ABSTRACT

Early blight caused by *Alternaria solani* (Ell. and Mart.) is one of the most important diseases, which caused considerable loss in tomato yield and quality under Egyptian conditions. The research aimed to study the relationship between climate change and disease severity for prediction in future seasons. Disease severity was recorded for three growing seasons i.e. summer (May. - Aug), autumn (Jul. - Oct) and winter (Nov. - Mar.), at three governorates (Behira, Ismailia, and Assuit). Severity of early blight disease on tomato has been predicted by regression estimated accumulative disease severity values during (2007/2008) – (2015/2016) season and average max and min temperature and humidity through these seasons. Prediction of disease has been formed as $Y = b_0 + b_1x_1 + b_2x_2 + ........... bqxq$. Three models were created to describe the severity disease by multiple regressions (MINITAB® program). The highest value of early blight disease was recorded through season (2010-2011) and low in season (2013-2014), but in Assuit governorate, the highest value of disease was in season (2010-2011), and the lowest value was in season (2013-2014). For Forecasting, significantly differences among between disease severity through (2020/2030), (2030/2040) and (2040/2050) seasons compared with (2008/2018) seasons and relation with climate change in tested governorates. Severity of tomato early blight disease may increase from 11.8% to 15.4 during (2008/2018) seasons to (2040/2050) seasons at Behira governorate, from 18.8% during (2008/2018) seasons to 36.3% (2040/2050) seasons at Ismailia governorate and 18.8% during (2008/2018) seasons to 40.4% (2040/2050) seasons at Assuit governorate with slight change in maximum or minimum temperatures and percentage of relative humidity.

Keywords: Tomato Early blight disease, *Alternaria solani*, Climate change, Forecasting, GIS.

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L., syn. *Lykopersicon esculentum* Mill.) is one of the most popular and widely grown vegetables in the world. It occupied the second rank in importance after potato in many countries (Prajapati et al 2014). It considers an important cash and industrial crop in many parts of the world (Ayandiji and Omidiji, 2011). Early blight disease of tomato caused by the fungus *Alternaria solani* is one of the most common foliar diseases of tomatoes, which damages the leaves, stalks, stems and fruits causing severe destruction of the aerial part and reduction of the size and number of fruits, resulting heavy
Disease severity was assessed on 100 randomly selected plants / 10 smaller units / field. Disease severity was estimated according to a disease rating scale from 0-5, where 0 = no visible symptoms apparent, 1 = A few minute lesions to about 10% of the total leaf area is blighted and usually confined to the 2 bottom leaves, 2 = Leaves on about 25% of the total plant area are infected, 3 = Leaves on about 50% of the total plant area are infected, 4 = Leaves on about 75% of the total plant area are infected and 5 = Leaves on the whole plant are blighted and plant is dead (Sethumadhava et al 2016). The formulae in calculating the disease severity follow:

\[
\text{Percentage of disease severity (PS)} = \left( \frac{\text{Number of Individual Ratings}}{\text{Number of Plants Assessed}} \right) \times 100
\]

Influence of Environmental conditions on Tomato Early Blight disease

Meteorological data were recorded through the growing seasons (2007/2008) – (2015/2016). These data were obtained from the Central Laboratory for Agricultural Climate (CLAC). The data consist of average temperature (daily maximum and minimum temperature) and relative humidity (daily maximum and minimum RH %). The diseases severity was estimated as the percentage of infected fields. The data of disease severity were obtained from the Central Administration of Pest Control, Ministry of Agriculture, Egypt (unpublished data). The effect of each factor separately was obtained by applying simple correlation formula (r) and the regression coefficients (b). The combined effects of these factors were obtained by applying multipliers formula and expressed as percentage of explained variance. (E.V) according to Hassan (2016).

