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Research Article

Assessment of Economically Important Tomato (*Solanum lycopersicum* L.) Fungal Diseases in Raya Valley, Southern Tigray, Ethiopia

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Tomato is one of the most important vegetable crops in Ethiopia. Notwithstanding, tomato production was hampered by a number of biotic and abiotic factors. Among the biotic factors limiting tomato productivity, diseases caused by fungal pathogens are the most significant. However, the importance and distribution of the diseases in Raya valley, Tigray region, have yet to be studied. As a result, the current study was carried out to assess the relative importance and distribution of tomato fungal diseases in Southern Tigray, Ethiopia. The survey was carried out in 2018 and 2019 to assess the distribution and relative importance of the diseases limiting tomato production in the study area. The assessment was carried out purposive multistage sampling procedures and systematically based on tomato fields at 5-10 km intervals along the main and feeder (accessible) roadsides on pre-planned routes in areas where tomato predominantly grown. Results indicated that late blight, early blight, septoria leaf spot, fusarium wilt and powdery mildew were among the most important fungal diseases observed in tomato fields of the study areas. The survey results revealed that tomato fungal diseases were prevalent and significantly ($p<0.05$) varied in disease intensity among the districts and peasant associations. The highest extent of prevalence and intensity of the diseases have been recorded from Raya Azebo than Raya Alamata district for both consecutive years. Similarly, under peasant association level there was a significant variation in prevalence and intensity of the diseases. Overall, the present survey showed that fungal diseases are found in a different extent of prevalence and intensity with different degrees of economic importance in the study areas. Therefore, research should focus on the variability of pathogens, the association of agronomic practices, and environmental conditions with these major diseases detected. Besides, all management practices must be consolidated in the form of integrated disease management to avoid annihilation and yield losses.

Keywords: - Disease, Fungal, Incidence, Prevalence, Severity, Tomato

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INTRODUCTION

Tomato (Solanum lycopersicum L.) is a popular warm-season vegetable crop grown all over the world, and it is the most important crop in the industrialized world (Herrera et al, 2010). It is grown for its fruits, which are high in nutrients, minerals, and vitamins and are consumed, both fresh and processed (Herrera et al., 2010). Ethiopia has grown the crop for the past eight decades (Samuel et al., 2009; Gemechis et al., 2012). However, Merti Agro-industry began commercializing crop cultivation in 1980 for both domestic and foreign markets (Lemma, 2002).

Gradually, cultivation of this crop was promoted to other parts of the country. Consequently, small-scale commercial production of this crop is currently taking place in different parts of the country (EIAR, 2007).

In Ethiopia, tomato is an important food ingredient in the daily diet of people (Abate 2007; Shamil *et al*, 2017). In recent decades, the crop has received top priority in the country's vegetable research, and it is envisioned as a high-value commodity crop in the country's future research strategies. The crop is important to the country's economy because it serves as a raw material for processing industries, a cash crop for farmers, and a source of employment for the population. Tigray region contributes a significant portion of the country's total tomato production when the southern zone of Tigray region is the highest tomato-producing zone (CSA, 2020). Despite its economic importance, the average national yield (6.52 t/ha) of the crop was low in Ethiopia (CSA, 2021). This might be occurred due to different biotic and abiotic constraints (Worku and Sahe, 2018).

Among the major constraints, diseases caused by different fungal pathogens are the major ones (Kebede *et al*., 2014; Seid *et al.,* 2015; Worku and Sahe, 2018). Sommer (1985) reported that fungi are the most important and prevalent pathogens causing yield losses of 30 - 100% on crops. Accordingly, yield losses of 14.2% to 52.9% under field conditions were reported due to tomato early blight (*Alternaria solani*) from southern Tigray (Mehari and Mohammed, 2015) while up to 100% loss was recorded from tomato late blight (*Phytophthora infestans*) (Gudero *et al.,* 2018). Septoria spot (*Septoria lycopersici)* is also capable of causing complete defoliation of plants, reducing fruit yield and loss of quality greatly (Cabral *et al.,* 2013). Additionally, reports indicated the economic importance of fusarium wilt (*Fusarium oxysporum*) (Aydi-Ben-Abdallah *et al*., 2020).

