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Evaluation of Cultural Practices, Fungicides and Bio Control Agents for the Control of Tomato Late Blight *(Phytophthora infestans* (Mont) de Bary) in West Showa, Ethiopia

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Abstract

Late blight caused by *Phytophthora infestans* (Mont) de Bary) is one of the most important and widespread pathogenic soil borne fungal pathogen, which posed a significant constraint to tomato (*Lycopersicon esculentum* Mill.) production mainly in the rainy season. Therefore, this study was carried out to evaluate cultural practices, fungicides and bio agents with an attempt to identify the best option(s) for controlling tomato late blight under field condition. The study was conducted during the main cropping season of 2012 at Guder, Toke kutaye district of West Showa, Ethiopia. Treatments consisted of two fungicides (Victory 72 WP and Ridomil gold), mixture of micro nutrients (copper sulphate, zinc sulphate and Ferrous sulphate in combination), two mulch types (plastic and dry grass mulch) and antagonistic bio agents (*Pseudomonas fluorescens, Trichoderma viride and Pseudomonas fluorescens*+ *Trichoderma viride*) along with untreated control. The treatments were laid out in randomized complete block design (RCBD) with three replications. Results indicated that there was significant differences among treatments in terms of disease severity (DS), area under disease progressive curve (AUDPC), disease progressive rate (r), yield and yield components, and cost-benefit ratio. The application of fungicide treatments considerably reduced late blight progress, with a corresponding increase in tomato fruit yields over the other treatments including control. Victory 72 WP and Ridomil gold treated plots respectively recorded significantly lower DS (15.57 % and 18.9%), AUDPC (711.7%_days and 894.6_days), disease progressive rate (0.65 and 0.68), and higher marketable fruit yield (210.98 kg / ha and 184.9 kg/ha). Moreover, plot sprayed with combination of micronutrient ($ZnSO_4.H_2O$ + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$) showed lower disease severity (36.67%) next to Victory 72 WP and Ridomil gold. The biocontrol agents and both mulch types did not significantly differed from each other as well as from the control in disease severity. Apart from Victory 72 WP and Ridomil gold, the application of micronutients, seed treatment with *P. fluorescens* alone and the use of plastic mulch showed significantly lower AUDPC value over the other treatments. Significantly lower per cent fruit infection was recorded from plots treated with Victory 72 WP and Ridomil gold and with the use of plastic mulch. The application of Victory 72 WP, Ridomil gold, mixture of micronutrients, and the use of plastic mulch gave significantly higher marketable yield over the other treatments including control. The result of the cost- benefit analysis indicated that plastic and grass mulch recorded the highest total variable costs. Likewise, the lowest variable cost was observed with the application of micronutrients and bio control agents. Nevertheless, the highest gross field benefit was maintained from Victory 72 WP followed by Ridomil gold. In addition, the highest net benefit was obtained from Victory 72 WP and Ridomil gold with mean values of 161,464 and 139,784 Birr/ha, respectively. The highest marginal rate of return (15,902 %) was obtained from micronutrient treatments when compared with untreated control. followed by Victory 72 WP (13,106 %). The application of both Victory 72 WP and Ridomil gold fungicides significantly reduced disease development and increased marketable tomato fruit yield over all the other treatments including control.

Keywords*:* Plastic mulch, Grass mulch, Fungicides, Bio agents, Tomato, Late blight, Micronutrient

Introduction

Tomato (*Lycopersicon esculentum* Mill) is among the most important vegetable crop in Ethiopia, and its production 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 *et al*., 1992). The total area under production reaches 51,698 hectares and annual production is estimated to be more than 230,000 tons in Ethiopia (CSA, 2010). However, the national average of tomato fruit yield in Ethiopia is low (1.25 tones/ha) when compared even to the neighboring African country like Kenya (1.64 tones/ha) (CSA, 2009).

Tomato crops are more susceptible to diseases as compared to other vegetable especially during the rainy season. Various biotic and abiotic factors are responsible for causing diseases in vegetables. Early and late blight fungal diseases are the most destructive and widespread for Solanaceous vegetables in Ethiopia (Mutitu *et al*., 2008). According to CABI (2004), tomato yield losses in East Africa can be as high as 88%, of which diseases account for 56 % of the loss. In Ethiopia, as high as 50% incidence has been recorded for the late blight of tomato in major tomato producing areas (HARC, 2005). This give a good indication of the loss caused due to this disease.

Phytophthora infestans is one of the most important, notorious and widespread phyto-pathogenic soils borne and airborne fungal pathogen that causes late blight disease in vegetable crops including tomato in all the production areas of Ethiopia (Ghorbani *et al*., 2007; Mutitu *et al*., 2008; Mesfin, 2009), but it is more severe in humid and high rainfall areas and occurs at a low intensity in dry areas (Denitsa and Naidenova, 2005). The disease causes serious loss of yield and affects quality as well as reduces its marketability (Srivastava and Handa, 2010). Due to the devastating nature of the disease, it poses a threat to food security since many resource poor farmers cannot afford the fungicides required to control it (Denitsa and Naidenova, 2005). In the past few decades, the frequency and severity of this disease have increased in many parts of the world including Ethiopia and have been a serious threat to tomato production (Bakonyi *et al*., 2002).