Effect of expected future climate change on incidence of early blight of tomato

The future climate data (2030s to 2050s) has been obtained from the downscaling process on global climate model (ECHAM6) of scenario Representative Concentration Pathways RCP 4.5 by a horizontal resolution 50 km using regional climate model (RegCM 4) (Khalil et al 2016). The severity...
Survey of tomato early blight disease

Several fields of tomato plant, at three different Governorates (Behira, Ismailia, and Assiut) were surveyed for incidence of early blight during seasons (2016/2017) - (2017/2018) three growing seasons i.e. summer (May. - Aug.), autumn (Jul. - Oct.) and winter (Nov. - Mar.). Data in Fig. (1) show that, in Behira governorate, the mean disease severity value of disease was ranged from 25.7% to 6.3%. The highest disease severity value (25.7%) was recorded in autumn growing period (2016-2017). The minimum disease severity (6.3%) was recorded in autumn growing period (2017-2018). Finally, the highest value of disease was appeared through season (2016/2017), while the lowest value was estimated through growing season (2017/2018).

While, in Ismailia governorate, mean disease severity was ranged from 27.9% to 1.6%. Highest disease value (27.9%) was recorded in autumn growing period (2017-2018), but, minimum disease was (1.6%) recorded in autumn growing period (2016-2017). Generally, the highest severity of disease was recorded during season (2017/2018) and the lowest value was recorded during season (2016/2017).

In Assiut governorate, the mean disease severity was ranged from 13.1% to 5.0%. The highest disease (13.1%) recorded in autumn growing period (2017-2018), but the minimum disease (4.8%) recorded in winter growing period (2016-2017). Also, the highest value of disease was appeared through season (2017/2018), and the lowest value recorded during season (2016/2017). Meanwhile, the high disease severity was recorded summer period, while, the least and moderate severity were recorded in the winter and autumn growing period, respectively.

Influence of environmental conditions on tomato early blight disease

Results in Fig. (2) reveal that mean severity of disease in Behira governorate was 18.8%, but the highest disease severity (25.7%) was recorded in season (2010-2011), where the mean maximum and minimum temperature was 29.4°C and 16.3°C respectively and the mean percentage of relative humidity was 52.6%. While the lowest disease (14.0%) was detected in season 2012-2013, where the mean maximum and minimum temperature was 29.4 °c, 16.1 °c, respectively and the mean percentage of relative humidity was 48.6%. The mean severity of disease in Ismailia governorate was 14.6%, but the highest disease severity (24.6%) was estimated in season (2010-2011), where mean maximum and minimum temperature was 29.4 °c and 16.6 °c, respectively and mean percentage of relative humidity was 55.0%. Meanwhile, the lowest disease (10.1%) was recorded in season (2013-2014), where the mean maximum and minimum temperature was 28.7 °c and 16.1 °c, respectively and the mean percentage of relative humidity was 53.7%. Also, the mean prevalence value of disease in Assiut governorate were 26.9%, but the highest value of disease (30.7%) was in season (2010-2011), where the mean maximum and minimum temperature was 32.1°C, 16.6°C, respectively and the mean percentage of relative humidity was 52.6%. While, the lowest value (22.7%) was recorded in season (2013-2014), where mean maximum and minimum temperature was 31.0°C and 15.91°C, respectively and mean percentage of relative humidity was 50.4%. Finally, the highest severity of disease was estimated at Assiut governorate (26.9%) compared with Behira and Ismailia governorates, where the mean maximum and minimum temperature was 31.2 °c and 15.9°C, respectively and mean percentage of relative humidity was 50.8%.

