. Fruit symptoms begin small, but quickly develop into golden to chocolate brown firm lesions or spots that can appear sunken with distinct rings within them; The pathogen can also sporulate on tomato fruit giving the appearance of white, fuzzy growth. The time from first infection to lesion development and sporulation different from place to place depending up on the weather condition but most of the time it reproduce as fast as seven days’ interval.

Late blight *(Phytopthora infestance)* manly affect all above-ground parts of the tomato plant when the crop is susceptible to late blight or there is high soil moisture and high relative humidity in the tomato farm. Symptoms usually appear first in the upper portions of affected plant. The initial lesions on foliages are small, somewhat circular, and water-soaked. Gradually when the infestation rate increases these lesions become enlarge, their color changes from pale-green to darker green or black. Tufts of white fungal growth may be present in lesions on the undersides of leaves when humidity is high. As the disease progresses, foliage become blacken and die. If climatic condition is conducive to the pathogen it will translate to petioles and stems, develop water-soaked, darkened areas that enlarge over time. Plant tissue above the infected areas quickly collapses during disease favorable conditions. Lesions on fruit begin as darkened, oily spots that expand and eventually cover the whole fruit. As with the foliage, fungal growth may be present in lesions when humidity is high. Fruits affected by late blight usually succumb to rots caused by secondary invaders, such as fungi and bacteria.

The damage level of tomato late blight, if it gets conducive environmental conditions can cause considerable yield losses and even some times can lead to 100% yield losses [11,12,13]. Production and productivity decline in tomato my not be happened only due to late blight diseases rather it might to be due to different factors biotic and abiotic factors, but tomato late blight disease had the major contribution on the reduction of quantitative and qualitative yield losses on tomato producer in the study area Rama. To solve such serious production bottle neck in our irrigation command area we decide to conduct research and developed research proposal and conducted the in 2018 and 2019 irrigation season with the objective of evaluating efficacy of fungicides chemicals against tomato late blight and to estimate tomato yield loss due to late blight.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The field experiment was conducted at Rama Aksum agricultural Research station in Mereb Leke District of Central Administrative Zone of Tigray, northern Ethiopia, during the 2018 and 2019 irrigation season. Rama is located at 14o 22'25" N latitude and 038o 47'32" E longitude at an elevation of 1390 meters above sea level. Rama is 258 and 1041 km far from Mekelle and Addis Ababa, respectively, towards the northern direction. It lies in the dry agro-ecological zone and the soil type is sandy clay loam. The mean annual rainfall in the area ranges from 400 to 600 mm and the rainfall distribution is mono-modal with an erratic distribution beginning late in June and ending in the last week of August. Mostly the average temperature of the study area was 26.3 0^{C} while the average annual rainfall of the experimental site was 586.9 mm according to the district office of agriculture and natural resource and National Metrological Agency Mekelle sub branch [14].

2.2 Experimental Materials

Tomato late blight management experiment was carried out during the irrigation season in 2018 and 2019 respectively with irrigation. The treatment were six fungicide chemicals of which (Redomill Gold 68WG, Honor, Carbenchor, Agro laxylMz 63.5WP, Curzate M 68 WP and one control check spraying without any fungicide but sprayed only water were evaluated for two consecutive years at the main irrigation seasons) were used as foliar spray based on the manufacturers label doses for each fungicide chemicals and spray frequency at 14 days' interval for three times. The three fungicide chemicals (Redomill Gold 68WG, Agro laxylMz 63.5WP and Curzate M 68 WP) were used as standard check as they were using for a year's to manage tomato late blight diseases and the other two fungicide chemicals Honor and Carbenchlor were newly introduced to the study area as means of verification in comparison with the other fungicides already underutilizing by growers. These two new fungicides were purchased from the national chemical importer namely of Hamlin trading PLC. found in Addis Ababa to be used as experimental materials and here are the detail of fungicide chemicals, active ingredient and the dosage used for the experiment.

2.3 Experimental Designs and Treatment Combinations

In both 2018 and 2019 irrigation seasons the treatment consisting of five fungicide chemicals and one control without any chemical fungicide were randomly arranged in factorial randomized complete block design(RCBD) with three replications. Randomization and assignment of each treatment to each experimental unit was done with SAS software within a block. This experiment was conducted at Rama Aksum Agricultural Research Center testing site under irrigation condition. The most popular and recently recommended by horticulture researchers of Aksum Agricultural research center researchers and currently under production Melkashola tomato variety was used as a testing variety.

