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PREDICTION OF TOMATO EARLY BLIGHT DISEASE UNDER CLIMATE CHANGE CONDITIONS IN EGYPT

[159]

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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= b0+b1x1+b2x2+.......... 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 (2017/2018), while the lowest value was recorded during season (2016/2017). Also, highly disease severity was estimated during summer period compared with autumn and winter growing periods, however, the least severity was estimated through winter growing period and moderate severity estimated in the autumn growing period. Influence of environmental conditions on the severity of early blight disease during seasons (2007/2008) – (2015/2016), in Behira governorate, the high disease severity was showed in season (2010-2011), and the lowest disease was in season (2012-2013), but in Ismailia governorate, highest disease severity was estimated in 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. *Lycopersicon 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 solaniis* 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 losses in yield up to 79% **(Sherf and MacNab, 1986; Gwary and Nahunnaro, 1998).** The Alternaria fungus can cause the disease on all parts of the plant (leaf blight, stem collar rot, and fruit lesions) and result in severe damage during all stages of plant development **(Abada et al 2008)**. Climate factors that influence the growth, spread and survival of crop diseases including temperature, precipitation humidity, dew, radiation, wind speed, circulation patterns and the occurrence of extreme events. Higher temperature and humidity and greater precipitation result in the spread of plant diseases, as wet vegetation promotes the germination of spores and the proliferation of fungi and bacteria and influence the life cycle of soil nematodes (**Rosenzweig et al 2000)**. Environmental condition is a complex term that includes many factors, which must be behind a minimum threshold for the disease to occur. A change in one environmental factor may alter the effect of other environmental factors on diseases development **(Abdel-Hak et al 1966)**. The relationship between weather and plant disease are routinely used for forecasting and managing epidemics and disease severity over the number of years can fluctuate according to climatic variation **(Scherm and Yang, 1995)**. There was a positive relationship between development and severity of wheat rust diseases and location, date or mean temperatures, at eight governorates, on growing seasons 2005s, under Egyptian conditions, where the severity of leaf rust disease, on growing seasons 2050s and 2005s were **(Abolmaaty, 2006).** The present work aimed to study the influence of climate change on the severity of tomato early blight disease and Prediction of disease severity under future condition.

MATERIALS AND METHODS

Survey of tomato early blight disease

This study was conducted at three governorates i.e. Behira, Ismailia in lower Egypt and Assuit middle Egypt, during growing seasons (2016/2017)-(2017/2018), where three locations were selected each governorate at least 25 feddan per location for survey a tomato early blight disease. Plant samples based on visual symptoms of the disease were drawn from each field at random. Sampling for smaller units (25^{m2}) was done along the diagonals of the fields at regular intervals each month of each growing season. Selected units were drawn following a zigzag pattern and ten plants per unit were selected to estimate the severity of the disease **(Syed et al 2016)**. Disease severity was recorded after 60 days form sowing date for three consecutive growing seasons i.e. summer (May. - Aug), autumn (Jul. - Oct) and winter (Nov. - Mar.). The severity of disease 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:

$$\text{Percentage of disease severity (PDS)} = \frac{\text{Number of Individual Raitngs}}{\text{Number of Plants Assesed}} \times \frac{100}{\text{Maximum Scale}}$$

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 of tomato early blight disease during the period 2030s and 2050s in Egypt were estimated using disease severity data during 2008 - 2018 seasons, using the Statistical programs for windows and **MINITAB®** program, where the climate data in the future 2030 season to 2050 according to **Abolmaaty (2006)**.Using geographical information system (GIS) generated base classification maps of the research area according to programs (**ArcGIS®**) for windows.

