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Integrated Management of Tomato Late Blight (*Phytophtra infestans* Mont.) of *Tomato* (*Lycopersicon esculentum* MILL.) at Ataye and Shewarobit Districts, Eastern Amhara, Ethiopia

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Abstract: Field experiments were conducted at Ataye and Shewarobit districts during 2017/18 main cropping season to evaluate the fungicide against late blight on tomato varieties under natural conditions and to assess the integrated effect of fungicides (Ridomil MZ 68%WP, Metalaxy (0.25%), More720Wp and Mancozeb) and tomato varieties (Margoble and Melkasalsa) against late blight and yield. The experiments were arranged randomized complete block design in factorial with three replications. Fungicides were applied two weeks intervals starting from the onset of the disease. The integration of varieties and fungicides exhibited significant difference at ($p<0.05$) in disease parameters, and yield. Significantly, the lowest Percentage severity index (PSI) (28%) with AUDPC (592.67%-days) and the highest yield (50.3 t/ha) were recorded from Melkasalsa variety treated with Ridomil MZ 68% WP at Ataye while the lowest PSI (35%) with AUDPC (630%-days) and the highest yield (43 t ha^{-1}) were recorded from Melkasalsa variety treated with Ridomil MZ 68% WP at Shewarobit. On the contrary the highest PSI (60.7%) with highest AUDPC (1373.17%-days) and the lowest yield (27 t ha^{-1}) were obtained from untreated Margoble at Ataye, while the highest severity (69.3%) with highest AUDPC (1248.33%-days) and the lowest yield (22 t ha^{-1}) were obtained from untreated Margoble at Shewarobit. As compared to yield losses from protected plots with Ridomil MZ 68%WP, the highest fruit yield loss of 44.9% at Ataye and 47% at Shewarobit were recorded from unsprayed Margoble variety. The best management of late blight and the higher yield were obtained from integration of two varieties treated with Ridomil MZ 68% WP. Thus, it is recommended to use tomato varieties with sprays Ridomil MZ 68% gave the highest protection against late blight and the highest yield benefit. However, further extensive studies have to be undertaken for late blight management options through integration of varieties and frequency of fungicide applications that may contribute to sustainability of tomato production in the country.

Keywords: Disease Progressive Rate, Disease Severity Index, Late Blight, Varieties

1. Introduction

Tomato (*Lycopersicon esculentum Mill.*) is one of the most widely grown vegetable crops in the world; second to potato and it belongs to the family Solanaceae. It originated from tropical Mexico to Peru [13, 22]. The introduction of cultivated tomato into Ethiopian agriculture dates back to the period between 1935 and 1940 [14]. Tomato is a popular and widely grown vegetable crop in Ethiopia, ranking 8th in terms of annual national production [4]. In Ethiopia, the crop is grown between 700 and 2000 meters above sea level, with about 700 to 1400 mm annual rainfall, in different areas and seasons, in different soils, under different weather conditions, with different levels of technology [8].

On the world scale, about 170.8 million tons of tomatoes were produced in 2014, and with a yield potential of up to 48.1 tons/ha [13]. In 2016 cropping season, tomato production in Ethiopia was about 913,013 tons harvested from 9767.78 ha of land [10]. However, the production of the crop is constrained by several biotic and abiotic factors. Hence, the average fruit yield is 15-30 ton/ha [23]. Among biotic constraints, fungal diseases are major factors affecting the production and productivity as well as quality of the crop. Many diseases are attacking this crop, and can cause 15-95% crops loss both in lowland and highland areas of the tropics [20].

Late blight caused by *Phytophthora infestans* is one of the most significant constraints to tomatoproductions, caused up to 90% of crop losses in cool and wet weather conditions in Antarctica [11]. Yield losses due to the disease are attributed to premature death of foliage, stems and fruits of tomato. The disease is more severe in humid and high rainfall areas and it occurs at a low intensity in dry areas [27]. It causes serious loss in yield and quality as well as reduces its marketability values [15]. Tomato yield losses due to the disease were estimated to range between 65-70% and complete crop failures are frequently reported in Ethiopia [2, 21]. The estimated potato yield losses reported in Ethiopia due to late blight is 2.7%-70% [6], 22–46% [16] and 29-57% [7].

