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Relation between climatic cariables and tomato powdery mildew caused by *Leveillula taurica*

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Tomato powdery mildew caused by *Leveillula taurica* is a severe disease that infects all aerial parts of tomato, excluding the fruits. The aim of this paper was to observe factors that influence the development of *Leveillula taurica* on tomato. In vitro and under controlled conditions, we observed the rates of conidial germination at temperature degrees of 10, 15, 20, 25, 30 and 35˚C. Also, the same experiment was applied but with different relative humidity (RH) levels of 50, 65, 75, 85 and 100%. Optimal conditions for appressoria formation were 30˚C and100%RH. For four different growing seasons, data were collected from tomato fields located in Behera and Giza Governorates involving various climatic parameters collected by Agro-Weather Stations. The collected data was then used to estimate correlations regarding the effects of temperature and RH on the disease severity. Severity of powdery mildew was positively correlated with the range of 15 to 30˚C and RH levels of 60 to 100%. Temperatures in the low and the high ranges (5 to 10˚C and 35 to 40˚C) and relative humidity less than 60%. These conducted results suggest that the combination of high temperatures and high RH provides the highest severity of powdery mildew (caused by *Leveillula taurica*) in tomatoes fields.

Keywords: *Leveillula taurica,* powdery mildew and tomato.

Tomato is one of the most significant crops around the world. It is produced and consumed for both the fresh fruit market and the processed food industries. Egypt is ranked as one of the highest five countries in tomato production all over the world; where the total production reached nearly 8.5 million tons (FAOSTAT, 2013). Consequently, it is one of the most important crops to look for methods in order to increase its quantity and quality.

Tomato powdery mildew caused by *Leveillula taurica* may cause losses of up to 40% of tomato crop yields (Jones and Thomson, 1987).The losses depend on various parameters like environmental conditions, time of appearance of disease infection, and effectiveness of fungicide control.

Powdery mildew is very easy to identify, as its symptoms are fairly unique. On one side, the infected tomato leaves grow irregular, bright yellow blotches; severely affected leaves die but rarely drop. Spots of dead tissue, sometimes bordered by a yellow halo, eventually appear in the blotches. On the other side, the infected plants show white powdery spots on the leaves which may also appear on stems. Although powdery mildew can appear on any above-ground part of the plant, it mostly affects the lower leaves. As the disease grows leaves die which results in sunburn damage on fruit, reduced soluble solids, and weakened plants (Reis *et al*., 2005).

High humidity and moderate to high temperature are the perfect environments within condition for powdery mildew incidence. In an agriculture field, different techniques, *i.e.* chemical methods (Keinath and DuBose, 2004 and Anand *et al*., 2010), biological control (Keinath and DuBose, 2004 and Anand *et al*., 2010), genetic resistance (Chunwongse *et al*., 1994 and Bai *et al*., 2003) and other scan be used in controlling disease pathogens.

The reduction of fungicide application is a target for all parties of interest from growers to consumers. Using disease management programs helps in reducing the number of fungicide applications which reduces production costs, potential residues on the product, and risk of development of fungicide resistance in the pathogens. There are ways to reduce the amount of required fungicide applications without intimidating disease control. One of these ways is using disease warning systems that predict possible outbreaks or increases in disease severity based on the weather parameters. According to the Intergovernmental Panel on Climate Change (IPCC), climate change will cause global mean temperatures to rise by 2 to 3 K in the next 50 years (IPCC, 2011). Also, there will be a change in the intensity of precipitation events and seasonal precipitation distributions. For these reasons, problems such as early summer drought may get worse and the possibility of severe weather events could increase. Consequently, all this will have a great effect on plant disease incidence, pest occurrence and plant protection. As, using fungicide application only when microclimate conditions are suitable for powdery mildew incidence is a main strategy in order to reduce the amount of chemicals required to control the disease (Guzman-Plazola, 1997).