Seedlings were raised and transplanted to the experimental site after 45 days when the seedlings height reached of about 15cm. Healthy and vigorous seedlings were transplanted and un healing transplanted seedling were replanted up to seven days.

The size of the experimental unit (plot size) was 4m*2.4m which was 9.6m^2 having five rows per plot with three central and harvestable rows and used for all data collection purposes. Spacing of between plots and blocks were 1.5m and 2m respectively and the spacing between plants and rows were 0.3m and 0.8m respectively per the recommendation of tomato spacing of AxARC.

A recommended fertilizer rate of 100 kg DAP ha-1 was applied in rows at transplanting and 100 kg urea ha-1 was used by split application as side-dressing at transplanting and early flowering stage, 30 and 50 days after transplanting in 2018 and 2019 irrigation seasons, respectively. weeding and cultivation were performed manually whenever they were necessary in both cropping seasons. Fungicide spraying was started with the first appearance of typical disease symptom 54 days after transplanting and continued according to spray schedule designated in every 14 days' interval. Fungicide unsprayed plots were left as controls but sprayed only water with similar amount of used to dilution the fungicide chemicals to control variations to this moisture. During fungicide sprays, each plot was shielded with polyethylene sheets, which was 2 m high on all sides of the plot to reduce inter plot interference or spray drift.

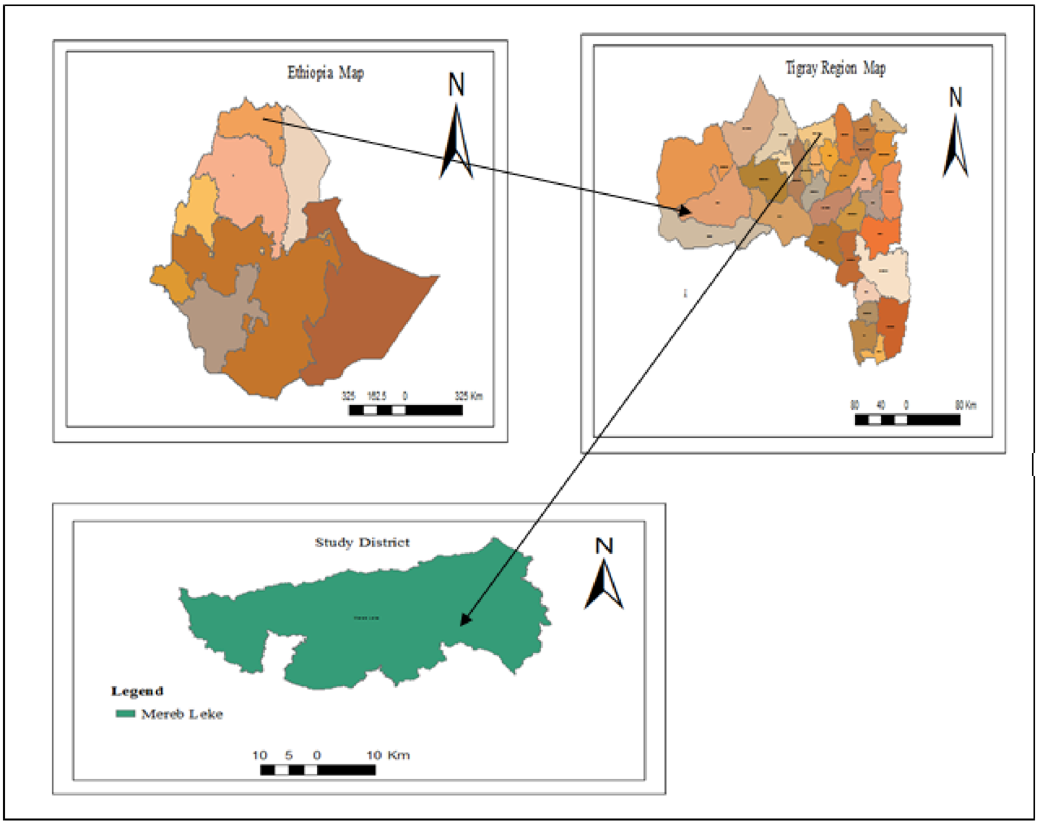

Fig. 1. Map of the study area, Mereb- Leke district in central zone of Tigray, northern Ethiopia