The management of tomato against this pathogen is important to maximize the crop's yield. *Phytophthora infestans* has a high pathogenic variability and therefore, specific resistance has contributed little in controlling the disease while varietal resistance only helps in reducing the amount of fungicides required and the rate of disease development (Denitsa and Naidenova, 2005). Agricultural practices for the management of soil borne pathogens in the field includes: cultural practices, use of disease free seeds, mulching, good soil drainage, crop rotation, crop sanitation, fungicide applications, methyl bromide fumigation, soil solarization, use of resistant or tolerant varieties and the use of bio control agents. The use of micronutrients has also been employed in regulating the disease severity. Gupta and Singh, (1995) observed that the application of zinc and iron, each at 5 ppm were effective in controlling primary incidence of downy mildew in pearl millet. Mathur and Bhatnagar, (1990) reported that zinc sulphate (0.5%) and boric acid (0.2%) were most effective in reducing the stripe disease of barley followed by ferrous sulphate (0.5%) and copper sulphate (0.3%). Garg *et al.,* (1995) found that metal sulphates of iron, manganese, cobalt, nickel and zinc inhibited the growth of *Alternaria raphani*, *A. brassicicola* and *A. verticillium*. Rathi *et al.,* (1998) reported that micronutrients offer resistance against powdery mildew.

The use of *Pseudomonas fluorescens* and *Trichoderma* spp. are becoming increasingly common as it is effective, economic and environment friendly and also effectively control many soil borne pathogens including *P. insfestans* (Sabaratnam and Traquair, 2006; Ghorbani *et al*., 2007; Negi *et al.,* 2008; El-Mohamedy *et al.,* 2011). In Ethiopia, the biological control methods have received comparatively little attention from pathologists. However, *T. viride* and *P. fluorescens* were tested against potato late blight in the greenhouse condition at HARC and was found to reduce the disease severity as measured by AUDPC (Ephrem, 2005).

Tomato is a major crop in Toke Kutaye area which is cultivated both in the main and off seasons. However, production in the area is hindered by late blight disease during the main rainy season. Much work still needs to be done in Ethiopia, particularly in Toke Kutaye district of West Shoa, especially with the late blight of tomatoes through cultural practices or fungicides or bio agents, since the disease is still causing much devastation on the crop. Therefore, the present work was carried out under field condition with the main objectives of evaluating cultural practices, fungicides, micronutrients and bio control agents with an attempt to identify the best tomato late blight (***Phytophthora infestans)*** control option(s).

Materials and Methods

Description of the study area

Field experiment was conducted at Ambo University Agricultural Research Farm in Guder, Toke Kutaye District, Western Showa, Oromia Regional State, Ethiopia during the main cropping season of 2012. The experimental site is located at 127 km west of Addis Ababa and 12 km away from Ambo. is located at 8^{o} 57 'North latitude and 38^{o} 07 'East longitude at an elevation of 1800 – 2300 m. a. s. l. The site received mean annual rainfall of 780 mm and the temperature of the district ranged between 15 to 25^{o}C with average of 22^{o}C. The soil of the experimental site is light red in color, clay loam in texture and pH value of 6.8.

Experimental design and treatment applications

Two fungicides (Victory 72 WP and Ridomil gold), Mixture of micro nutrients (copper sulphate + zinc sulphate + Ferrous sulphate), two mulch types (plastic and dry grass mulch), two antagonistic bio agents (*P. fluorescens and T. viride*), and absolute control were used. The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications. Ridomil gold was used as a standard check. A susceptible tomato variety, Roma-VF, was sown on a plot having a size of 1.8 m x 2.4 m. Apparently healthy seeds were sown into experimental plots with a total plot size of 8.4 x 29.6 m (248.6 m^2). Spacing between plants and rows was 45 cm and 60 cm, respectively. Each experimental plot consists of a total of four rows including two harvestable middle rows. DAP and urea were split applied (half at the time of sowing and remaining half at 45 DAS) at the rate of 200 kg/ha and 150 kg/ha, respectively. All agronomic practices were kept uniform for all plots. The treatment descriptions were as follows:

T1 = Plastic mulch

T2 = Dry grass mulch

T3 = *Pseudomonas fluorescens* alone

T4 = *Trichoderma viride* alone

T5 = *Pseudomonas fluorescens* + *Trichoderma viride*

T6 = $ZnSO_4.H_2O + CuSO_4.5H_2O + FeSO_4.7H_2O$

T7 = Victory 72WP (Metalaxyl + Mancozeb)
T8 = Ridomil gold (Standard check)
T9 = Absolute control (Untreated plot)