Therefore, the aim of this study was studying the weather parameters and their correlating with the disease incidence and disease severity which plays a great role in producing an accurate disease warning systems; which by default has a great impact on crop production quality and quantity.

Materials and Methods

Effect of some environmental factors on the causal fungus:

In vitro, two experiments were conducted in order to specify the effect of different degrees of temperature, and relative humidity on the conidial germination of *L. taurica*. Collected data were analyzed by statistical analysis program ASTAT.

Experiment 1: Effect of temperature on conidial germination:

Naturally infected tomato leaves with powdery mildew were shaken on glass slides, followed by putting each two slides on a glass rode in a Petri dish bottled with moist filter paper to maintain 100% R.H. The prepared Petri dishes were sealed with plaster, and then incubated at different degrees of temperature, i.e.10, 15, 20, 25, 30 and 40˚C for 12 and 24 hours. At each degree of temperature, three replicates were used. The average percentage of germinated conidia was recorded, and was calculated by: (No. of germinated conidia)/(Total no. of conidia).

Experiment 2: Effect of RH on conidial germination:

In this experiment, five different levels of relative humidity (RH), *i.e.* 50, 65, 75, 85 and 100% were set using sulphuric acid and distilled water as explained by Mclean and Cook (1951). Ten ml from the prepared solution were distributed in each Petri dish to provide the desired RH level. Naturally infected tomato leaves showing heavy infection with *L. taurica* were shaken on the cavity of glass slides. Afterward, each two slides were put onto glass rode in each dish containing the desired RH level. The dishes were sealed with plaster, and then incubated at 25±1˚C for 12 and 24 hours. Three replicates of Petri dishes were used for each treatment. The average percentage of germinated conidia was recorded, and was calculated using the formula by% germinated canadia: No. of germinated conidia, Total No. of conidia.

Experiment 3: Effect of temperature and relative humidity on disease severity in the field:

In vivo, the cultivar (Super Marmande) was planted in two Governorates Giza and Behera.

The experiments were conducted as randomized complete blocks design where the area of each plot was 7.5 m2. Transplants were planted in a clay soil, where each plot was one ridge of 6 meters in length and 1.25 meters in width and the distance between plants was 50 cm apart. The same way was applied for the 4 seasons from August to November for both 2013 and 2014, and from March to June 2014 and 2015 in both locations. An automated agro-weather station (Adcon telemetry) with temperature and relative humidity sensors programmed to collect data every hour and giving a daily reading was installed at each field at the level of the plant's aerial parts. At the beginning of each season, the weather station was put in a protecting container and located in the canopy of tomatoes in the field. As the plants grew, the station transferred to be in the middle of the field. Daily microclimate data were collected by the station. Characterization of *L. taurica* was confirmed by inspection of damaged leaflets with a microscope. The disease progress was evaluated by measuring disease severity which was measured every week using randomized samples from each plot according to Horsfall and Barrat (1945). In this experiment, the correlation was applied to the collected data starting from the first day where the plant is considered susceptible to powdery mildew infection till harvesting date. Data were analyzed using Spearman rank correlation which is a non-parametric assessment that is used to compute the degree of association between two variables. This correlation was chosen as it does not assume any assumptions about the distribution of the data and the data don't have to be linear which applies for our collected data.

Results and Discussion

In vitro effect of different temperatures on conidial germination:

Data tabulated in Table (1) and Figs. (1) show that germination of conidia occurred at temperature ranged from 10ºc up to 40ºc after 12hrs and 24hrs. The best temperature for spore germination was estimated to be around 30ºc after 24hr, being 46.4%, while the least conidial germination was 11.5%, after 12hr. incubation at 10ºc. There were positive correlation between temperature between 10ºc – 35ºc and percentage of spore germination after 12hrs and 24hrs, while they were negatively correlated between 35ºc and 40ºc.