Powdery mildew, caused by Leveilul ataurica, is another major concern for tomato-growing communities, causing up to 40% yield losses (Bhatia et al., 2020). Fungal diseases have recently caused serious problems in Ethiopian tomato production, particularly in the southern Tigray region (Getachew et al., 2018; Worku and Sahe, 2018; Hailu, 2021). In the southern zone of Tigray, farmers are forced to abandon their production due to disease pressure in the field. Despite this fact, the distribution of fungal diseases and their relative importance across the study areas has received less attention. Therefore, this study was initiated to determine the distribution and relative importance of tomato fungal diseases across the study areas, which could be used as information to develop proper management strategies for the diseases.

Material and Methods

Description of the Study Area

A comprehensive diagnostic survey was conducted in the southern zone of the Tigray region during 2018 and 2019 under an irrigation cropping system. Two major tomato growing districts namely Raya Alamata and Raya Azebo districts purposively selected. The study area is found at 665 km far apart from Addis Ababa to the northern part of Ethiopia. This area is found between an elevation range of 930 - 3171 meters above sea.

Assessment of Tomato Fungal Diseases

The study was conducted in 2018 and 2019 cropping season under an irrigation cropping system to determine the distribution and relative importance of tomato diseases. Districts and peasant associations were selected by consulting zonal agricultural bureaus and districts agricultural and natural resource offices, respectively. From each peasant association, five farmer's fields were assessed by random sampling of the fields. The survey trips were made following the main roads and accessible routes in the surveyed district, and stops were made randomly at every 5-10 km intervals based on vehiclesodometers. The assessment was carried out along the two diagonals (in an ‘’X’’ fashion) using $2m^2$ quadrants at least 10m far apart from each other approximately. In each field, 5 quadrants were systematically assigned to the respective points and tomato plants within the quadrant were counted and recorded as an infected and healthy plants. Incidence and severity of the diseases were assessed through direct visual observation of the symptoms of the diseases on the tomato plants across the quadrants.

The diseases were assessed based on the incidence of the diseases; the number of diseased plants compared to the total number of assessed plants expressed as a percentage.

$$\textbf{\textit{Disease Incidence}}\ (\%) = \frac{Number\ of\ diseased\ plants}{Total\ number\ of\ plants\ in\ quadrant}\ x100$$

Severity of diseases, as the infected area of tissue to the total area of tissue expressed as a percentage. Severity of each disease was examined visually on the whole plants within the quadrants and recorded as the percentage of plant part (tissue) affected, using the respective scoring scale of each disease. Assessment of tomato late blight, early blight and septoria leaf spot severity was done from ten plants randomly from each quadrant using a 0-9 disease scoring scale according to Shutong *et al*. (2007), Ghosh *et al*. (2009) and Mayee and Datar (1986), respectively. Similarly, a 0-5 disease scoring scale (Sibounnavong *et al.,* 2010) was used for fusarium wilt while powdery mildew was assessed using a 0-6 disease scoring scale according to Yan *et al*. (2006). Percent severity index was calculated for each disease separately based on the formula used by scholars previously.

$$\text{PSI} = \frac{\text{Sum of numerical ratings}}{\text{No. of plants scored x maximum disease score on scale}} \text{x } 100$$

To determine the prevalence of tomato diseases across the study area, the number of tomato fields with disease infection and the total number of tomato fields assessed per district were recorded and calculated using a formula described by Aggarwal (2003).

$$\textbf{\textit{Disease Prevalence}}\ (\%) = \frac{Number\ of\ infected\ fields}{Total\ number\ of\ fields\ assessed}\ x100$$

Data Analysis

The data on disease incidence and severity were analyzed using the SAS 9.4 statistical software two-stage nested design GLM procedure. The LSD test was used to calculate the significance of mean difference differences at a significance level of 0.05.