The management of tomato against late blight is important to maximize the productivity and the production of the crop. The disease occurs throughout the major tomato production areas in Ethiopia; especially, in various parts of Shewa rift valley. Different ranges of yield loss due to the disease and complete crop failures are frequently reported and it is difficult to produce the crop during the main rainy season without chemical protection [3, 24]. Many strategies have been investigated in the field to control late blight on tomato. However, there have been limited research efforts that evaluated the effect of integrated managementof fungicides and tomato varieties against of late blight in the study areas. The high efficacy of fungicides and varieties against late blight are very important disease management options for enhancing yield parameter. Fungicides are among the most efficient control options available to the growers.

This is particularly important in developing countries such as Ethiopia, where the setup of efficient control programs for tomatoes are inadequate [3]. Many growers also use different fungicides like Mancozeb, Agrolaxyl, Metalaxy, copper, phosphorus acid and Ridomil for the control of late blight of tomato [1, 18]. Among many alternative measures available, use of resistant varieties has beenthe most important and a cost-effective approach for the management of the disease. Therefore, the lack of information about the effect of integrated late blight management practices in controlling late blight of tomato at Ataye and Shewarobit Districts of eastern Amhara, Ethiopiaforced the researchers to conduct this research. Therefore, this study was conducted to evaluate the effect of fungicides and tomato varieties for the management of late blighttomato and to evaluate the efficacy of fungicides and their effect against late blight on tomato varieties as well as to evaluate the effect of the integrated management options on the yield of tomato.

2. Materials and Methods

2.1. Descriptions of the Study Area

The experiments were conducted at Ataye and Shewarobit districts, North Shewa, Amhara Regional State of Ethiopia, during 2017/18 main cropping season with supplemented irrigation. Shewarobit is located 225 kilometers from Addis Ababa at the north eastern part of the country between 09, 57’ N latitude and 39, 51’ E longitude at an altitude of 1356 meters above sea level (recorded by GPS in 2018). The area has an average annual rainfall of 1007 mm and annual mean minimum and maximum temperatures of 16.5 and 32 ^{o} C, respectively. Ataye is located 290 kilometer from Addis Ababa at north eastern part of country between 10,21’N latitude and 39,56 ‘ E longitude at an altitude of 1497 meters above sea level (recorded by GPS in 2018). The area has an average annual rainfall of 1085 mm, with short rainfall between March and April and long rainfall between June and September and annual mean minimum and maximum temperatures of 15.18 and 32.95 ^{o}C, respectively. The soil of the experimental site is well drained with loam and sandy loam.

2.2. Experimental Materials

Two-released tomato varieties Margoble (susceptible) and Melkasalsa (moderately resistance) were used. The varieties were obtained from Melkassa Agricultural Research Center, Ethiopia. Four different fungicides: More 720 WP, Ridomil MZ 68% WP, Metalaxy (0.25%) and Mancozeb (2%) were applied two times at every two weeks interval after the onset of disease occurrence because the diseases have been latent stage. In addition, 200 kg/ha of DAP was applied in rows at transplanting and 100kg/ha of urea was side dressed at early flowering stage [12].

2.3. Experimental design and Treatments

The experiments were arranged in a factorial randomized complete block design with three replications. Four fungicide treatments (More 720 WP, Ridomil MZ 68% WP, Metalaxy (0.25%) and Mancozeb (2%)) and untreated or control treatment and two tomato varieties were used. The total experimental plot was 30 (10x3). The plot size was 4.4×2.8 m. Spacing between plants and rows were maintained as 40 cm and 70 cm, respectively. Each plot and blocks were separated by a buffer zone of 0.75 and 1.25m, respectively to prevent fungicide drift or cross contamination for tomato field trials. There were 10 plants per row and the two central rows were used for disease assessment and harvested fruit yield. The seedlings were then adapted to the field environment thoroughly and transplanted after 25-31 days of sowing. Natural disease infestation was used upon all experimental plots. First spray of fungicides was started soon after the initial appearance of disease symptoms. The fungicides were applied at the recommended rates manufactures such as 3.7g/$m^2$of Metalaxy (0.25%) with 0.92L of water, 2.5g/$m^2$of More720Wp with 0.92L of water, 3.39g/m^2ofRidomil Mz68% with 0.55L of water and 2.6g/$m^2$of Mancozeb(2%) with0.37L of water were sprayed to each plot areas. All agronomic practices such as weeding, cultivation were kept uniform for all treatments in each plot.

