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Research Article

EFFICIENCY OF MEANS TO CONTROL MAJOR DISEASES OF TOMATO IN HUMID SUBTROPICS OF GEORGIA

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ABSTRACT. Tomato is one of the most widespread and popular vegetable food crops in the world including Georgia. The average yield of tomatoes in Georgia is very low comparing with other countries and local production, so far, cannot meet the domestic demand. In Georgia, tomato production in open fields is highly constrained by the early blight (*Alternaria solani*) and late blight diseases (*Phytophthora infestans)*. Key to successfully controlling the most common fungal foliar diseases is an integrated management program where the main component is using resistant varieties and fungicides. This study aimed to determine the effectiveness of biological fungicide and resistant variety to combat tomato late and early blights under field conditions in the humid subtropics in Western Georgia. The research was conducted at the experimental field of the Institute of Phytopathology and Biodiversity in 2020-2021. Tomato varieties, moderately resistant (De-Barao Rozovii) and susceptible (Vardisferi Choportula) to late and early blights, and chemical (Ridomil gold) and bacterial fungicides (Phytosporin M) were research objects. The analysis of variance showed that the effect of fungicides and tomato variety was highly significant for late blight severity and tomato fruit yield. The Ridomil gold was the most effective than biofungicide Phytosporin M as the severity of *Phytophthora infestans* on susceptible variety was reduced by 41.5% and yield increase was 77.6%. In treatment with Phytosporin M, the disease severity was reduced by 23.2% and yield increase was 40.5%. The severity reduced by 15% and yield increased by 35.3% on moderately resistant variety De Barao.

Keywords: *Blights, fungicide, severity, tomato, variety, yield.*

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is one of the most widespread and popular vegetable food crops in the world. Tomato production ranks first among vegetable crops, which is due to the good taste and high nutritional value of tomato fruits [1, 2]. Tomatoes have been known in Georgia since the second half of the 18th century, they are grown everywhere from sea level 10m to 1700 m with a wide range of climate [3]. According to Geostat data, the planted area of tomatoes and the average yield in open ground for the past two years were 4.0 thousand hectares and 13.8 t/ha, respectively. The highest average yield of tomatoes in Georgia was recorded in Kvemo Kartli zone (25.3 t/ha) [4]. These data are very low comparing with other countries, such as Turkey, China, India, Egypt, Senegal, Niger etc. [5]. Local production, so far, cannot meet the domestic demand, accordingly, about 9-10 million dollars' worth of tomatoes are imported into the country every year.

The lower yields in our country are attributable to poor crop management practices and biotic and abiotic factors. In Georgia, tomato production in open fields is highly constrained by pests and diseases, especially, the early and late blight diseases caused by the fungus *Alternaria solani* and *Phytophthora infestans,* respectively [6]. The blight diseases appeared in Europe in the middle of the 19th century and are still considered the most harmful diseases of tomatoes and potatoes in many countries. In the presence of favorable conditions for development, the diseases can easily turn into an epiphytoty. These pathogens affect the leaves, stems, and fruits of tomato caused severe damage and yield losses can reach 80-100% of high severity levels [7, 8, 9, 10, 11, 12].

All this dictates the need to constantly improve protective measures against tomato diseases. Key to successfully controlling the most common fungal foliar diseases is an integrated management program [13, 14]. The main component of this program is using resistant varieties and fungicides. To prevent the development and spread of Phytophthora and Alternaria diseases, the timely and qualitative use of appropriate treatments are very important [15, 16, 17]. An alternative and a more environmentally friendly method is applying the bioagents [18,19]. *Bacillus subtilis* is one of the most widely used biological agents to combat late and early blights of tomato because the protective enzymes of *Bacillus subtilis* work effectively against pathogens [20, 21]. The application of *B. subtilis* helps to strength the tomato plant's protective system by improving antioxidant activity and to decrease the negative effect of pathogenic stress [22]**.** Our objective was to determine the effectiveness of biological fungicide and resistant variety to combat tomato late and early blights under field conditions in the humid subtropics in Western Georgia.

MATERIALS AND METHODS

Experimental site

The study on the effectiveness of a fungicides was conducted at the experimental field of the Institute of Phytopathology and Biodiversity (Adjara region, humid subtropical zone) in 2020 and 2021. The climate of the region is characterized by high humidity of air and soil in a complex with high temperatures in July-August. The annual rainfall here was about 700 mm, the main of which falls on the summer period. For the trials, weather data (air temperature, relative air humidity, precipitation) recorded daily and monthly at the Institute weather station are given in Table 1 below.