Results and Discussion

Distribution of Tomato Diseases

The survey results indicated that tomato diseases were prevalent in both assessed districts of the Raya valley, Southern Tigray zone with different levels of disease intensity. During the assessment, five tomato diseases like; late blight, early blight, septoria leaf spot, powdery mildew and fusarium wilt was observed as the main bottleneck of tomato production. In line with the present result, previously the importance of these diseases has been reported from different parts of Ethiopia (Seid *et al*., 2015; Worku and Sahela, 2018; Getachew *et al*., 2018). The result of the present study depicted that the extent of the distribution and intensity of each disease was varied within and among districts. Of the 40 fields assessed, the mean prevalence of tomato late blight was 100%. Tomato late blight disease was equally prevalent in both districts for both consecutive years. Statistically, there was no significant difference ($p < 0.05$) among the districts in the incidence of tomato late blight. However, there was a significant difference among districts in the 2018 cropping season in the severity of tomato late blight. The incidence of late blight was 79.1 and 73.7% in the Raya Azebo district, whereas 67.5 and 68.5 % were recorded from the Raya Alamata district in the 2018 and 2019 cropping season, respectively. Severity of tomato late blight was the higher in Raya Azebo district with a mean value of 36.7 and 31.3% in the 2018 and 2019 years respectively. Our results identified that late blight was economically the important and widely distributed disease in Raya valley known by dryness and rainfall shortage. However, this is by far disagreed with previous facts that the disease is more severe in humid and high rainfall areas (Srivastava and Handa, 2010).

Early blight was among the important diseases recorded during 2018 and 2019 in southern Tigray. During the survey, early blight was 100% prevalent in the Raya Azebo and majority fields of Raya Alamata districts. Statistically, there was a significant difference ($p < 0.01$) in the intensity of tomato early blight among the districts of the study area. The highest

incidence of early blight was recorded from Raya Azebo district for both years. Similarly, the highest disease severity was recorded from Raya Azebo district with a mean of 24.7% and 27.4% in the 2018 and 2019 cropping seasons, respectively. The present result proved the report of Mehari and Mohammed (2015) that identified the economic importance of early blight in southern Tigray. Concurrently, Prasad (2002) and Abhinandan *et al*. (2004) reported significantly different extent of disease intensity of early blight from a survey conducted in different locations. This variability of early blight intensity between the districts could be associated with tomato variety used, the virulence of the pathogen, environmental conditions and agronomic practices prevailing across the locations (Ahmad *et al.*, 2014).

Septoria leaf spot was another important disease in both surveyed districts of the zone. Prevalence of the disease was the highest in the Raya Azebo district with mean values of 95.8% and 100% during the 2018 and 2019 cropping seasons, respectively. In the same way, intensity of this disease was higher Raya Azebo district consecutively for both surveyed years (Table 1). Statistically, there was a significant difference ($p<0.05$) between districts in incidence and severity of tomato septoria spot. In addition, powdery mildew and fusarium wilt were among the diseases that have been identified as the bottleneck of tomato production in southern Tigray. The result of this survey was showed that diseases that have been considered economically minor, have become economically emerging in course of time. Powdery mildew is becoming an important disease in all tomato-growing areas of southern Tigray (Worku and Sahela, 2018).

Table 1. Prevalence and intensity of tomato fungal diseases during 2018 and 2019 in Southern zone of Tigray region under irrigation cropping system

Year of survey	Districts	Late Blight			Early Blight			Septoria Leaf Spot			Powdery Mildew			Fusarium Wilt	
		Pre	Inc	Sev	Pre	Inc	Sev	Pre	Inc	Sev	Pre	Inc	Sev	Pre	Inc
2018	Raya Azebo	100	79.1	36.7[a]	100	72.6[a]	24.7	95.8	51.3[a]	16.5[a]	87.5	33.7	14.8	66.7	22.1
	Raya Alamata	100	67.5	25.8[b]	87.5	46.1[b]	20.6	79.2	27.7[b]	8.7[b]	70.8	31.7	11.1	62.5	20.1
	LSD		NS	8.1		9.4	NS		9.2	4.2		NS	NS		NS
2019	Raya Azebo	100	73.7	31.3	100	78.7[a]	27.4	100	53.0[a]	16.7[a]	100	36.7[a]	12.2	83.3	19.7
	Raya Alamata	100	68.5	26.2	91.7	52.1[b]	22.9	83.3	32.7[b]	12.1[b]	87.5	27.5[b]	11.5	62.5	14.6
	LSD		NS	NS		6.6	NS		6.9	3.8		6.4	NS		NS

**Mean values with the same letter within a column did not significantly differ at $p < 0.05$; LSD = least significant difference; Pre = disease prevalence; Inc = disease incidence; Sev = disease severity; NS = no significant difference;

Distribution and Intensity of Tomato Fungal Diseases across the Peasant Associations