Table 1. Effect of different degree of temperature on the conidial germination of *Leveillula taurica*, after 12 and 24 hr. of incubation

Temperature (ºC)	Germination (%) after		$\bar{X}$
	12 hr	24 hr	
10	11.5	27.2	19.4
15	13.6	31.5	22.6
20	15.1	34.9	25.0
25	17.8	42.2	30.0
30	19.2	46.4	32.8
35	16.3	37.5	26.9
40	14.6	32.4	23.5
Mean	15.4	36.0	-
L.S.D (0.05) for Temp.:	2.91	5.7	

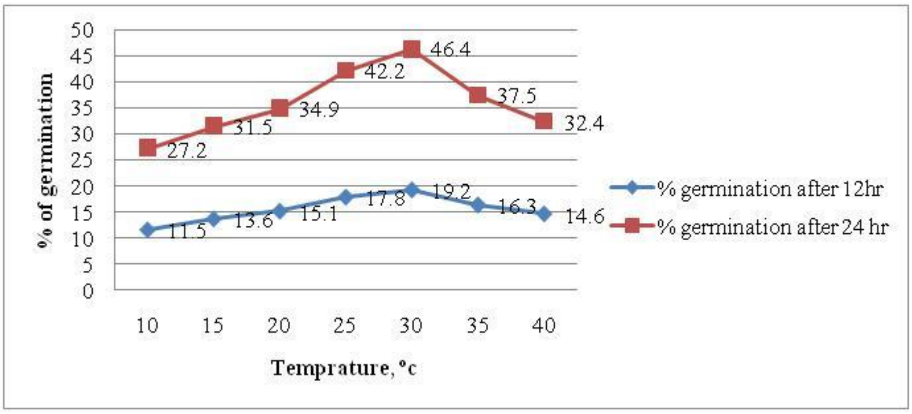

Fig. 1. Effect of different degrees of temperature on the conidial germination of *Leveillula taurica* after 12 and 24 hr of incubation.

In vitro effect of relative humidity (RH) on conidial germination:

Conidia of *L. taurica* were transferred into Petri dishes containing different solutions to give different levels of RH to study their effect on spore germination. Data presented in Table (2) and illustrated in Fig. (2) evidently show that high humidity is essential for spore germination. The best results, being 43.6, 48.4, and 52.3% were obtained due using 75, 85 and 100RH levels for 24 hrs. Obviously, RH at 100% is the optimal. There were positive correlation between percentage of relative humidity and percentage of spore germination.

3. In vivo effect of temperature and Relative Humidity on Disease Severity:

The results of our analysis for the effect of selected weather parameters on powdery mildew severity are presented in Figs. (3)-(10). Regarding relationships between temperatures and powdery mildew severity levels, there were positive correlations in the temperature range from 15 to 30˚C and relative humidity more than 60%. Conversely, the negative correlations were observed from 35 to 40˚C.

Table 2. Effect of different levels of relative humidity on the conidial germination of *Leveillula taurica* after 12 and 24 hr. of incubation

Relative humidity (%)	Germination (%) after		$\bar{X}$
	12 hr	24 hr	
50	4.2	34.3	19.2
65	8.1	39.8	23.9
75	8.8	43.6	26.2
85	9.5	48.4	28.9
100	11.3	52.3	31.8
Mean	8.3	43.6	-
L.S.D (0.05) for Humidity levels:	1.52	2.7	