Table 1. List of treatments used in this experiment

Treatment	Active Ingredient	Dosage kg/lit/ha
Honor	Cymoxanil+Mancozeb	2.5kg
AgrolaxylMZ63.5WP	Mancozeb + Metalaxyl	3kg
Carbenchlor	Carbendazim+Chlorothalonil	2.5lit
Redomil gold 68 WG	Metalaxyl-M 40g/Kg +Mancozeb 640g/Kg	2.5kg
Curzate M68WP	Cymoxanil 45 gm/kg + Mancozeb 680 gm/kg	1.5kg

2.4 Diseases Assessment

Disease incidence: Tomato late blight disease incidence was recorded from the central three rows with total of five pre tagged plants of ever plot having 24 plants. As disease incidence dose not told as the level of infection of the crop we were recorded plants showed symptoms regardless of their damaging level. To know the diseases dynamics, we had recorded incidence data three times every fourteen days' interval starting from the first disease symptoms observed 54 days after trans planting (DAT) on the crop until the crop attained its physiological maturity. Finally, disease incidence was determined by counting the number of plants showed typical disease symptoms and expressed in percentage in relation to the total number of plants in each plot as follows:

$$DI(\%) = \frac{\text{number of diseased plants}}{\text{total number of plants inspected}} x100$$

Disease severity: Disease severity assessment was recorded and estimated as the percentage of diseased leaf area over the total area of the plant diseased, and with these three assessments were made until the crop attained its physiological maturity. The percent estimates of disease severity for late blight disease were assessed at the disease onset at three time at fourteen days' interval until the crop attained its physiological maturity. The disease severities were assessed visually as the percentage leaf area diseased following assessment scales described by [15,16]. Tomato late blight diseases severity was recorded from five pre-tagged plants using systematically arranged pattern in the middle three rows of each plot starting from the first appearance of the disease symptoms of 54DAT. It was ratted using a 0 to 9 disease scoring scale; where, 1 = no infections; 2 = 1-10% leaf area infected; 3 = 11- 20% leaf area infected; 4 = 21-30% leaf area infected; 5 = 31-40% leaf area infected; 6 = 41-50% leaf area infected; 7 = 51-60% leaf area infected; 8 = 61-70% leaf area infected; and 9 = 71-100% leaf area infected as described by [15]. Disease severity scores were converted into percentage severity as follows [17].

$$\text{Disease Severity (\%)} = \frac{\text{Area of diseased tissue} \times 100}{\text{Total area tissue observed}}$$

The severity grades were converted into percentage severity index (PSI) for analyses as indicated by [18]:

$$\text{PSI} = \frac{\text{Sum of numerical ratings}}{\text{No. of plants scored x maximum disease score on scale}} \text{x100}$$

The relative diseases severity

Area under disease progress curve

Area under disease progress curve (AUDPC): It was also computed from PSI values for each plot as described by [18].

$$\text{AUDPC} = \sum_{i=1}^{n-1} 0.5(\text{Xi} + \text{xi} + 1)(\text{ti} + 1 - \text{ti})$$

Where, n is the total number of plants disease assessed, ti is the time of the i^{th} assessment in days from the first assessment date and xi is the PSI of disease at the i^{th} assessment. AUDPC was expressed in %-days because severity(x) is expressed in percent and time (t) in days.

Marketable yield (t/ha): The total amount of healthy tomato fruit yields harvested from the three central_rows and converted yield in to hectare wise with adjustment of adjusted of 0% reduction when we are converting yield of experimental plots to hectare [19].

Unmarketable yield (t/ha): Un marketable yield is total amount of un healthy or disease damaged fruit yield harvested from the central three rows and converted yields in to hectare wise with similar manure as mentioned above marketable yield.

Data analysis: The collected data during the study were subjected to Analysis of Variance (ANOVA) using Statistical Analysis Software (SAS) version 9.1.3 computer software [20]. The Least Significant Difference (LSD) test was used to compare the treatment means at 5% probability level and percentage data were arc sine transformed.