Application of mulches, micro nutrient fertilizers, fungicides and bio agents

Tomato seeds were sown on seed beds under plastic and grass mulches. Transparent plastic shelters (3m long and 2m wide) was prepared and positioned above the plot. The plot was covered with plastic mulch before sowing the seeds, and 3-5 cm diameter holes were made to allow for seedling emergence. Mulching with dry grass was made after sowing the tomato seeds. The three micronutrients mixture; zinc sulphate ($ZnSO_4.H_2O$), copper sulphate ($CuSO_4.5H_2O$) and ferrous sulphate ($FeSO_4.7H_2O$) was applied 30 days after emergence through foliar application at frequency of seven days interval at the recommended rate of 0.24, 0.69 and 5.33 mg/L, respectively. Both fungicides (Victory 72WP and Ridomil gold) were applied at the 30th day of emergence at 7 days interval at the rate of 2.5 kg/ha. A total of three times application were applied using a knap-sack sprayer. First spray of fungicides was soon after 10th day of the initial appearance of disease symptoms. To inoculate the bio agents, a seed treatment method which was used by El-Mohamedy *et al.*, (2011) was applied. The tomato seeds were directly soaked in suspension that contains the bio agents, independently and in combination. The talc based formulation (28 x10^6 cfu/g productof *T. viride*) was used for seed treatment at the rate of 4g/kg of seeds and kept in stoppered glass vials at 29^0 C room temperature. Similarly, the bacterium, *P. fluorescens* was used as seed treatment following the same procedure at the rate of 10 g/kg of seeds soaked in 1 liter of water for about 2 hours to allowed adherance on tomato seeds. The treated seeds were sown immediately at recommended sowing depth.

Inoculation and disease assessment

Natural inoculation was relied up on in all experimental plots. Disease incidence and severity on tagged plants was assessed on weekly basis. Starting from the first appearance of disease symptoms, a total of nine disease assessments were conducted throughout the cropping season. Disease assessment was made for the various treatments from the central two rows. Incidence of late blight was assessed by counting the number of plants on the middle two rows and expressed as percentage of total plants. Disease incidence was computed according to the following equation:

$$\text{PDI} = \frac{No\ of\ diseased\ plants}{Total\ number\ of\ plants}\ x\ 100$$

Five plants were randomly selected from each plot at the central two rows to determine the disease severity (Wheeler, 1969). Severity of late blight was recorded on the basis of 1-6 rating scales as described by Gwary and Nahunnaro, (1998), where scale 1 = trace to 20% leaf infection, 2 = 21- 40% leaf infection, 3 = 41-60 % infection, 4 = 61-80 infection, 5 = 81-99% infection, 6 = 100% leaf infection or the entire plant defoliation and then the rating scales were converted into percentage severity index (PSI) for the analysis of disease severity using the following formula:

$$PSI = \frac{SNR}{NPS\ x\ MSS}\ \text{x}\ 100$$

Where; PSI = per cent severity index; SNR = Sum 0of numerical rating; NPS = Number of plants scored and MSS = Maximum score on scale.

Disease progression analysis

The rate of disease increase in the fields and the cumulative amount of disease over a season (expressed as area under the disease progress curve) provides useful overall measures of disease progress.AUDPC values were calculated for each plot using the Campbell and Madden (1990) equation.

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

Since late blight severity was expressed in per cent and time (t) in days. Logistic, in [(Y/1-Y)] and Gompertz, -in [-in(Y)] (Van der Plank, 1963) models were compared for estimation of disease progression parameters from each treatment. The data were regressed over time (DAP) to determine the model. The goodness of fit of the models was tested based on the magnitude of the coefficient of determination (R^2). The "appropriate model" was used to determine the apparent rate of disease increase (r) and the intercept of the curve. Correlation analysis on fruit yield and fruit infection with those of disease parameters was made to compare the relationship among the treatments.

Assessment of yield and yield components

Data related to yield and yield components were recorded from the central two rows for each treatment. Fruits were considered ready for picking when 50% of fruits turned yellow or red. Harvested fruits were categorized as clean marketable fruits (smooth, glossy surface and firm skin) or unmarketable if they had symptoms of damage, disease infection or other physiological disorder. The weights of marketable and unmarketable fruits were recorded separately. Mean number of fruits per plant was assessed on each plot. Fruits from each plot were sorted into infected and healthy groups and counted. The numbers of infected fruits were expressed as percentage of the total number of fruits produced during the season to obtained per cent fruit infection.