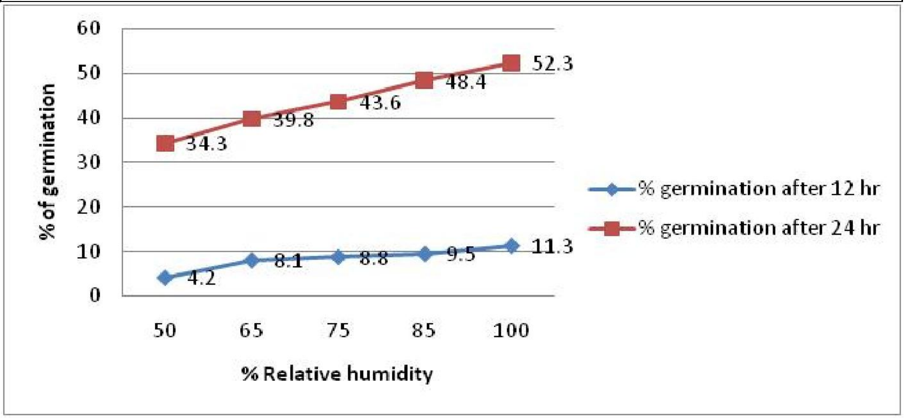

Fig. 2. Effect of different levels of relative humidity on the conidial germination of *Leveillula taurica* after 12 and 24 hr. of incubation.

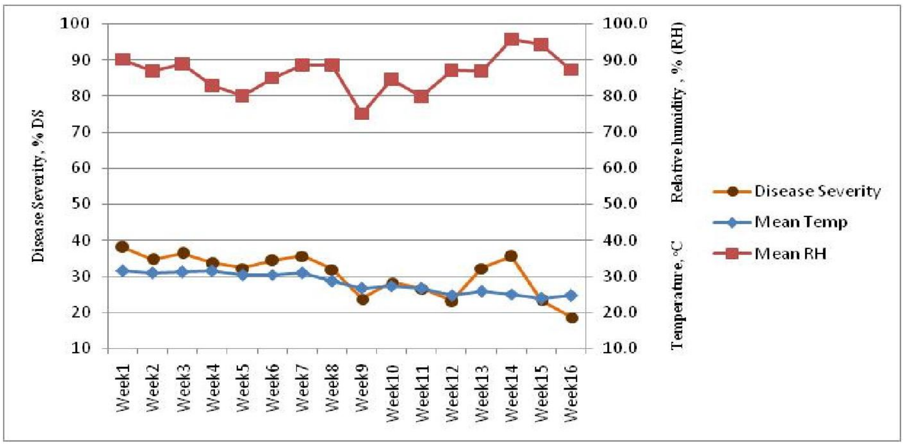

Fig. 3. Effect of temperature and relative humidity levels on disease severity on tomato grown from August to November 2013, Behera Governorate.

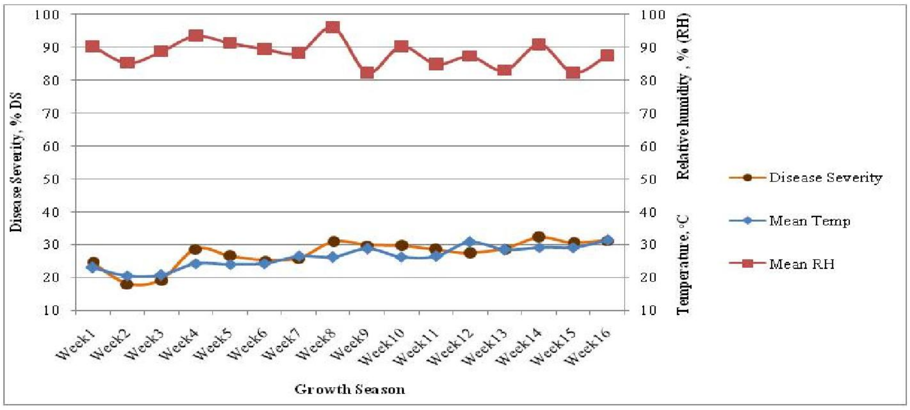

Fig. 4. Effect of temperature and Relative humidity levels on disease severity on tomato grown from March to June 2014, Behera Governorate.