3. RESULTS AND DISCUSSION

The analysis of variance for diseases incidence at both in 2018 and 2019 did not revealed significant ($P \geq 0.05$) difference while statistically significant difference was observed in disease severity and AUDPC parameters among fungicide treated and untreated check at($P \leq 0.05$) provability level. The highest severity and AUDPC were scored (5.28) and 21.12 respectively in 2018 as well as 2.91 and 17.84 in 2019.However no significant difference among all fungicide chemical treated plots was observed although there was numerical difference among the severity level fungicide chemical treated plots. This might have happened that all the fungicide chemicals used in this experiment for the management of tomato late blight diseases may have similar efficacy/capacity of contorting the severity level of tomato late blight diseases in 2018 and 2019 irrigation season but not absolutely true as infestation level and efficacy of chemicals is more time and weather and climatic condition dependent. This result was also an opportunity for the farmers in the study area because, we found chemicals having equal efficacy and capacity of controlling tomato late blight and they can widen the chance of using different fungicide chemicals at different spraying intervals/ frequencies not develop the pathogens resistance for the reputedly spraying fungicide chemicals and more effectively killed this pathogen by spraying interchangeability at the periods of crops growth stages as each fungicide chemicals have their own special way of inhibiting/ killing ability of diseases causing pathogens. This result is in agreement with [21] who had reported that redomil gold treated tomato varieties showed significant disease severity reduction as compared to the non-treated once.

Table 2. Mean performance of fungicide chemicals on the management of tomato late blight in 2018 and 2019

treatment	incidence (%)		severity(%)		AUDPC(%-days)	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**
Honor	7.27[a] (53.3)	8.14ab (66.67)	3.53[b] (12.6)	2.3b (5.37)	14.02[b] (198)	13.39b (182.63)
Agrolaxyl	8.42[a] (73.3)	8.42ab (73.33)	3.78[b] (14.4)	2.5b (6.10)	14.32[b] (207)	14.77b (218.87)
Carbenchlor	7.27[a] (53.3)	8.14ab (66.67)	3.77[b] (14.2)	2.5b (6.29)	15.63[b] (248)	14.75b (217.63)
redomill gold	8.54[a] (73.4)	8.14ab (66.67)	4.02[b] (16.3)	2.46b (6.11)	16.06[b] (259)	14.34b (205.99)
Curzate	7.41[a] (60.0)	8.54ab (73.4)	3.79[b] (14.3)	2.47b (6.11)	15.44[b] (241)	14.88b (221.00)
control	7.55[a] (60.0)	9.29a (86.67)	5.28[a] (27.9)	2.91a (8.51)	21.12[a] (450)	17.84a (318.69)
Lsd (5%)	Ns	1.22	0.77	0.424	3.07	59.53
CV(%)	22.17	8.06	10.53	9.24	10.49	14.37

The analysis of variance showed that significantly highest 28.48 tha^{-1}marketable yield of tomato was obtained from the fungicide chemical treated plots as compared to the non-treated control plots except plots treated with fungicide chemical of Curzate which was not significantly different with control plots whereas there was no significant difference was revealed among the fungicide treated treatments although there was a numerical difference of 28.48 tha^{-1} in the maximum and 23.43tha^{-1}in 2018. Similarly, in 2019 treatments of Redomil gold, Curzate and honor showed significant difference over the non-treated control treatments. No significantly different yield was obtained among the Agrolxyl, Carbenchlor fungicide treated plots and control treatments as showed in (Table 3).

Significantly highest (4.85) $tha^{-1}$and (4.04) tha^{-1} weight of unmarketable tomato yield was obtained from the un treated plots respectively in 2018 and 2019 irrigation season followed by 3.06tha^{-1} in 2018 from Redomil gold treated plots and 2.90tha^{-1} from Carbenchlor and 2.69tha^{-1} from honor treated in 2019 irrigation seasons. However, the lowest un marketable tomato yield was recorded on honor, Agrolaxyl and Carbenchlor fungicide treated plots in 2018 and Curzate, Redomil gold and Agrolxyl treated treatments plots in 2019 irrigation as mentioned in (table 3). Similar result was reported that significantly highest (228 ha-1) weight of marketable tomato yield was obtained from plots treated with Etisa 80% WP a followed by Sabozeb 80% WP (220.7) at the same rate. The result of the two indicated non-significant difference with in the treatments. However, significantly lowest (93 q ha-1) yield was obtained from untreated plots [22].

Moreover, all fungicide treatments provided significantly better foliar late blight control and significantly gave higher marketable and total yield of tomato and similarly the minimum AUDPC value also observed on fungicide treated treatments as compared to the untreated plots. Similar experiment conducted to evaluate efficacy of two (Victory 72 WP and Redomil gold) fungicide chemicals on the management of tomato late blight was reported comparable results of this research findings that Victory 72 WP consistently retarded late blight development and the highest yields were obtained from plots treated with Victory 72 WP followed by Redomil gold [23]. The efficacy of these fungicides chemicals can be improved by increasing the dosage and frequency of application [24,25].