2.4. Data Collection

2.4.1. Disease assessments Data

Disease incidences and severity were assessed five times from the central two rows after onset of disease every week. Incidence of late blight was assessed by counting the number of plants showing late blight symptoms and expressed as percentage of total assessed plants. Ten plants were selected randomly from each plot and then five leaves of each plant were used to determine the disease severity [17].

$$\text{DI} = \frac{\text{Number of diseased plants}}{\text{Total number of plants inspected}} \text{x}100$$

Disease severity was recorded by estimating the percentage of leaf area diseased. Disease severity was assessed by using the 1- 9 scale suggested by Henfling [19], where1= none or very few lesions on the leaf lets, 2 = less than 10% of the leaf area covered, 3= more than 10% but less than 25% of the leaf area covered, 4 = more than 25% but less than 50% of the leaf area covered, 5 = half of the foliage destroyed, 6 = morethan 50% but less than 75% of the leaf area covered, 7 = more than 75% but less than 90% of the leaf area covered, 8= only very few green leaf areas (much less than 10%) and9 = 100% of the foliage destroyedbased on percent foliage damage. The severity scores are then converted into Percentage Severity Index (PSI) according to the formula by Wheeler [30].

$$\text{PSI} = \frac{\text{Sum of numerical rating}}{\text{Number of plants scored x Maximum score on scale}} x\ 100$$

The Area under Disease Progress Curve (AUDPC) was computes from the PSI and data was record at each date of assessment as describing by Campbell and Madden [9].

$$\text{AUDPC} = \sum_{i=1}^{n-1} 0.5(x_{i+1} + x_i)(\text{t}_{i+1} - t_i)$$

Where, n is the total number of assessments,‘t_i’ is the time of the i^{th} assessment in days from the first assessment date; ‘x_i’ is percentage of disease severity at i^{th} assessment. AUDPC is expressed in percent-days because the severity (x) was expressed in percent and time (t) in days.

The rates of disease progress in time were determined by recording the severity of late blight at 7 days interval right from the appearance of the first disease symptoms till the maturity of the crop in the different treatments. Logistic, in [(Y/1-Y)] model was used to compare for estimation of disease progression parameters from each treatment [29]. The goodness of fit of the models was tested based on the magnitude of the coefficient of determination (R^2).

2.4.2. Assessmentof Yield Data

Data related to yields were recorded from the central two rows of each plot for each treatment. Fruits were considered ready for picking, when 50% of tomato fruits turned yellow or red forfour intervals. Mean yield of fruits was assessed on each plot of two central rows. Yield data was directly analyzed and relative yield loss was calculated using the formula of Robert and James [25]. Finally, yield per plot was converted to yield per hectare as

$$\%\text{L} = \frac{Y\,P - YT}{Y\,P} x100$$

Where L = relative percent yield loss, YP = yield from the maximum protected plot and YT = yield from plots of other treatments (i.e. with different level of diseases). Yield increase over the change of yield increase to untreated plots was calculated with the formula:

$$\text{Yield increase over control} = \frac{\text{Treated yield} - \text{Untreated yield}}{\text{Treated yield}} \text{X } 100$$

2.5. Data Analysis

Data on disease parameters (disease incidence, disease severity, PSI, AUDPC, disease progressive rate (r), yield and yield component were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) version 9.1 software (SAS, 2009). Least Significant Differences (LSD) values were used to separate differences among treatment means (P<0.05) level of significance.

3. Results and Discussion

3.1. Incidence and Severity

The analysis of variance (ANOVA) for late blight incidence showed significant difference at *(P<0.05)* between treatments. The highest mean disease incidence (93.3%) was observed on the Margoble variety with unsprayed (control)while the lowest mean incidence (63.3%) was observed on Melkasalsa variety sprayed with RidomilMz 68% WP at Ataye (Table 1). The highest mean incidence (91.7%) was observed on the Margoble variety sprayed with Metalaxy and Melkasalsa variety sprayed with Mancozeb while the lowest mean incidence (66.7%) was observed on Melkasalsa variety sprayed with Ridomil Mz 68% at Shewarobit. Whereas the highest percent late blight incidence was recorded at Ataye than Shewarobit (Table 1). The finding of this study is in line with work of Getachew [15] reported that 68.85% infestation from protected plot and 90.97% infestation from unprotected plot.