Experimental objects

Two varieties of tomatoes: De-Barao Rozovii and Vardisferi Choportula with different level of resistance to late and early blight were included in the experiment. Tomato variety De-Barao Rozovii introduced from Russia and tested in previous years, showed moderate resistance to late and early blight, and Georgian commercial variety Vardisferi Choportula was susceptible to both indicated diseases [23].

Treatments include the registered in Georgia system fungicide Ridomil Gold MZ WG with two active ingredients Mefenoxam 40 g/kg, Mancozeb 640 g/kg (Syngenta product) as a positive control and the microbiological preparation Phytosporin M (BashIncom company), wettable powder with a live spore culture of *Bacillus subtilis* strain 26 D (titre ~ 2 billion spores/g).

Table 1. *Average air temperature, humidity and precipitation for tomato growing seasons at experimental field in 2020-2021*

Year/ month	Temperature, ^{0}C	Humidity, %	Precipitation, mm	Rainy days >1mm/>5mm
2020				
May	18.3 ± 1.7	69.6 ±2.8	23.1 ±16.1	17/10
June	20.8 ±0.2	77.3 ±1.7	14.8±13.3	18/5
July	24.5 ±1.0	80.3 ±2.1	26.3±11.3	19/6
August	24.7 ±2.4	78.7 ±0.3	49.3 ±6.6	13/9
Mean	21.4 ±1.3	83±1.7	85.2±22.0	
2021				
May	14.0 ± 1.4	74.3 ±1.4	22 ±12.4	13/3
June	19,2 ±1.4	68 ±1.1	24.6±10	18/7
July	23.0 ±0.3	72± 3.6	106.5±30	19/8
August	23,3 ±1.4	69 ±2.4	53.3±12.4	23/10
Mean	20.0±2.2	75.5±1.3	130.8±36.1	

Trial design

Tomato seedlings for field experiment were grown in glasshouse by using plastic pots, each of 30 cm diameter and containing a soil mixture consisting of sand 3 kg/pot and 10 g fertilizer per kg (N:P: K 12:4:6). Seedlings with the four leaves were transplanted in the field plot at 20-25 days after sowing. The field experiment was laid out in a randomized complete block design with three variants (1- treated by Ridomil Gold, 2- treated by Phytosporin M, 3- untreated-control plot) and four replications. Each variety was planted in rows of two-meter length with a spacing of 50 cm between and 70 cm within rows. Each row included 3 plants [24, 25]. A standard agronomic practice, including periodic weeding by hand and NPK (17-17-17) fertilization at the rate of 200 kg/ha after seedling establishment, was applied. Plants were watered as needed.

Treatments with chemical fungicide and Phytosporin M were carried out with hand sprayer at the recommended doses, 2kg/ha and 0.2kg/ha, respectively, according to the label instruction. The liquid preparation of Phytosporin M was prepared by dissolving 1 part of the powder in 2 parts of plain unchlorinated water. For further processing of plants, 15 ml of liquid drug is also diluted with per 10 liters of water.

The first spraying - in the first decade of June (when first symptoms of *Alternaria solani* appeared on the leaf surface of the tomato), the next four - with an interval of 10-12 days, depending on weather conditions.

Data collection

Five leaves were selected from each observed plant for scoring the disease severity. Assessment of disease severity was taken place by visually estimating the percent of infected leaf surface using disease rating scale given by James [26] as mentioned below in the Table 2. The records of the surveyed replicates for each treatment were averaged.

Table 2. *The percentage scale for assessment of potato late blight*

Disease severity %	Description of symptoms
0	No symptoms on the leaf
5	Up to 10 spots per plant; or general light infection
5	About 50 spots per plant; up to 1 in 10 leaflets infected
25	Nearly every leaflet infected, but plants retain normal form; plants may smell of blight; field looks green although every plant is affected.
50	Every plant affected and about 50% of leaf area destroyed; field appears green, flecked with brown
75	About 75% of leaf area destroyed; field appears neither predominantly brown nor green
95	Only a few leaves on plants, but stems green
100	All leaves dead, stems dead or dying

Biological efficacy of fungicides under natural infections of late blight was evaluated in accordance with the standard methodology. It was calculated by Abbot's formula $X = \frac{(a-b)}{a}100$, where X – efficacy, %, a- average disease severity on untreated plots, b - average disease severity yield on treated plots [27].

The total number of fruits (kg/m^2) both marketable and unmarketable per plant of four harvests were collected at physiological maturity and weighted. Fruit yield increase over control (YOC) was calculated according to the formula: YOC%= Yt – Yc/ Yt x100, where -Yt mean yield of the protected plots and Yc- mean yield in control (unprotected) plots [28].