Statistical analysis for the effects of mean max and min temperature and relative humidity on early blight disease, during 2007/2008 to 2015/2016 season at Behira, Ismailia, and Assiut governorates are shown in Table (1). The results show that the max temperature, min temperature, and relative humidity had an insignificant negative effect whereas “r” value was -0.011, -0.32 and -0.30, respectively at Behira governate. The results also
show that the max temperature and min temperature had an insignificant positive effect whereas "r" value was 0.31 and 0.36, respectively. Relative humidity insignificant negative effect whereas "r" value was -0.41 at Ismailia governorate. In Assuit governorate, the max temperature and min temperature had a highly significant negative effect whereas "r" value was -0.52 and -0.69, respectively and relative humidity had a highly significant positive effect whereas "r" value was 0.96. The percentages of explained variances (E.V) for the selected ecological factors at seasons were 45%, 44% and 68% on the severity of disease, during (2007/2008) to (2015/2016) seasons, respectively. “F” values were 1.90, 1.85 and 68.58***, respectively.

Climate change can have positive, negative or neutral impact on individual path systems because of the specific nature of the interaction of host and pathogen. Also, climate change can influence the geographical and growth of plant species around the world (Coakley et al 1999), computable with study data. (Nicholls., 1997) analyzed historical trends in Australian wheat yield and found that recent climate changes are responsible for as much as 30 to 50% of the variation explained by an increase in minimum temperature.
land (Presidge and Pottinger, 1990) concluded that disease problems in the kiwifruit and pomefruit industries would probably amplify by increases in temperature and precipitation. In contrast, the impact on the vegetable industry should be minimal because this industry is annual and intensive in nature and management changes required to mitigate climate change impacts may be made more easily. A climate change has the potential to modify host physiology and resistance and to modify host and resistance and to alter stages and rates of development of the pathogen. The most likely impact could be shift in the geographical of the host and the pathogen, which may be could changes in the physiology of host-pathogen interactions and changes in crop loss. Change may occur in the type, amount and relative importance of pathogens and affect the spectrum of diseases affecting a particular crop. This would be more pronounced for pathogens with alternate hosts (Coakley et al. 1999). Increase in temperature can modify host physiological and resistance arise in temperature above 20 °C can inactivate temperature – sensitive resistance to stem rust in oat cultivars with Pg3 and Pg4 genes (Martens et al. 1967). In contrast, lignifications of cell walls increased in forage species at higher temperatures (Wilson et al. 1991) to enhance resistance to fungal pathogens (Strange 1993). The disease may develop if plants are stressed in a warmer climate. High temperatures may increase the damage caused by the disease such as scleroderris canker lodge pole pine (Karman et al. 1994 and Lonsdale and Gibbs, 1996). Suggest that severe weather events are making an important contribution to the emergence of plant diseases in new locations. There is a greater likelihood that invasive disease can become established as. Climate change can also allow some plants and pathogens to survive outside their historic ranges (Harvell et al. 2002).

Table 1. Simple correlation and partial regression values of the climatic changes and severity of early bight disease corresponding percentage of explained variance in Tomato plant fields at Beheira, Ismailia and Assuit governorates, during (2007/2008) – (2015/2016) growing seasons

<table>
<thead>
<tr>
<th>Beheira Early blight Tested</th>
<th>Simple Correlation</th>
<th>Partial Regression</th>
<th>% E.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>factors</td>
<td>r</td>
<td>P</td>
<td>b</td>
</tr>
<tr>
<td>Temp. MAX °C</td>
<td>-0.011</td>
<td>0.99</td>
<td>8.71</td>
</tr>
<tr>
<td>Temp. MIN °C</td>
<td>-0.3208</td>
<td>0.35</td>
<td>-12.18</td>
</tr>
<tr>
<td>Avg RH %</td>
<td>-0.3008</td>
<td>0.37</td>
<td>0.29</td>
</tr>
</tbody>
</table>

F=1.90

<table>
<thead>
<tr>
<th>Ismailia Early blight Tested</th>
<th>Simple Correlation</th>
<th>Partial Regression</th>
<th>% E.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>factors</td>
<td>r</td>
<td>P</td>
<td>b</td>
</tr>
<tr>
<td>Temp. MAX °C</td>
<td>0.31</td>
<td>0.36</td>
<td>8.66</td>
</tr>
<tr>
<td>Temp. MIN °C</td>
<td>0.36</td>
<td>0.63</td>
<td>-5.42</td>
</tr>
<tr>
<td>Avg RH %</td>
<td>-0.41</td>
<td>0.21</td>
<td>-0.30</td>
</tr>
</tbody>
</table>