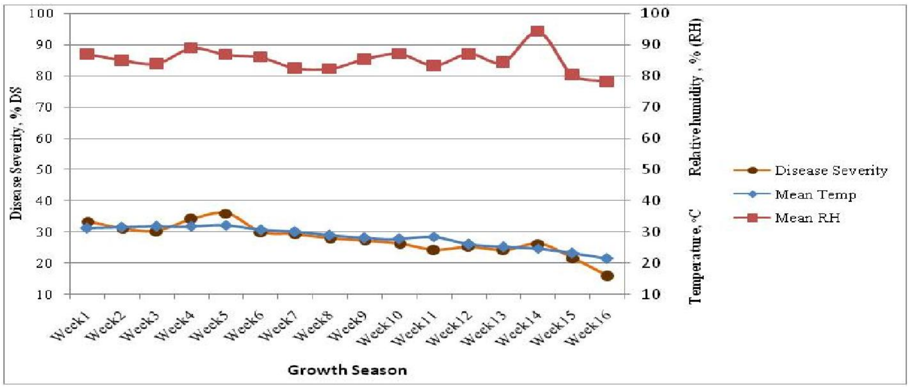

Fig. 5. Effect of temperature and Relative humidity levels on disease severity on tomato grown from August to November 2014, Behera Governorate.

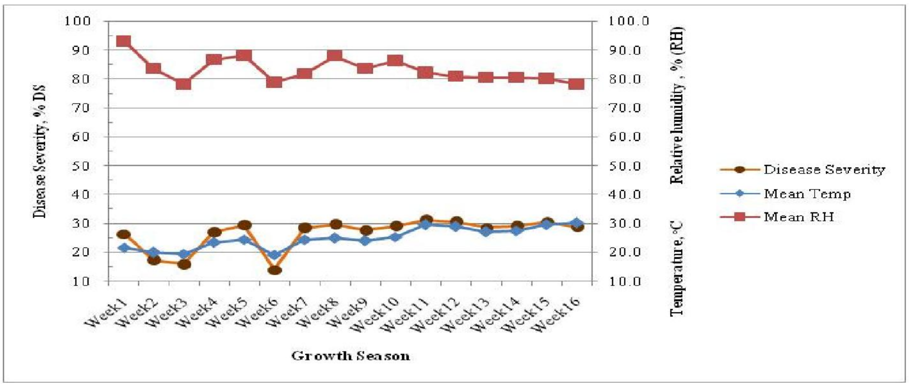

Fig. 6. Effect of temperature and Relative humidity levels on disease severity on tomato grown from March to June 2015, Behera Governorate.

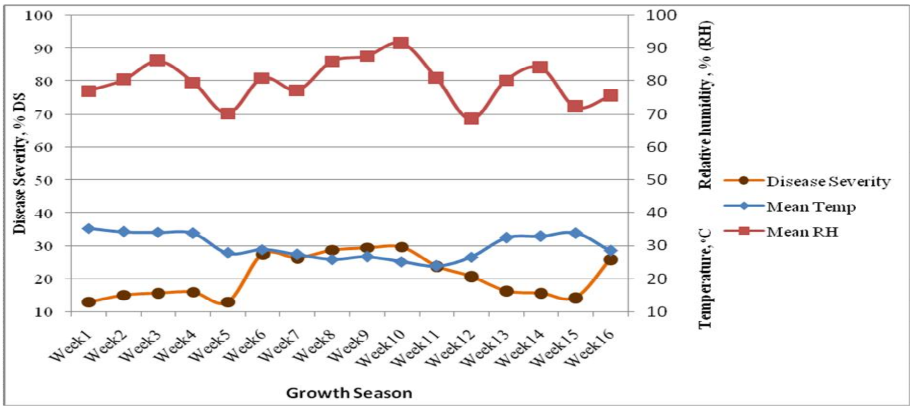

Fig. 7. Effect of temperature and Relative humidity levels on disease severity on tomato grown from August to November 2013, Giza Governorate.