Results of the present study indicated that late blight was 100% prevalent in all peasant associations of the study area whereas early blight was 100% prevalent in peasant associations of Raya Azebo district (Table 2). The extent of disease incidences and severities across the peasant associations were significantly different ($p < 0.05$) from each other for all diseases except incidence of powdery mildew and fusarium wilt in 2018 (Table 2). Similarly, in 2019, incidences and severities of the diseases across the peasant associations were significantly different ($p < 0.05$) from each other except severity of powdery mildew. The highest incidence of late blight was recorded from Wergeba, Kera Adisho, Werebaye and Kulugize Lemlem peasant associations with the mean of 95%, 85%, 78% and 75% in 2018, respectively (Table 2). However, there was a slight change in the incidence of the disease in the 2019 cropping season. Statistically, there was a significant difference ($p < 0.01$) among peasant associations in disease intensity of tomato late blight for both consecutive survey years.

The intensity of tomato early blight was also significantly different ($p < 0.05$) among peasant associations of the study areas. The highest incidence and severity of the disease were recorded from the Gerjele peasant association both of the years (Table 2). Whenever the lowest early blight intensity was observed in Selam Bekalsi and Limhat peasant associations of the Raya Alamata district. Correspondingly, Hailu (2021) reported significantly different extents of early blight intensity across the peasant associations of the same study areas. His study also identified variations of early blight intensity across the locations of southern Tigray was concerned with the altitude, crop growth stage, a crop variety used and tillage frequency, crop rotation, irrigation type, irrigation frequency, weed management, seed source and seedling preparation system that has been prevailing in the areas.

In addition, tomato septoria spot was found economically important in all the surveyed peasant associations of the area during the 2018 and 2019 cropping season. The prevalence of this disease was varied from 83.3 - 100% in Raya Azebo and 50 - 100% in Raya Alamata district whereas the incidence of the disease was recorded from Kara Adisho peasant association with the mean severity of 20% (Table 2). The balance of mean severity of septoria spot was the highest in Raya Azebo peasant associations than that of Raya Alamata peasant associations throughout the surveyed years. Our results also identified the importance of powdery mildew and fusarium wilt across the peasant associations regardless of the distribution and intensity of the diseases. Both of the diseases were 100% prevalent in the Werebaye peasant association of Raya Azebo district (Table 2). Incidence of the disease was not significantly different among peasant associations in the 2018 cropping season for both diseases. However, the incidence of fusarium wilt was significantly different among peasant associations during the 2019 cropping season.

In general, five fungal diseases were recorded during the present study with significantly different extent of disease intensity across the locations. Those significant variations between the locations could be occurred due to divergence of environmental conditions and cultural practices used by farmers. Additionally, growth stage of the crop and crop variety used (Kamble, *et al.,* 2009; Hailu, 2021) and virulence variations of the pathogen (Ahmad *et al.*, 2014) might be the possible reason for the variation of the intensity of the diseases across the peasant associations.

Table 1. Prevalence and intensity of tomato fungal diseases during 2018 and 2019 across the peasant associations in Southern zone of Tigray region under irrigation cropping system