Yield loss estimation

The relative losses in yield of each treatment were determined as percentage of that of the maximum protected plots of the experiment (in this case plots sprayed with Victory 72WP) . Losses were calculated separately for each of the treatment and yield component of the tomato was determined as a percentage of that of the protected plots and yield losses was calculated based on the formula of Robert and Janes, (1991):

$$RL(\%) = \frac{(Y_1 - Y_2)}{Y_1} \times 100$$

Where, RL = relative yields loss, Y_1 = mean value of the yield parameter for protected plots (yield of Victory 72 WP sprayed plots) and Y_2 = mean value of yield parameter in less protected plots. Per cent yield recovery was calculated to compare the yield difference among fungicides, bio agents and other treatments using the formula:

$$YR(\%) = \frac{PY - YUP}{YSP - YUP} \times 100$$

Where, YR is yield recovery in per cent, PY is plot yield, YUP is yield of unsprayed plot and YSP is maximum yield of sprayed plots.

Cost and benefit analysis

Price of tomato fruits (Birr/kg) was assessed from the local market and total price of the commodity obtained was computed on hectare basis. Input costs like fungicides, bio agents, micro nutrients and mulches and labor costs/ha were recorded. The total amounts of these materials used for the experiment were computed and their price also converted into hectare basis. Before doing the economic analysis (partial budget), the statistical analysis was done on the collected data to compare the average yields between treatments. Since there was a difference between treatment means, the obtained economic data were subjected to analysis using the partial budget analysis method (CIMMYT, 1988). Marginal rate of return was calculated using the formula:

$$\text{MRR}(\%) = \frac{DNI}{DIC} X100$$

Where, MRR is marginal rate of returns, DNI, difference in net income compared with control, DIC, difference in input cost compared to control.

Data analysis

Data on all disease parameters (disease incidence, disease severity, PSI, AUDPC and disease progression rate (r), yield and yield components, yield loss and cost benefit analysis) were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) version 9.1 software (SAS Institute, 2002). Fisher's protected Least Significant Difference (LSD) values was used to separate differences among treatment means ($P<0.05$) where there is a significant difference. Regression analysis was used to examine the relationship between severity of foliage disease (AUDPC, the independent variables) and change in yield and yield components (dependent variables),

Results and Discussion

Disease incidence

Result of disease incidence revealed that there was no significant differences ($P<0.05$) observed among treatments in the initial and final per cent disease incidence (Table 1).

Table 1 Effect of different treatments against tomato late blight on initial and final per cent of disease incidence

Treatments	Initial disease incidence (%)	Final disease incidence (%)	Reduction in incidence over control (%)
Plastic mulch	33.33[a]	100[a]	_
Grass mulch	50.0[a]	100[a]	_
P. fluorescens alone	20.0[a]	100[a]	_
T. viride alone	13.33[a]	100[a]	_
P. fluorescens + *T. viride*	13.33[a]	100[a]	_
$ZnSO_4.H_2O$ + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$	20.0[a]	100[a]	_
Victory72 WP	20.0[a]	93.33[a]	6.67
Ridomil gold	20.0[a]	100[a]	_
Untreated control (Absolute control)	40.0[a]	100[a]	_
Mean	23.70	99.23	_
CV (%)	9.40	3.99	_
LSD (5%)	6.2	11.94	_

CV= Coefficient of variation, LSD = Least Significant Difference
Means in column followed by the same letter(s) are not significantly different at α=5%..

At first disease assessment (53 DAP), there was no uniform initial disease incidence among treatments. Minimum initial per cent disease incidence was observed in *T. viride* treated plots and plots treated with *P. fluorescens* + *T. viride* with mean values of 13.33% each. On the contrary, the highest initial disease incidence was observed on grass mulch and unprotected control with values of 50 and 40%, respectively. At the end of the disease assessment, most of the experimental plots recorded 100% disease incidence, after 113 DAS, except for Victory 72WP which recorded a disease incidence of 93.33%.

Disease severity

There were significant differences ($P < 0.05$) among treatments for final per cent disease severity. The least per cent disease severity was recorded for Victory 72 WP and Ridomil gold treatments with mean values of 15.57% and 18.90%, respectively. Moreover, the combination of micronutrients ($ZnSO_4.H_2O$ + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$) also showed lower disease severity next to fungicides with mean value of 36.67%. This could be that micronutrient offers resistance to the invasion of disease causing pathogen. The bio-control agents and both mulch types did not significantly differed from each other as well as from the control in disease severity. Victory 72 WP and Ridomil gold treatment were superior over the other treatments in reducing the severity of tomato late blight disease over the control with a reduction value of 75.97 and 71.05, respectively (Table 2). The disease progressive curve of many treatments showed gradual increase and have been attained their maximum peak point at 80 DAP and remain constant up to the end of experimental period (113 DAP). Therefore, the shape of disease progress curve showed almost sigmoid nature (Figure 1).

Table 2. Effect of various treatments on disease severity percentage and mean AUDPC of tomato late blight.