F= 1.85

<table>
<thead>
<tr>
<th>Assute Early blight Tested</th>
<th>Simple Correlation</th>
<th>Partial Regression</th>
<th>% E.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>factors</td>
<td>r</td>
<td>P</td>
<td>b</td>
</tr>
<tr>
<td>Temp. MAX °C</td>
<td>-0.52</td>
<td>0.098</td>
<td>8.2</td>
</tr>
<tr>
<td>Temp. MIN °C</td>
<td>-0.69</td>
<td>0.018</td>
<td>-0.919</td>
</tr>
<tr>
<td>Avg RH %</td>
<td>0.96</td>
<td>0.0001</td>
<td>-1.72</td>
</tr>
</tbody>
</table>

F= 68.58***
Effect of expected future climate change on tomato early blight disease

This study was carried out to figure out the influence of climate change on severity of early blight disease of tomato, during (2020/2030), (2030/2040) and (2040/2050) seasons, under Egyptian condition, at three governorates, using the multiple equation regression analysis (MINITAB®). The severity of disease has been predicted by regression estimated disease severity versus the accumulative disease’s severity values during (2007/2008) to (2015/2016) seasons and average max and min temperature and humidity through the both seasons. Prediction of disease has been formed as 

\[ Y = b_0 + b_1 x_1 + b_2 x_2 + \ldots + b_q x_q \]  

(Fahim, 2002). Three models were created to describe the severity disease by multiple regressions (MINITAB® program, 1995). Regression between disease severity values at during seasons from 2007/2008 to 2015/2016 and average max and min temperature and humidity during the seasons resulted in the following relationship:

1. **Beheira**
   \[ y = -236.1 + 6.03 x_1 - 3.59 x_2 + 2.72 x_3 \]
   \[ R^2 = 93.1\% \]
2. **Ismailia**
   \[ y = -289.6 + 13.25 x_1 - 2.84 x_2 - 0.389 x_3 \]
   \[ R^2 = 82.4\% \]
3. **Assuit**
   \[ y = 186.8 - 12.96 x_1 - 14.82 x_2 + 0.896 x_3 \]
   \[ R^2 = 82.5\% \]

Where:
- \( Y \): prediction of disease severity (%)
- \( X_1 \): average max temperature (°C)
- \( X_2 \): average min temperature (°C)
- \( X_3 \): average humidity (%)

Model 1, 2 and 3 could Lower Egypt and Upper Egypt, respectively. Formal tests have been used to evaluate statistical assumption. The coefficient of determination \( R^2 \) were ranged between 82.4 and 93.1 for climate change scenarios for Behira, Ismailia and Assuit Governorates were assessed according to future conditions derived from the downsampling process on global climate model (ECHAM6) of scenario Representative Concentration Pathways RCP 4.5 by a horizontal resolution 50 km using regional climate model (RegCM 4) and these relation with severity of early blight disease of tomato. Generated base classification maps of the research area according to program (ArcGIS®) for windows.

Data presented in Fig. (3) showed that severity of tomato early blight disease, through (2020/2030), (2030/2040) and (2040/2050) in tested governorates maybe highly changed in during (2020/2030) and (2030/2040) seasons compared with seasons (2008/2018), where disease severity was 18.8% during (2008/2018) season and was 24.7% and 27.3% during (2020/2030) and (2030/2040) seasons, respectively. Also, slight changes in severity of disease through seasons (2040/2050) compared with seasons (2008/2018), where disease severity was 20.0 and 13.8%, respectively at Beheira governorate. Highest changes in disease severity was estimated through seasons (2020/2030), (2030/2040) and (2040/2050) compared with seasons (2008/2018) (15.4%), where disease severity was 30.0, 33.5 and 36.3% during (2020/2030), (2030/2040) and (2040/2050) seasons at Ismailia governorate, respectively.