Recorded data related to disease severity and tomato fruit yield were analyzed using statistical analysis of variance (ANOVA) and treatment means were compared by Fisher's least significant difference test (LSD) at 0.05 level.

RESULTS AND DISCUSSION

As it is known, the optimal climatic conditions for the development of early blight and late blight diseases are: 18-22^{0}C air temperature, 80-100% humidity and high rainfall. The difference is that if there are cool and wet days during the growing season, *Phytophthora infenstance* outbreaks will occur. And hot, rainy weather favors the superior development of *Alternaria solani* [19, 29, 30].

As shown in the Table 1, air humidity was almost the same in the growing season of both years, the average air temperature in 2021 was slightly lower (20.0±2.2), and the amount of precipitation (130.8±36.1) was significantly higher than in 2020. August 2021 was particularly rainy (23 days with 1 mm of rain). Accordingly, the development of *Phytophthora infenstance* prevailed. In both years, the first symptoms of *Alternaria solani* (1-5%) appeared on the leaf surface of tomato plants in early June, and a week later the symptoms of late blight revealed. Due to favorable conditions the disease spread rapidly on the leaves of the plants, especially in 2021. It reached a high severity on the susceptible variety Vardisferi Choportula at the end of July, and spread widely on tomato fruits in August. During July-August period symptoms of *Alternaria solani* could not be distinguished due to Phytophthora dominance.

The disease scoring data showed that in tomato growing seasons 2020 and 2021, the mean severity of late blight on unprotected plots was the highest on both susceptible and moderately resistant varieties: Vardisferi Choportula 62.1 - 65.5% and De Barao 51.3-54.3%, respectively. The mean disease severity on plots treated with Ridomil Gold and Phytosporin M decreased. However, the mean disease severity over two years on the leaves of moderate resistant variety De Barao (43.4%) and susceptible Vardisferi Choportula (49.1%) treated with biopreparation Phytosporin M was higher compared to severity (27.3-37.2%) on the plots protected with Ridomil Gold. Accordingly, the average value of efficacy of chemical fungicide Ridomil Gold for moderately resistant (49.6%), and susceptible varieties (41.7%) was higher than the efficacy (23.2-20.5%) of biofungicide Phytosporin M (Table 3). According to Chowdappa et al. [21] and Kumbar et al. [31] the *Bacillu*s sp. inhibited mycelial growth of 7 plant pathogenic fungi including *P. infestans* in vitro and in vivo tests and protected tomato plants. The *Bacillus subtilis* strain 26 D inhibited the development of *P. infestans* in the presented study too. However, the biological efficacy of Phytosporin M based on *Bacillus subtilis* was lower than of Ridomil gold. In accordance with the Anova results, both effect of fungicide and tomato variety on disease severity was significant that was confirmed statistically at 0.05 level of confidence.

Of course, the reduction of the disease led to an increase in the fruit yield of tomato varieties. According to the results of assessment of variety and treatments effect on the tomato fruit yield, the highest yield was obtained from plots treated by Ridomil Gold, and it ranged by year and variety. Particularly, in 2020 the average yield from local variety Vardisferi Choportula and moderate resistant variety De Barao Rozovii were 9.9±0.39 kg/m^2 and 10.7±0.11 kg/m^2, respectively. In 2021, almost same average yield of Vardisferi Choportula (9.6±0.43 kg/m^2) and De Barao Rozovii (10.4±0.21 kg/m^2) were obtained. The mean yield over both years obtained from Vardisferi Choportula (3.7±0.17 kg $/m^2$) and De Barao (5.4±0.2 kg/m^2) plants treated with bioprapartion Phytosporin M were less as compared to the tomato fruit yield of Vardisferi Choportula (9.8±0.4 kg/m^2) and De Barao (10.6±0.16 kg/m^2) obtained from chemically treated plots, but it was higher comparing with to untreated control plots (2.2±0.16 kg/m^2 and 3.4±0.18 kg/m^2, respectively Vardisferi Choportula and De Barao).Means are statistically significant at 0.05 as F> P. i.e. both impact of fungicide and tomato variety on fruit yield was significant.

Accordingly, over two years of the research, yield increase in Ridomil Gold MZ treatment for varieties Vardisferi Choportula and De-Barao Rozovii was 77.6% and 67.8%, respectively, but in treatments with Phytosporin M the yield increase was 40.5% and 37.0%, respectively (Table 4). Based on the data obtained from untreated control plots, the efficiency of the resistant tomato variety De-Barao over 2020 and 2021 seasons comparing to the susceptible variety Vardisferi Choportula was high-35.3%. This indicated that moderately resistant variety reduced infection of *Phytophthora infestans* and improved fruit yield.