Treatments	Initial Severity (%)	Final Severity (%)	Reduction in Severity (%)	AUDPC (%-days)
Plastic mulch	4.43^{a}	47.7^{ab}	28.51	1440.9^{bc}
Grass mulch	5.0^{a}	50.0^{ab}	25.11	1772^{ab}
P. fluorescens alone	3.33^{a}	53.30^{ab}	20.24	1508.7^{bc}
T. viride alone	2.20^{a}	54.43^{ab}	18.57	1528.9^{abc}
P. fluorescens + *T. viride*	2.23^{a}	54.43^{ab}	18.57	1547.9^{abc}
$ZnSO_4.H_2O$ + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$	3.33^{a}	36.67^{bc}	44.80	1312.2^{dc}
Victory 72WP	3.30^{a}	15.57^{d}	75.97	711.7^{e}
Ridomil gold	3.33^{a}	18.90^{cd}	71.05	894.6^{de}
Untreated control	6.67^{a}	67.70^{a}	_	1923.4^{a}
Mean	3.71	44.09	_	1390.33
CV (%)	9.68	15.26	_	10.79
LSD (5%)	4.9	20.26	_	452.2

CV= Coefficient of Variation, LSD = Least Significant Difference, AUDPC = Area under Disease Progress Curve.
Means in the column followed by the same letter(s) are not significantly different at α=5%..

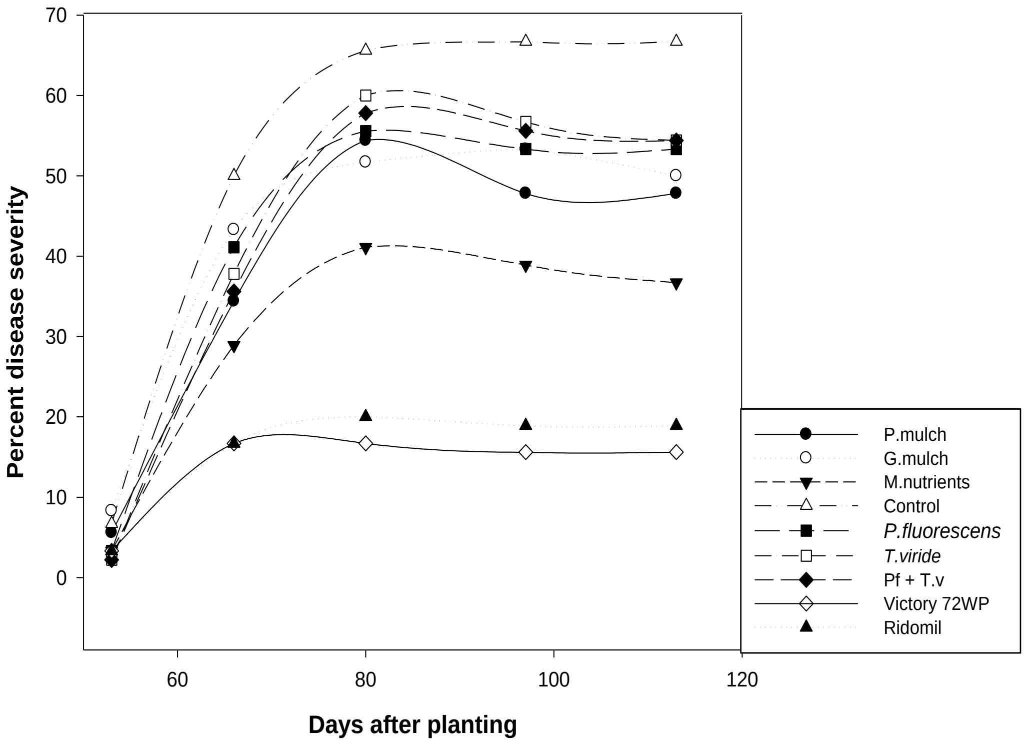

Figure 1. Disease progressive curves of tomato late blight severity as affected by different treatments.

Area under disease progressive curve (AUDPC)

The late blight symptoms appeared to start in treated and untreated plots at about the same time with uneven distribution of the pathogen. But gradually the disease severity varied within treatments., all fungicide treatments resulted in significantly better foliar late blight control and gave significantly higher total yield compared to the rest of treatments. Treatments significantly differed in terms of AUDPC values ($P<0.05$). Significantly lower AUDPC values (711.7% _days and 894.6%_days, respectively)were observed for Victory 72 WP and Ridomil gold treated plots. Treatment such as grass mulch, *T. viride* alone, *P. fluorescens* + *T. viride* recorded significantly higher AUDPC values which did not differed from the untreated control (Table 2; Fig 1). Three fungicides (Metalaxyl-M4% + Mancozeb 64% (Ridomil gold 68 WP) 350g/100liters, Fungomil 250gm/100liters, and Mancozeb + Metalaxyl (Mancolaxyl 72%) 250gm/100liters) were found effective in controlling the disease on tomato and consequently increased marketable fruit yield by 40-66%' which supports our present finding Moreover, compared to the rest of treatments, all fungicide treatments provided significantly better foliar late blight control and significantly recorded higher total yield (Mohammed et al., 2009). Similarly, effective control of late blight disease was achieved through the use of the Phenyl amide fungicides like Ridomil gold across the Sub Saharan region (Dekker, 1984). Disease severity, disease progress rate and area under disease progress curve have all been used as by different researchers as a measure to determine the level of late blight attack on potato and categorize tomato varieties into different level of resistance to late blight (Andrivon *et al*., 2006, Elsayed, 2010).