Meanwhile, highest changes in severity of disease during seasons (2020/2030), (2030/2040) and (2040/2050) compared with seasons (2008/2018) (18.8%), where expected disease severity are 38.1, 38 and 40.4% during (2020/2030), (2030/2040) and (2040/2050) seasons at Assut governorate, respectively.

Climate change may have minor impact on diseases compared with the impact of crop management and genetic improvement (Kropff et al 1993). Hulme et al (2002) predicate that temperature will rise by 0.5-1.5 °C by the 2020s and by 2-4°C by the 2080s. Warning will be great in summer than in winter and there will be an increased frequency of very hot summers, partially by the 2080s. Total annual projected to fall by up to 10% and 50% by the 2020s and 2080s, respectively. Abolmaaety, (2006) concluded also that there is a positive relationship between development and severity of wheat rust diseases and location, date or mean temperature, during growing seasons 2005s, under climate conditions at eight governorates in Egypt.
Prediction of tomato early blight disease under climate change conditions in Egypt

Fig. 3. Distributive maps for forecasting severity of early blight disease of tomato, under climate change in Egypt, during 2020/2030, 2030/2040 and 2040/2050s growing seasons using estimated diseases severity in 2008/2018s seasons, at three different governorates
REFERENCES


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التنبؤ بمرض لفحة الطماطم المبكرة تحت ظروف تغير المناخ في مصر

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رقم الاستقادات: 21 أكتوبر 2019

الموجز

يعتبر مرض لفحة الطماطم المبكرة المستقبلي عون (Alternaria solani) من أمراض الطماطم المبكرة تحت ظروف تغير المناخ في مصر. تحت ظروف تغير المناخ في مصر، يمكن توقع نشوء مرض لفحة الطماطم المبكرة في موسم النمو 2016/2017. وشملت دراسة تأثير نظام اسبرت موان النمو من 2007/2008 إلى 2015/2016، وكمية متوسط درجة الحرارة العظمى والصغرى 31 °C و15.9 °C على التوالي، وكمية متوسط الرطوبة الفصلية 50.8%. بالتحليل الإحصائي كان تأثير درجة الحرارة العظمى والصغرى والرطوبة النسبية ذات تأثير غير معنوي سالب بمحاولة الбережة، بينما كان تأثير منخفضة الإسماعيلية كان تأثير درجة الحرارة العظمى والصغرى غير معنوي موجب، ولكن تأثير متوسط درجة الحرارة العظمى والصغرى معنوي موجب. بينما في محاولة الбережة كان تأثير متوسط درجة الحرارة العظمى والصغرى معنوي موجب. ولكن درجة الحرارة العظمى والصغرى، يمكن الاستفادة من دراسة العلاقة بين العوامل المناخية وانتشار مرض لفحة الطماطم المبكرة.

أحصائية بواسطة برنامج (Minitab® program) إمكانية الاستفادة منها للتنبؤ بالمرض.

تحكيم: أ.د. أحمد عابد الخاطق على البحيري

أ.د. أحمد موسى
التنبؤ بمرض لفحة الطماطم المبكرة تحت ظروف تغير المناخ في مصر


نلاحظ أن تطور و شدة مرض الفضة تحت ظروف البيئية. في المحافذ المصرية الملونة. تتوقع وجود احتمال كبير بين شدة الإصابة بمرض الفضة تحت ظروف البيئية والظروف المستقبلية. حيث تترتفع شدة الإصابة بمرض الفضة تحت ظروف البيئية في الطماطم من

الكلمات الدالة: مرض لفحة الطماطم المبكرة، التغيرات المناخية، التنبؤ، نظم المعلومات الجغرافية.