The effect of fungicides on late blight severity showed significant (*P≤0.05)* difference among treatments from initial to final stage of disease assessment on both locations (Table 2). The percent severity analysis was performed from the disease assessment data of 46 and 48 days after transplanting from Ataye and Shewarobit, respectively. During the initial disease assessment the highest mean percent severity (23.6%) was recorded from unsprayed (control) Margoble variety while the lowest mean severity (13.3%) was recorded from Melkasalsa variety sprayed with Ridomil MZ 68% WP at Ataye (Table 2). While at Shewarobit the highest mean percent severity (20.7%) was recorded from unsprayed (control) plots of Margoble variety while the lowest PSI (13.0%) was recorded from Melkasalsa variety sprayed with Ridomil MZ 68% WP (Table 2). The result this study is in agreement with the work of Amin*et al*.[3] that reported late blight severity of 15.67% from protected plot of tomato in Ethiopia and with the work of Getachew [15] reported that late blight severity of 11.1% from protected plot of all tested tomato variety.

Table 1. *Effect of tomato varieties on disease incidence and AUDPC of late blight of tomato under natural condition during 2017/18 cropping season at Ataye and Shewarobit.*

Treatment		**Locations**			
		Ataye		**Shewarobit**	
Variety	Fungicides	Incidence (%)	AUDPC%-days	Incidence (%)	AUDPC%-days
Margoble	Metalaxy (0.25%)	73.3bc	1033.6c	91.7a	876.2cd
	More720wp	76.7bc	1044.1c	70.8ab	889.0cd
	Mancozeb (2%)	86.7ab	1172.5b	66.7ab	941.5bc
	RidomilMz 68% Wp	73.3bc	851.7e	79.2b	801.5d
	Control	93.3a	1373.1a	83.3ab	1248.3a
	Mean	80.7	1095	78.3	951.3
Melkasalsa	Metalaxy (0.25%)	73.3bc	777.0ef	75ab	833.0cd
	More720wp	76.7bc	827.2e	70.8ab	803.8d
	Mancozeb (2%)	80.3ab	995.2d	91.7a	784.0d
	RidomilMz 68% wp	63.3c	592.7f	66.7b	630.0e
	Control	83.3ab	1170.1b	87.5ab	1053.5b
	Mean	75.4	872.4	78.3	820.76
LSD (5%)		14.8	195.8	24.5	134.9
CV%		11.1	11.6	18.7	8.9

AUDPC-Area Under disease progressive curve

The percent severity index (PSI) during the final disease assessment was very highly significant difference at (p<0.001) observed between treatment at both locations (Table 2). During the final period of disease assessment, the lowest PSI was recorded from plots treated with Ridomil MZ 68% WP at both locations, while the highest PSI was recorded from unsprayed plots of both varieties at both locations (Table 2). The highest mean final PSI(60.7% and 69.3%) were recorded at Ataye and Shewarobit respectively, on unsprayed (control) plots of Margoble variety while the lowest PSI (28% and 35%) were recorded at Ataye and Shewarobit, respectively from Melkasalsa varietysprayed with Ridomil MZ 68%wp.

Table 2. *Effect of tomato varieties and fungicides on percent severity index of late blight of tomato under natural condition during 2017/18 cropping season at Ataye and Shewarobit.*

Treatment		**Location**			
		Ataye		**Shewarobit**	
Variety	Fungicides	Initial	Final	Initial	Final
Margoble	Metalaxy (0.25%)	18.7ab	50.0bcd	18.7bcd	47.7cde
	More720wp	17.7bc	48.0cde	18.3cde	50.3bcd
	Mancozeb (2%)	19.7ab	58.7ab	19.7abc	52.7b
	RidomilMz68% Wp	18.3bc	41.0ed	16.3e	42.7e
	Control	23.6a	60.7a	20.7ab	69.3a
	Mean	19.6	51.68	18.74	52.54
Melkasalsa	Metalaxy (0.25%)	16bc	40.0e	17.3de	44.7ed
	More720wp	18.3bc	42.7ed	16.7de	46.3cde
	Mancozeb (2%)	19.3ab	53.7abc	17.3de	44.7de
	RedomilMz68%Wp	13.3c	28.0f	13.0f	35.0f
	Control	21.0ab	58.7ab	21.3a	51.0a
	Mean	17.58	44.62	17.12	44.34
LSD (5%)		5.2	9.9	2.2	5.8
CV%		16.4	11.9	7	7