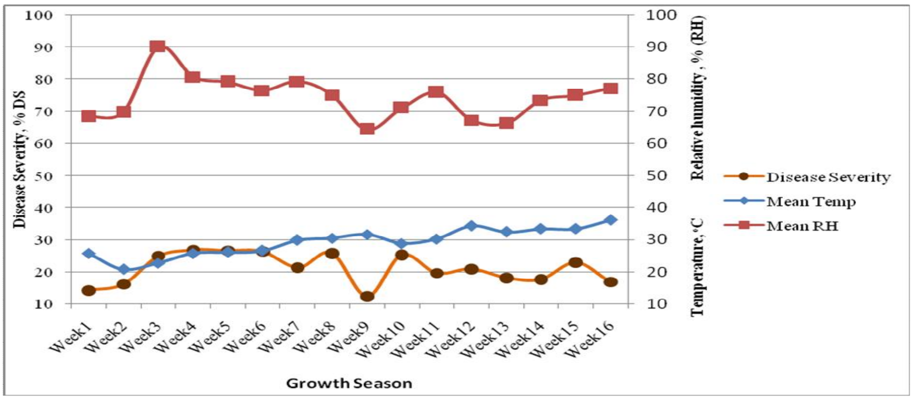

Fig. 8. Effect of temperature and Relative humidity levels on disease severity on tomato grown from March to June 2014, Giza Governorate.

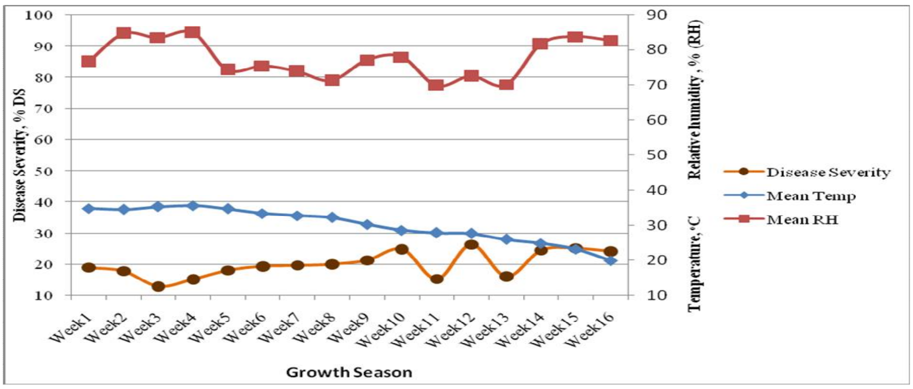

Fig. 9. Effect of temperature and Relative humidity levels on disease severity on tomato grown from August to November 2014, Giza Governorate.

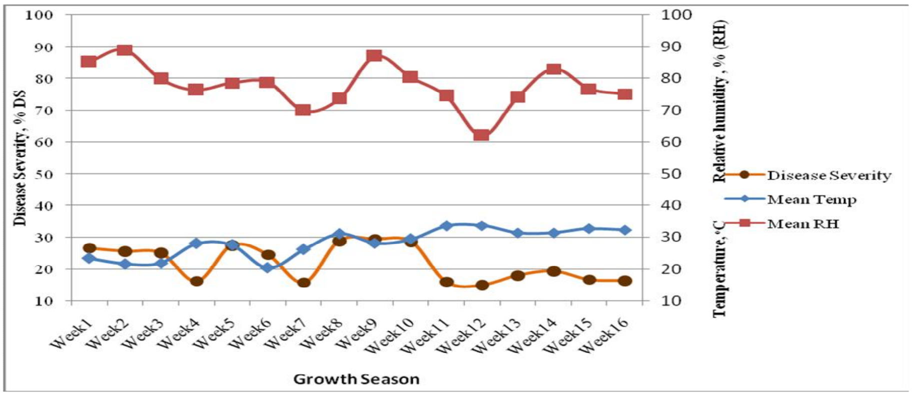

Fig. 10. Effect of temperature and Relative humidity levels on disease severity on tomato grown from March to June 2015, Giza Governorate.