In addition, a combination of micronutrients treatment was found to be effective in reducing tomato late blight severity by 44.80 % when compared to the control (Table 2). The use of plastic mulch and dry grass mulch reduced disease severity only by 28.51 and 25.11%, respectively over the control, indicating that they were less effective compared to fungicides and micronutrient treatments. The moderate reduction in disease severity due to mulching could be attributed to a reduction in the plant contact with the soil which hinders the dissemination of the soil borne pathogen to the plant.

On the other hand, there was no significant difference between treatments in which tomato seeds was treated with spore suspension of *T. viride* alone, *P. fluorescens* alone and *T. viride* + *P. fluorescens,* all of which were found not to have reduced the disease severity effectively compared to other treatments. The recorded AUDPC values for the bio agent's was 1528.9, 1508.7 and 1547.9 %_days, respectively (Table 2). Even though, the bio-control agents gave a better per cent disease severity reduction compared to untreated plot (table 2). Dorn *et al* (2007) and Kurzawinska and Mazur (2009) in a study conducted with commercially available preparations of bio control agents against late blight on potato crops under field conditions, have both reported that bioagents were not effective in controlling lare blight which agrees with the result of the present study However, Ephrem (2005) reported a reduction in disease severity as measured by AUDPC due to treatment with *T. viride* and *P. fluorescens* against potato late blight under green house condition at HARC, Holleta. . He also reported that the mixed culture of the two bio agents was not as effective as the single culture application indicating a lack of synergy.

Table 3. Disease progressive rate (r) of tomato late blight severity as affected by various treatments

Treatments	Disease progressive Rate (r)	R^2	SEE	Significance (P<0.05)
Plastic mulch	0.80	0.64	0.482	0.0001
Grass mulch	0.80	0.64	0.375	0.0001
P. fluorescens alone	0.81	0.66	0.476	0.0001
T. viride alone	0.81	0.66	0.500	0.0001
P. fluorescens+ *T. viride*	0.81	0.66	0.314	0.0001
$ZnSO_4.H_2O + CuSO_4.5H_2O + FeSO_4.7H_2O$	0.76	0.57	0.412	0.0001
Victory72WP	0.65	0.43	0.368	0.0001
Ridomil-gold (standard check)	0.68	0.47	0.297	0.0001
Control(Absolute control)	0.83	0.68	0.476	0.0001

SEE = Standard error of estimate

Disease progressive rate (r)

The comparisons of the disease development rate among treatments using the logistic model showed that disease progressive rates significantly differed between treatments (p< 0.05) The lowest disease progressive rate was recorded for Victory 72WP (0.65).In other treatments, the acceptable regression equation with coefficient of determination (R^2) ranging from 0.43 to 0.68 which produced a linearized final late blight severity over time, in days after planting. The highest disease progressive rate was observed from untreated plot with a value of 0.83, which exceeds victory 72WP by 0.18 units per day.

Yield and yield components

Number of fruits and Percent fruit infection

The result indicated that there was a significant differences between treatments in number of healthy tomato fruits and number of fruits per plant (P<0.05). On the other hand, there was no significant difference between treatments in the number of infected fruits/plot (P>0.05). Victory 72 WP and Ridomil gold treated plots gave significantly higher number of fruits per plant (35.84 and 33.4) followed by plastic mulched plot (26.75) (Table 4). The use of bio agents and grass mulch gave significantly lower and similar number of fruits /plant to the control treatments. All the treatments did not significantly differed in number of infected fruits per plot. The per cent fruit infection was significantly lower for Victory 72 WP and Ridomil gold treated plots as well as for plastic mulched plot compared to all the other treatments (Table 4). The number of healthy fruits/plot was significantly higher for Victory 72 WP and Ridomil gold treated plots, followed by plastic mulched and micronutrients sprayed plots as compared to the control, bio agent treatments, and grass mulched plots (Table 4).

Table 4. Yield and yield components of various treatments against tomato late blight under field condition.