Comparing the two fields, the higher PSI (69.3%) was recorded at Shewarobit while lower (60.7%) was recorded at Ataye from untreated plots of Margoble variety. Melkasalsa variety sprayed with Ridomil MZ 68% WP showed better reduction of late blight severity at Ataye than Shewarobit (Table 2) although lost final PSI was recorded from this treatment combination. The application of Ridomil MZ 68% WP for Margoble and Melkasalsa varieties had better reduction in the severity of late blight by 32.7% and 31.4% over control, respectively at Shewarobit.

Similarly, at Ataye, application of Ridomil MZ 68%WP showed late blight severity reduction by 32.5% and 52.3% over control on Margoble and Melkasalsa varieties, respectively. The finding of this study ispartially in line with the results of Adissu [2] reported that Ridomil MZ-68%wp gave the best control against late blight and reducing the disease severity by 60% on Roma VF, 62% on Melkasalsa and 66%on Margoble variety. Amin *et al*. [3] also reported that Ridomil MZ-68% WP gave the control of 67.7% on tomato and 69.72% on potato compared to untreated (control) plot. This differences might be due to the crop type although potato and tomato are found in the family.

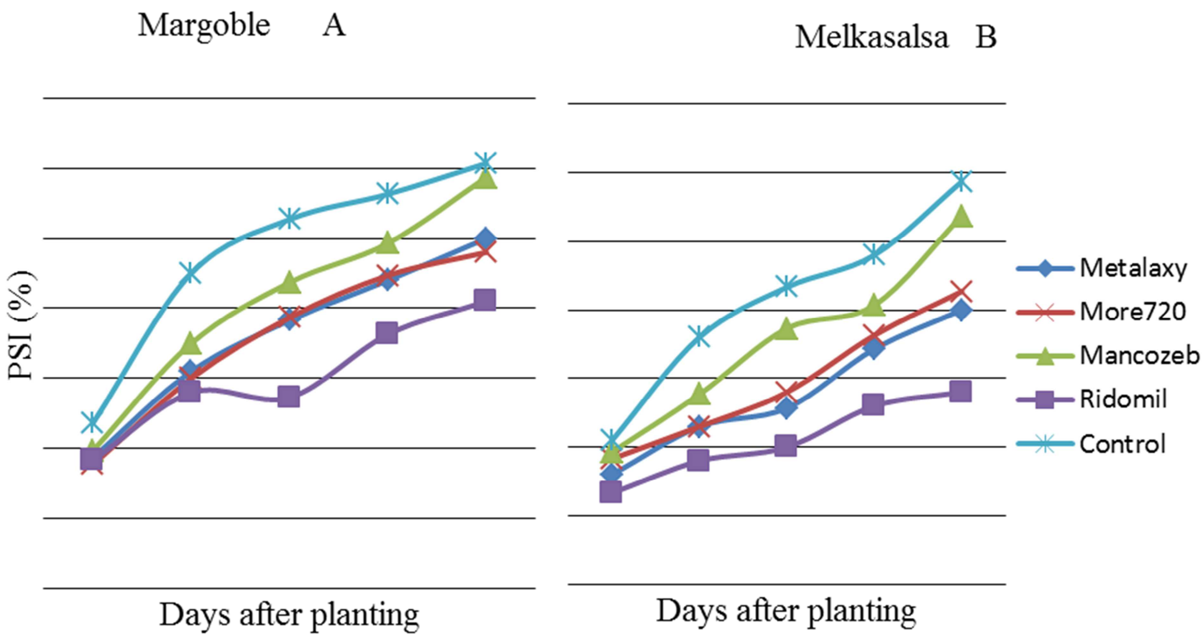
3.2. Area under Disease Progress

Area under disease progress curve (AUDPC) was very highly significantly (P <0.001) affected by treatments (Table 1). The highest AUDPC (1373.17%-days) was observed on the unsprayed plot of Margoble variety while the lowest AUDPC (592.67%-days) was exhibited in Melkasalsa variety sprayed with Ridomil MZ 68%WP at Ataye (Table 1). The highest AUDPC (1248.33%-days) was observed on the unsprayed (control) plot of Margoble variety while the mean lowest AUDPC (630%-days) was exhibited in Melkasalsa variety sprayed with Ridomil MZ 68%WP at Shewarobit (Table 