According to the review conducted by [26] environmental conditions significant affect tomato late blight disease progression as it is characterized by the disease triangle, which integrates the host, pathogen and environmental conditions. The pathogen is highly responsive to weekly or even daily environmental changes and several components of the pathogen affect the survival, germination, penetration, and sporulation of late blight disease. The diseases to be initiation the optimum temperatures must be between 15 and 20°C and high relative humidity has to be presented. Temperature and relative humidity are the most important factor for infection, although the exact effects dependent on the genotype. Temperature above 30°C is not appropriate for reproduction but survival might be possible but not in all phases [27]. Cloudy days are most conducive for late blight diseases since high light intensity, UV radiation can reduce sporangia viability by 95% within an hour [28].

Table 3. Mean performance of fungicide chemicals on the management of tomato late blight in 2018 and 2019

Trt	MY(t/ha)		UMY(t/ha)		TY(t/ha)	
	2018	2019	2018	2019	2018	2019
Honor	27.64a	30.81a	2.32b	2.69ab	29.96a	33.50ab
Agrolaxyl	27.39a	30.54ab	2.26b	2.60b	29.65a	33.14ab
Carbenchlor	28.48a	29.13ab	2.56b	2.9ab	31.034a	32.03ab
Redomill Gold	24.97a	33.09a	3.06ab	2.47b	28.031ab	35.56a
Curzate	23.43ab	31.44a	2.05b	2.42b	25.49ab	33.86ab
Control	18.11b	24.11b	4.85a	4.04a	22.96b	28.15b
LSD(5%)	5.73	6.53	2.05	1.4	5.71	6.67
CV(%)	12.96	12.02	32.00	26.92	11.27	11.20

4. CONCLUSIONS AND RECOMMENDATIONS

All chemicals applied for the management of tomato late blight were not efficient enough for the management of disease incidence both in 2018 and 2019 irrigation season as compared to the non-sprayed plots because disease incidence dose not told as the infection level of the crop. Whereas all fungicide chemical statistically reduced the severity level of tomato late blight as compared to the non-treated plots and similarly the area under diseases progress rate also showed significant difference among fungicide treated and untreated check at($P \leq 0.05$) provability level. The highest severity and AUDPC were scored (5.28) and 21.12 respectively in 2018 as well as 2.91 and 17.84 in 2019.However no significant difference among all fungicide chemical treated plots was observed although there was numerical difference among the severity level. Management of tomato late blight diseases may have similar efficacy/capacity of contorting the severity level of tomato late blight diseases in 2018 and 2019 irrigation season but not absolutely true as infestation level and efficacy of chemicals is time and climatic condition dependent.

In the case of marketable and un marketable yield of tomato, significantly highest 28.48 tha^1 marketable yield of tomato was obtained from the fungicide chemical treated plots as compared to the non-treated control plots except plots treated with fungicide chemical of Curzate which was not significantly different with control plots whereas there was no significant difference was revealed among the fungicide treated treatments.

Significantly highest 4.85 tha^{-1} and 4.04) $tha-^1$ weight of unmarketable tomato yield was obtained from the un treated plots respectively in 2018 and 2019 irrigation season followed by 3.06$tha-^1$ in 2018 from Redomil gold treated plots and 2.90$tha-^1$ from Carbenchlor and 2.69$tha-^1$ from honor treated in 2019 irrigation seasons. However, the lowest un marketable tomato yield was recorded on honor, Agrolaxyl and Carbenchlor fungicide treated plots in 2018 and Curzate, Redomil gold and Agrolxyl treated treatments plots in 2019 irrigation as mentioned in (Table 3).

This was an opportunity for the farmers in the study area because, we found chemicals having similar efficacy and capacity of controlling tomato late blight and they can widen the chance of using different fungicide chemicals at different spraying intervals/ frequencies. As a result, tomato late blight causal pathogens cannot develop resistance mechanisms for the repeatedly spraying single fungicide chemicals. So that we recommend farmers to use the evaluated fungicide chemical having non-significant among themselves on the management of tomato late blight can use interchangeably one after the other but not at the same time can effectively killed this pathogen at a crops growth stage as each fungicide chemicals have their own special way of inhibiting diseases causing pathogens.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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