Year of survey	Districts	Peasant associations	Late Blight			Early Blight			Septoria Leaf Spot			Powdery Mildew			Fusarium Wilt	
			Pre	Inc	Sev	Pre	Inc	Sev	Pre	Inc	Sev	Pre	Inc	Sev	Pre	Inc
2018	Raya Azebo	K.Adisho	100	85.0^{ab}	39.2^{ab}	100	86.7^{a}	27.5^{bc}	100	60.0^{a}	18.3^{a}	83.3	41.7	15.0^{ab}	66.7	16.7
		Wergeba	100	95.0^{a}	51.7^{a}	100	73.3^{ab}	24.2^{bc}	83.3	45.0^{ab}	15.0^{ab}	66.7	21.7	1.7^{b}	50.0	15.0
		Werebaye	100	78.0^{abc}	34.0^{bc}	100	72.0^{abc}	30.0^{b}	100	50.0^{a}	13.0^{ab}	100	26.0	10.0^{ab}	100	34.0
		B.Delbo	100	58.0^{c}	21.7^{c}	100	58.3^{bc}	18.3^{cd}	100	50.0^{a}	19.2^{a}	100	44.2	17.5^{a}	50.0	20.0
	Raya Alamata	Gerjele	100	60.0^{c}	20.0^{c}	100	88.5^{a}	44.2^{a}	100	51.7^{a}	15.0^{ab}	66.7	26.7	14.2^{ab}	66.7	18.3
		K.Lemlem	100	75.0^{abc}	29.2^{bc}	100	54.2^{c}	23.3^{bc}	100	29.2^{bc}	8.3^{bc}	66.7	38.3	21.7^{a}	50.0	20.0
		Limhat	100	67.0^{bc}	30.0^{bc}	83.3	26.7^{d}	10.0^{de}	50.0	16.7^{c}	5.8^{c}	100	42.5	13.3^{ab}	50.0	23.3
		S.Bekalsi	100	67.0^{bc}	24.2^{bc}	66.7	15.0^{d}	5.0^{e}	66.7	13.3^{c}	5.8^{c}	50.0	19.5	10.0^{ab}	83.3	26.7
		LSD $_{(0.05)}$		24.8	16.2		18.9	10.5		18.4	8.5		NS	15.4		NS
2019	Raya Azebo	K.Adisho	100	90.0^{a}	44.2^{a}	100	83.3^{a}	25.8^{bc}	100	62.5^{a}	20.0^{a}	100	40.0^{ab}	14.5	66.7	11.7^{b}
		Wergeba	100	84.2^{ab}	36.7^{ab}	100	85.0^{a}	30.0^{bc}	100	53.3^{ab}	18.3^{a}	100	31.7^{abcd}	7.5	83.3	19.2^{ab}
		Werebaye	100	69.0^{bcd}	28.0^{bcd}	100	84.0^{a}	33.0^{b}	100	52.4^{a}	13.0^{ab}	100	32.0^{abcd}	13.0	100	30.0^{a}
		B.Delbo	100	50.8^{d}	15.8^{d}	100	63.3^{b}	21.7^{c}	100	45.8^{b}	15.0^{ab}	100	42.5^{a}	13.3	83.3	21.5^{ab}
	Raya Alamata	Gerjele	100	55.0^{cd}	19.2^{cd}	100	93.3^{a}	45.8^{a}	100	60.8^{a}	20.0^{a}	66.7	20.0^{d}	9.2	66.7	17.5^{ab}
		K.Lemlem	100	75.0^{ab}	29.2^{bc}	100	63.3^{b}	26.7^{bc}	66.7	41.7^{b}	15.8^{a}	83.3	25.0^{cd}	11.7	50.0	8.3^{b}
		Limhat	100	73.3^{abc}	30.8^{bc}	100	33.3^{c}	12.5^{d}	100	18.3^{c}	7.5^{bc}	100	35.8^{abc}	12.5	66.7	15.0^{ab}
		S.Bekalsi	100	70.8^{bc}	25.8^{bcd}	66.7	18.3^{d}	6.7^{d}	66.7	10.0^{c}	5.0^{c}	100	29.2^{bcd}	12.5	66.7	16.7^{ab}
		LSD $_{(0.05)}$		19.1	12.9		13.3	9.1		13.8	7.6		12.7	NS		15.7

Mean values with the same letter within a column did not significantly differ at $p < 0.05$; LSD = least significant difference; Pre = disease prevalence; Inc = disease incidence; Sev = disease severity; NS = no significant difference; K.Adisho = Kara Adisho; B.Delbo = Bagedelbo; K.Lemlem= Kulugize Lemlem; S.Bekalsi= Selam Bekalsi

Summary and Conclusion

Tomato production is constrained by different fungal diseases primarily late blight, early blight, septoria spot, fusarium wilt and powdery mildew in the southern zone of the Tigray region. The complexes of these diseases have been causing significant yield losses of the crop. The study results have been shown the significant extent of distribution and intensity of the diseases in the study areas that could be influenced by environmental and agronomic practices used by farmers. Therefore, regular assessment of the diseases distribution and intensity might play a crucial role in the planning of proper diseases management strategies. In addition, association of the diseases with environmental and agronomic factors should be intensively investigated to suggest the optimum manipulation of those factors to the farmers. Furthermore, future research should be emphasized on identifying integrated disease management options to reduce the risk of yield losses caused by these diseases in the study areas.

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