Table 3. *Effect of foliar spraying of Phytosporin-M and Ridomil Gold on Phytophthora infenstance severity under field conditions*

Treatments*	Mean Disease severity, %				Mean severity/ fungicide efficacy, % for 2020-2021	
	Season 2020		Season 2021			
	Variety*					
	Vardisferi Choportula	De Barao Rozovii	Vardisferi Choportula	De Barao Rozovii	Vardisferi Choportula	De Barao Rozovii
Ridomil Gold MZ (MetalaxylM-mancozeb	36.3±0.14	26.3±0.17	38.3±0.5	28.3±0.4	37.2/41.7	27.3/49.6
Phytosporin M (*Bacilus subtilis*)	46.8±0.31	42.2±0.8	51.3±0.4	44.6±1.4	49.1/23.2	43.4/20.5
Untreated control	62.1±0.25	53.4±0.15	65.6±0.7	54.3±1.7	63.9	53.9

** Significantly at 0.05, LSD for treatments - 3.7 and for variety - 0.9*

Table 4. *Effect of foliar spraying of Phytosporin-M and Ridomil Gold on the tomato fruit yield under field conditions*

Treatments*	Mean yield, kg/m^2				Mean yield, kg/m^2 and Yield Increase, % over two seasons 2020-2021	
	Season 2020		Season 2021			
	Variety*					
	Vardisferi Choportula	De Barao Rozovii	Vardisferi Choportula	De Barao Rozovii	Vardisferi Choportula	De Barao Rozovii
Ridomil Gold MZ (MetalaxylM-mancozeb	9.9±0.39	10.7±0.11	9.6±0.43	10.4±0.21	9.8±0.4 77.6	10.6±0.16 67.8
Phytosporin M (*Bacilus subtilis*)	3.6±0.18	5.6±0.3	3.8±0.16	5.2±0.16	3.7±0.17 40.5	5.4±0.2 37.0
Untreated control	2.3±0.15	3.45±0.17	2.1±0.2	3.3±0.16	2.2±0.16	3.4±0.18

** Significantly at 0.05, LSD for treatments - 2.4 and for variety – 0.5*

So, evaluation of the efficacy of tomato protecting measures (resistant variety, chemical and biological fungicides) against late blight showed that chemical fungicide Ridomil gold was the most effective than bacterial fungicide Phytosporin M as the severity of *Phytophthora infestans* on susceptible variety was reduced by 41.5% and yield increase was 77.6% in treatment with Ridomil gold. In treatment with Phytosporin M the severity of *Phytophthora infestans* on Vardisferi Choportula was reduced by 23.2% and yield increase was 40.5%. The severity of late blight reduced by 15% and yield increased by 35.3% on moderately resistant variety De Barao.

Our results are in an agreement with those reported by several authors [32, 33, 34, 35, 36]. They concluded that the treatment with chemical fungicides (Ridomil gold, Score, Amistar) gave the best protected results, and it was more efficient to manage tomato late blight and early blight than biofungicides. Filippov [10] and Vasilieva [37] concluded that the Phytosporin M was high effective, and they recommended Phytosporin M for controlling potato and tomato blights. *B. subtilis* strains were also successfully utilized by Kilani-Feki et al [38]. for the suppression of *Botrytis cinerea*, the causal agent of tomato fruit rot. Several researchers [39, 40, 41] suggested that different bioagents (*Bacillus subtilis, Bacillus megaterium, Pseudomonas fluorescens, Trichoderma harzianum)* might be playing important function in management of tomato early blight. It is advisable to continue the research to determine the efficacy of Phytosporin M for prophylactic usage on healthy and slightly diseased tomato plants in order to reduce the frequency of use of the chemical fungicide.

Based on the results of this research and like to the other authors [42, 43, 44], it can be concluded that different methods (cultural practices, biological and chemical control, use of disease free planting material) should be used for the better management of the tomato blights and the farmers should cultivate the resistant varieties, apply chemicals when and where necessary, and apply alternatives means such as bacterial and fungal control.

CONCLUSION

Late blight is the most harmful disease of tomato. Commercially available fungicides like Ridomil gold and Phytosporin M suppressed the development of late blight in tomato under field conditions. The integrated protection system included chemical fungicide Ridomil gold, biofungicide Phytosporin M and moderate resistance tomato variety can be recommended to control of late blight in Adjara subtropical area.

Conflict of Interest. The authors declared that there is no conflict of interest.

Authorship Contributions. Concept: Z.S., T.T., Data Analysis or Interpretation: Z.S., K.N., T. T., Investigation and Data Collection: T.T., K.N., N.A., K.S., Literature Search: K.S., N.A., Writing: Z.S., T. T.

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