1). Therefore, based on the result of AUDPC, cumulative of disease severity index, one can conclude the resistance and susceptibility levels of different varieties meaning, highest AUDPC is corresponding with susceptible to late blight while the lowest AUDPC is corresponding with resistance to late blight.

These results coincide withthe result of Getachew (2017) reported that AUDPC value of 661.11%-days was obtained from protected plot of Roma VF varieties with four times sprayed Redomil Mz68%Wp and 1245.52% from unprotected plot of Melkashola varieties. Amin et *al*. (2013) also reported that 1170.57% mean of AUDPC from tomato and 1186.57% mean of AUDPC from potato of unprotected plots in Ethiopia.

3.3. Disease Progressive Curves

The disease progress curves of tomato late blight (severity versus day after transplanting) for each tomato variety with the respective location were presented separately (Figure 1). Each disease progress for both tomato varieties revealed that late blight sevrity progressed increasingly starting from the initial disease development to the final recordind date. All disease progress curves for the integrated management of late blight (variety + fungicides) indicated that the disease progress was similar for each varieties. Disease severity was relatively lower in both varieties sprayed with Ridomil MZ 68%WP (Figure 1). This result is in agreement with the idea of Adissu [2] and Getachew [15] that suggested it is always advisable to use resistant varieties, even when sprayed with fungicides are considered the main control strategy to late blight.



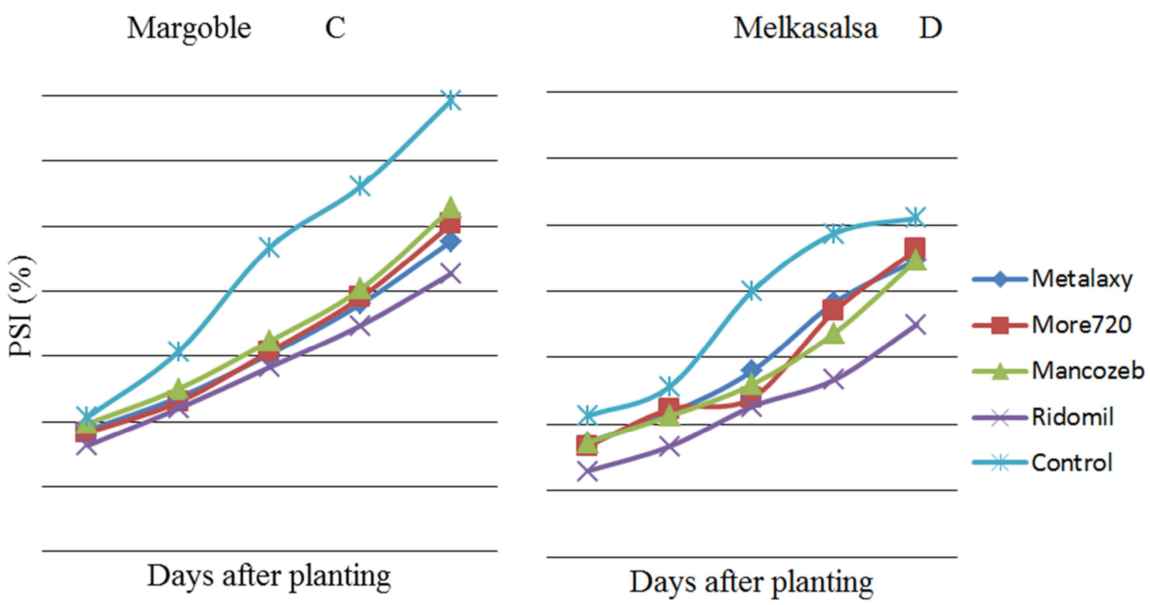


Figure 1. *Tomato late blight (Phytophthra infestans) disease progress curves affected by integrated disease management practices (varieties and fungicides) at Ataye (A and B) and Shewarobit (C and D) in 2017.*