According to the obtained data, the rates of spore germination are proportional to the RH level where as RH level gets higher the rate of germination increases. The greatest spore germination would occur at the highest possible air humidity (100% RH). This outcome is compatible with other studies on powdery mildews where most spore germination was reached at RHs near to 100% (Yarwood, 1957; Butt, 1978 and Husain and Akram, 1995). On the other hand, spore germination progress was generally higher at 30˚c than at 25˚c. While the germination started decreasing at temperature range from 35˚c till 40˚c. On contrary, the generated results didn't agree with other studies which indicated the absence of spore germination at temperature 30˚C or higher (Munshi and Singh, 1994; Guzman *et al*., 2003).

Two data of the effect extreme of weather data in field during the selected periods through 2013 and 2014 growing seasons in two governorates (Behera and Giza) on disease severity of tomato powdery mildew indicated that there was a positive relation between disease severity and temperature in range from 20 ˚c to 30˚c with high relative humidity (more than 60%). On the other hand, temperature from 35˚c and above showed negative track even in case of high humidity. It should be noted that the collection of data analysis in work station is hourly and this amount of data cannot be represented on graph but can be used by weekly averages. In some cases, it was noticed that in days with relative humidity less than 60% during the week, disease severity percentage during the whole week was affected. This observation was noticed in last week of November 2014 at Behera governorate. While in Giza, this incident was noticed more than once, during the 5th, 11th and 13th weeks of summer season 2013. Also, the same episode was repeated during the 1st, 2nd, 7th and 11th week of the spring season 2014; then again in the 11th and 13th weeks of summer 2014. Finally, it occurred in the 4th and 7th weeks of spring 2015.

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العلاقة بين العوامل البيئية والإصابة بمرض البياض الدقيقي علي الطماطم الذى يسببه فطر *Leveillula taurica*

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يعد مرض البياض الدقيقي علي الطماطم الذى يسببه فطر *Leveillula taurica* من الأمراض الخطيرة التي تصيب كل أجزاء المجموع الخضري في النبات ماعدا الثمار. ويعتبر محصول الطماطم أحد أهم محاصيل الخضر علي مستوي العالم. حيث ينتج ويستهلك للإستخدام الطازج وكذلك الصناعات الغذائية. الهدف الرئيسي لهذا البحث هو دراسة تأثير بعض العوامل المناخية علي تطور الإصابة بفطر *L. taurica* علي الطماطم. في المعمل تحت الظروف المتحكم فيها تم دراسة إنبات الجراثيم في درجات حرارة مختلفة 10-15-20-25-30-35 وإيضا تحت ظروف رطوبة نسبية مختلفة 50-65-75-85-100% وكانت أفضل نسبة إنبات للجراثيم عند درجة حرارة 30درجة مئوية ورطوبة نسبية 100%. وفي الحقل تم جمع بيانات العوامل المناخية باستخدام محطات الرصد الجوي الزراعي لمدة أربع مواسم في محافظتين مختلفتين (محافظة البحيرة والجيزة). وتم عمل ربط بين تأثير درجات الحرارة والرطوبة مع شدة الإصابة بمرض البياض الدقيقي علي الطماطم. وقد تزايدت شدة الإصابة مع ارتفاع درجة الحرارة من15-30 درجة مئوية وارتفاع الرطوبة النسبية من60%-100%. وإنخفاض شدة الإصابة في درجات الحرارة المنخفضة من (5-10) وأيضاً المرتفعة (35-40) درجة مئوية. بينما انخفضت شدة الإصابة في درجات رطوبة أقل من 60%. تظهر النتائج المتحصل عليها من هذه الدراسة أن هناك ارتباط بين ارتفاع درجة الحرارة مع ارتفاع الرطوبة النسبية و شدة الاصابة بمرض البياض الدقيقي علي الطماطم.