Treatments	Number of healthy fruits/plot	Number of infected fruits/plot	Number of Fruits/ plant	Fruits infection (%)
Plastic mulch	350.9[bc]	62.67[a]	26.75[abc]	15.13[dc]
Grass mulch	152.0[e]	70.40[a]	14.92[ed]	31.70[ab]
P. fluorescens alone	225.6[cde]	66.67[a]	19.23[cde]	23.50[bc]
T,viride alone	192.0[de]	67.20[a]	17.17[de]	26.36[b]
P. fluorescens + *T. viride*	173.9[e]	68.27[a]	16.11[de]	28.21[b]
$ZnSO_4.H_2O$ + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$	310.4d[c]	59.73[a]	23.99[cbd]	16.07[dc]
Victory 72WP	509.9[a]	51.73[a]	35.84[a]	9.40[d]
Ridomil-gold	457.7[ab]	62.40[a]	33.40[ab]	12.34[d]
Untreated control	122.1[e]	74.67[a]	13.13[e]	38.42[a]
Mean	285.67	64.65	22.59	21.99
CV (%)	17.29	13.61	13.48	15.07
LSD (5%)	26.85	26.49	9.48	9.98

CV= Coefficient of variation, LSD = Least Significant Difference
Means in column followed by the same letter(s) are not significantly different at α=5%..

Fruit Yield

There was significant difference ($P<0.05$) among treatments on marketable fruits yield while no significant difference was observed on unmarketable fruit yield ($P> 0.05\%$). The highest marketable fruit yield was harvested from plots treated with Victory 72 WP (210.98 kg / ha) and Ridomil gold (184.93 kg/ha) followed by plastic mulch (132.25 kg/ha), and mixture of micronutrients (116.21 kg/ha) as compared to all the other treatments. The highest per cent yield increase over control (395.26 %) was recorded from the Victory 72WP treated plot followed by Ridomil gold and micronutrients ($ZnSO_4.H_2O$ + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$) while the lowest percent yield increase was observed from grass mulched plot (Table 5).

Table 5. Effect of various treatments against tomato late blight on marketable and an unmarketable fruit yield

Treatments	Marketable yield (kg/ha)	Unmarketable yield (kg/ha)	Yield advantage over control (%)
Plastic mulch	132.25[bc]	24.10[a]	210
Grass mulch	55.0[e]	26.48[a]	29.10
P. fluorescens alone	82.13d[ce]	25.84[a]	92.79
T. viride alone	69.69[de]	26.44[a]	63.59
P. fluorescens + *T. viride*	63.11[e]	26.18[a]	48.14
$ZnSO_4.H_2O$ + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$	116.21[dc]	21.63[a]	172.79
Victory72WP	210.98[a]	18.87[a]	395.26
Ridomil-gold	184.93[ab]	25.45[a]	334.10
Untreated control	42.60[e]	29.31[a]	_
Mean	108.29	25.88	_
CV (%)*	17.40	13.77	_
LSD (5%)*	6.76	10.73	_

*Abbreviations as per table 4.

Correlation among yield and disease parameters

Disease incidence showed no significant positive correlation (P<0.05) between disease severity, fruit infection, AUDPC and disease progress rate. Disease severity showed significant positive correlation with AUDPC, fruit infection, and disease progress rate. Disease severity, fruit infection, AUDPC and DPR showed significant negative correlation with yield (Table 6).

Table 6. Correlation coefficient (r) values between yield and disease parameters among each other.

Disease Parameters	Disease incidence	Disease severity	Fruits infection	AUDPC	Disease progress rate (r)	Yield
Disease incidence	_	0.31[ns]	0.20[ns]	0.29*	0.47[ns]	-0.20[ns]
Disease severity		_	0.83**	0.89**	0.86**	-0.87**
Fruit infection			_	0.83**	0.79**	-0.91**
AUDPC				_	0.83**	-0.83**
Disease progressive rate(r)					_	-0.80**
Yield						_

* Correlation is significant at 0.05 probability level

** Correlation is highly significant at 0.05 probability level; ns = None Significance

Yield loss estimation

The variation in fruit yield losses was observed among the different treatments. In comparison, the untreated control plots had a notably higher fruit yield losses than the protected plots. Yield losses were significantly reduced by fungicide compared to control and the other treatments (Table 7). The highest fruit yield loss was recorded forum untreated control plots (79.81 %) compared to the most protected plots (Victory 72 WP) with a value of (12.35%) . While n *P. fluorescens* mixed with *T. viride,* recorded a per cent yield loss of 70.08.

Table 7. Yield loss estimation of tomato due to late blight disease under various treatments

Treatments	Mean fruits yield (kg/ha)	Yield loss (%)
Plastic mulch	132.25	37.32
Grass mulch	55	74
P. fluorescens alone	82.13	61.07
T. viride alone	69.69	66.97
P. fluorescens +*T. viride*	63.11	70.08
$ZnSO_4.H_2O + CuSO_4.5H_2O + FeSO_4.7H_2O$	116.21	44.92
Victory72WP	210.98	_
Ridomil gold	184.93	12.35
Untreated control	42.60	79.81
CV (%)	14.56	12.6
LSD (5%)	8.4	4.2

Cost benefit analysis

The partial budget analysis results indicated that plastic and grass mulch recorded the highest total variable costs (Table 8). Likewise, the minimum variable cost was observed for micronutrients and biocontrol treatments. The highest gross field benefit was obtained from Victory 72 WP and followed by Ridomil gold. In addition, the highest net benefit was also obtained from Victory 72 WP and Ridomil gold with mean values of 161,464 and 139,784 Birr/ha, respectively. Moreover, micronutrients and plastic mulch, also recorded a promising net benefits compared to the control.(Table 8). However, due to the cost of purchasing and laying plastic mulch, it might not be advised under large scale farming The least net benefit was maintained from plots treated with grass mulch with a value of 31,138 Birr/ha.