3.4. Disease Progressive Rate

Late blight progress rates showed variations among fungicides, between tomato varieties and between experimental sites. Disease progress rate was highly significantly (*P<0.001*) affected by each treatment. The highest disease progressive rate 0.042 and 0.0069 units per day were exhibited on unsprayed Margoble variety at Ataye and Shewarobit, respectively (Table 3). While the lowest disease progressive rate of 0.009 and 0.014 units per day were recorded from Melkasalsa variety sprayed with Ridomil MZ 68%WP at Ataye and Shewarobit, respectively (Table 3). When comparing the two experimental locations, higher mean disease progressive rate was reordered at Shewarobit than Ataye. From this result, one can understand that, disease progressive rate is faster in unsprayed (control) susceptible tomato variety than fungicide sprayed ones. Ridomil MZ 68%WP could play a vital role in reduction of disease progress rate much better than other fungicides and also moderately resistant tomato varieties sprayed with Ridomil MZ 68%WP was better in reduction of late blight disease progress rate. This result is in agreement with the result of Adissu [3]) and Getachew [15] that suggested it is always advisable to use resistant varieties, even when sprayed with fungicides are considered the main control strategy to late blight.

Table 3. *Disease progressive rate (r) of tomato late blight severity on ten different treatments at from November – January in Ataye and Shewarobit during 2017/18 main growing season.*

Treatment		**Ataye**		**Shewarobit**	
Variety	Fungicides	R^2	Rate	R^2	Rate
Margoble	Metalaxy (0.25%)	47	0.027	90.8	0.024
	More720wp	60.8	0.027	89	0.027
	Mancozeb (2%)	88.1	0.04	88.2	0.03
	RidomilMz68%Wp	70.7	0.016	71.3	0.02
	Control	83.7	0.042	89.1	0.069
Melkasalsa	Metalaxy (0.25%)	88.9	0.017	85.5	0.022
	More720wp	74.8	0.019	78.4	0.024
	Mancozeb (2%)	76.3	0.031	84.1	0.021
	RidomilMz68%Wp	77.7	0.009	85.5	0.014
	Control	85.5	0.038	94.2	0.031

R=disease progressive rate

3.5. Yield Assessment

The analysis of variance showed highly significant (*p<0.001*) different between tomato treatments for fruit yield. The highest fruit yield (50.3 t/ha) was obtained from Melkasalsa variety sprayed with Ridomil MZ 68%WP while the lowest yield (27 t/ha) was obtained from unsprayed (control) Margoble variety at Ataye (Table 4). On other hand, at Shewarobit, the highest fruit yield (43.0 t/ha) was obtained from Melkasalsa variety sprayed with Ridomil MZ 68%WP while the lowest yield (22 t/ha) was obtained from unsprayed Margoble variety (Table 4). This result indicated that higher yield was obtained from Melkasalsa variety treated with Ridomil MZ 68%WP on both field. When comparing the two experimental sites, higher tomato yield was obtained from Ataye than Shewarobit. Melkasalsa Variety sprayed with RidomilMz 68%Wp increased fruit yield by 29.4% and 37.3% at Ataye and Shewarobit, respectively compared to untreated control plots. This result is in agreement with the work of Shitendra [26] reported that the application of Ridomil Gold increased fruit yield by 24.31% compared to control plot.