Table 8. Yield and cost inputs for the management of tomato late blight by using different treatments.

	Unit	T1	T2	T3	T4	T5	T6	T7	T8	T9
Marketable Yield/ha	Kg	4260	5500	6311	6969	8213	11621	13225	18493	21098
Gross field benefits	Birr	34080	44000	50488	55752	65704	92968	105800	147944	168784
Cost of treatment	Birr	_	5430	150	150	150	8.14	23550	1,500	660
Cost of labour & management	Birr	6300	7432	7656	7656	7656	6660	7432	6660	6660
Total cost that vary	Birr	_	12862	7806	7806	7806	6668	30982	8160	7320
Net benefit	Birr	_	31138	42682	47946	57898	86300	74818	139784	161464

T1 = Control, T2 = Grass mulch, T3 = *P. fluorescens* + *T. viride*, T4 = *T. viride* alone, T5 = *P. fluorescens* alone, T6 = Micronutrients, T7 = Plastic mulch, T8 = Ridomil gold, T9 = Victory 72 WP

Marginal analysis indicated that the highest marginal rate of return was obtained from micronutrient treatments (15,902%) followed by victory 72wp (13,106%) when compared with untreated control plots. However, the least marginal rate of return was recorded from plots treated with grass mulch alone with values of 51.17 % (Table 9). Generally, successful tomato production and management are always challenging and, as for any agricultural commodity, difficult. However, tomato production remains an economically feasible and profitable enterprise for many growers at Guder of Toke kutaye district, West Shoa, Ethiopia.

Table 9. Partial budget analysis for various treatments against tomato late blight

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9
Tomato Yield(kg/ha)	13225	5500	8213	6969	6311	11621	21098	18493	4260
Tomato sale(Birr/kg)	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Sale revenue(1*2)	105800	44000	65704	55752	50488	92968	168784	147944	34080
Input & labor Cost(Birr/ha	30982	12862	7806	7806	7806	6668	7320	8160	6300
Marginal cost(Birr/ha)	24682	6562	1506	1506	1506	368	1020	1,860	0
Net profit(3-4)(Birr/ha)	74818	31138	57898	47946	42682	86300	161464	139784	27780
Marginal benefit (Birr/ha)	47038	3358	30118	20166	14902	58520	133684	112,004	0
MRR (7/5) (%)	190.6	51.17	2000	1339	989.5	15902	13106	6022	0
Cost Benefit Ratio (CBR)	2.41	2.42	7.42	6.14	5.47	12.94	22.06	17.13	0

T1 = Plastic mulch, T2 = Grass mulch, T3 = *P. fluorescens* alone, T4 = *T. viride* alone, T5 = *P. fluorescens* + *T. viride*, T6 = Micronutrients, T7 = Victory 72 WP, T8 = Ridomil gold, T9 = Control

Conclusion

The results of this study showed that there was a significant difference among treatments in terms of disease severity (DS), area under disease progressive curve (AUDPC), disease progressive rate (r), yield and yield components, and cost-benefit ratio. The application of fungicide treatments considerably reduced late blight progress, with a corresponding increase in tomato fruit yields over the other treatments including control. Victory 72 WP and Ridomil gold recorded significantly lower DS, AUDPC, disease progressive rate and higher marketable fruit yield. Aside Victory 72 WP and Ridomil gold, the application of micronutients, seed treatment with *P. fluorescens* alone and the use of plastic mulch showed a lower AUDPC value over the other treatments. Lower per cent fruit infection was recorded with Victory 72 WP and Ridomil gold followed by the use of plastic mulch. Moreover, higher marketable yield was achieved with Victory 72 WP, Ridomil gold, mixture of micronutrients, and the use of plastic mulch. However, there was no significant positive correlation (P<0.05) between disease severity, fruit infection, AUDPC and disease progress rate with disease incidence. In terms of yield loss it varied among the treatments. The highest fruit yield loss was recorded on untreated control plots followed by *P. fluorescens* mixed with *T. viride*. . For all the measured parameters, Victory 72 WP, Ridomil gold, plastic mulc and a combination of micronutrients were found to be effective in the control of late blight.

This study provides new possible alternatives for the management of tomato late blight in both small and large scale tomato producers of West Shoa, Ethiopia.

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