Table 4. *Effect of different tomato varieties and fungicide sprays on the fruit yield and relative yield loss due to late blight at Ataye and Shewarobit, during 2017/18.*

Treatment		**Ataye**			**Shewarobit**		
Variety	Fungicides	Yield	RYL%	CYI	Yield	RYL%	CYI
	Metalaxy (0.25%)	42.7	12.9	36.8	36.8	11.4	40.2
	More720wp	40.7	16.9	33.7	32.0	23.0	31.3
Margoble	Mancozeb (2%)	35.7	27.1	24.4	28.0	32.7	21.4
	Ridomil Mz68%Wp	49.0	0.0	44.9	41.5	0.0	48.2
	Control	27.0	44.9	0.00	22.0	47.1	0.0
	Metalaxy (0.25%)	43.3	13.9	18.0	38.8	9.8	32.1
	More720wp	41.0	18.5	13.4	31.7	26.3	16.9
Melkasalsa	Mancozeb (2%)	39.3	21.9	9.7	31.0	27.8	15.1
	RidomilMz 68%Wp	50.3	0.0	29.4	43.0	0.0	37.3
	Control	35.3	29.8	0.0	26.3	38.7	0.0

RYL=relative yield loss, CYI= change of increased of yield

3.6. Relative Fruit Yield Loss

The relative tomato fruit yield losses were different for all treatment on both fields. The highest fruit yield loss of 44.9% and 47.1% were recorded from untreated Margoble variety (control) compared to Ridomil MZ 68%WP sprayed plots at Ataye and Shewarobit, respectively. From the two experimental fields the highest yield loss (47.1%) was recorded at Shewarobit compare to Ataye (Table 4). From this result one can understand that, the higher yield loss of 44.9% - 47.1% was incurred from unsprayed (control) plots and this indicate that how much late blight disease is damaging tomato plant during favorable conditions when effective management practices were not applied. At Shewarobit, the season was highly conducive for late blight epidemics to cause higher fruit yield loss on tomato production far greater than people's expectation (Table 4). The result of this study was in line with previous reports that the disease caused higher yield loss (38-65%) in Ethiopia [28]. Girma*et al*. [16] and Binyam*et al*. [7]) also reported that the disease caused the yield loss of (22–46%) and (29-57%), respectively.

3.7. Correlation ofDisease and Yield Parameters

Theyield (Y) of two tomato varieties sprayed with fungicide had very highly significantly ($P<0.001$) and negatively correlated (r = - 0.61, -0.61 and = -0.72) with initial and final Percent Severity Index (PSI) and AUDPC, respectively atAtaye (Table 5). The same trend also observed at Shewarobit (Table 5). This result indicates that the observed values of the disease parameters had a considerable adverse effect on tomato fruit yield. Ashenafi*et al*.[5] also reported that the highly significant correlation between disease severity and percentage reductions in tuber yield due to late blight in Holeta Agricultural Research Center, Ethiopia.

Table 5. *Correlation coefficient (r) of disease parameters with yield and yield component in tomato varieties and fungicide sprays at Ataye and Shewarobit during 2017/18.*

		YTPH	**Initial**	**Final**	**AUDPC**
Ataye	YTPH	1			
	Initial	-0.61*	1		
	Final	-0.61*	0.69*	1	
	AUDPC	-0.72**	0.74***	0.93***	1
Shewarobit	YTPH	1			
	Initial	-0.8***	1		
	Final	-0.73**	0.76***	1	
	AUDPC	-0.73**	0.84***	0.95***	1

** refers to significant level at $P < 0.01$; ***refers to significant level at $P < 0.001$
* refers to significant at $P< 0.05$; Correlation is not significant ($p>0.05$), YTPH=yield per hectare per ton, initial severity=48 date of after transplanting, final severity=76 date of after transplanting, AUDPC=area under disease progressive curve.

4. Conclusions

Based on the results obtained from this study, it can be concluded that late blight severity, AUDPC and progress rates were strongly influenced by integrated management of tomato varieties and fungicides. Therefore, based on the findings of this study, it can be concluded that integrated management of two tomato varieties (Melkasalsa and Margoble) with Ridomil Mz 68% Wp for foliar sprays were found to be an effective to reducing tomato late blight epidemics and increasing fruit yield. Thus, it is recommended to use the spraying of tomato varieties with Ridomil Mz 68%WP since it gave the highest protection against late blight and gave the highest yield benefit as compared to the other treatment. Moreover, further extensive studies can be undertaken for developing concrete recommendation for late blight management options through integration of varieties with frequency of fungicide applications that may contribute to sustainability by stabilizing tomato production in the study area. Since the result is a single cropping season study, studies that are more extensive are needed for evaluation of the reaction of tomato varieties and other management options at different cropping seasons under different ecological conditions that require a great attention during the main cropping season in the areas.

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