RESULTS AND DISCUSSION

Survey of tomato early blight disease

Several fields of tomato plant, at three different Governorates (Behira, Ismailia, and Assuit) were surveyed for incidence of early blight during seasons (2016/2017)-(2017/20018) 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 Assuit 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 Assuit 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 was52.6%. 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 Assuit 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

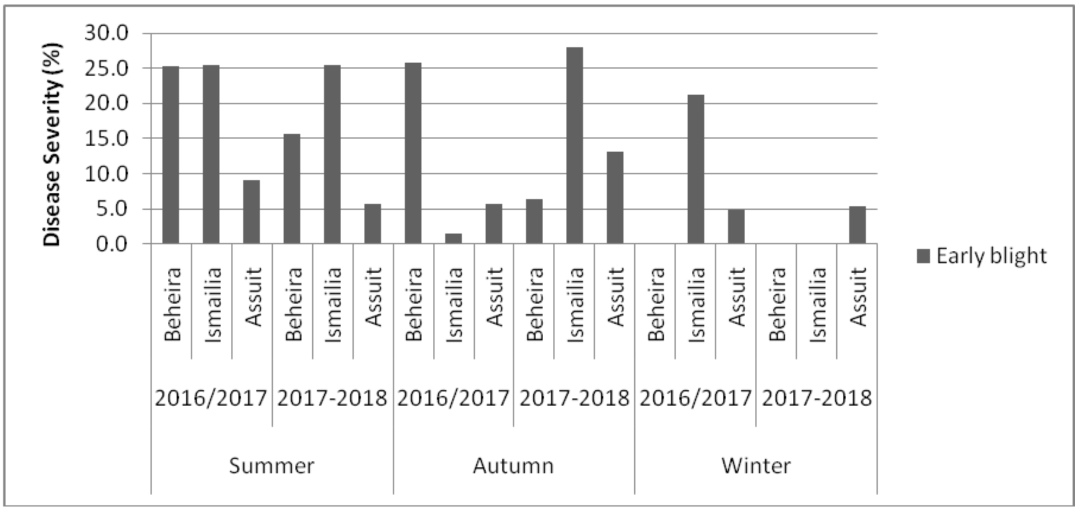

Fig. 1. Severity of tomato early blight disease, during (2016/2017-2017/20018) seasons, through growing periods (summer, autumn and winter) at Behira, Ismailia and Assuit governorates

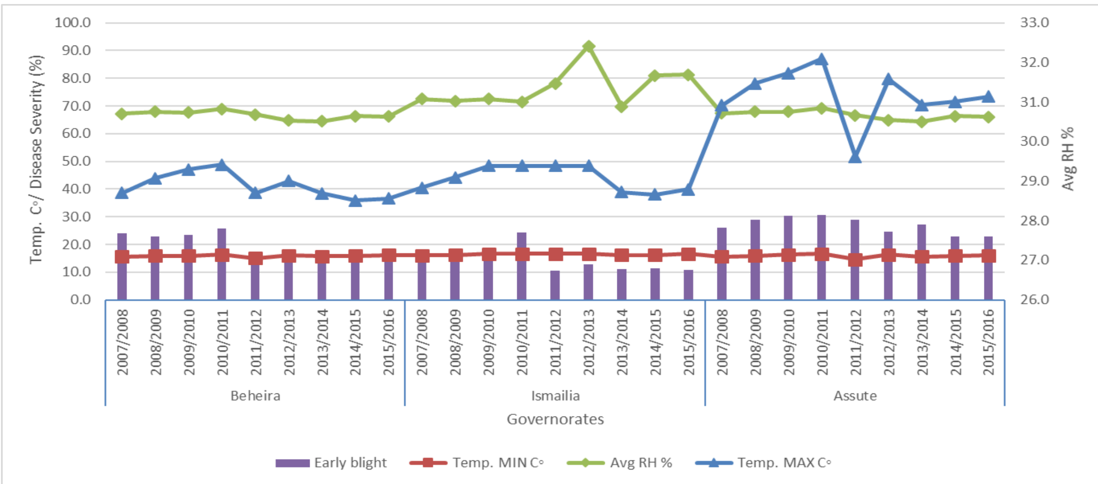

Fig. 2. Relationship between environmental conditions and severity of tomato early blight disease, during (2007/2008) to (2015/2016) seasons at Behira, Ismailia and Assuit governorates, under filed conditions

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 governate. In Assuit governate, 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. In New Zealand **(Presidge and Pottinger, 1990)** concluded that disease problems in the kiwifruit and pome fruit 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 mode 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 occurs 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 ^{o}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 **(Karlman 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

Beheira Early blight Tested	Seasons from 2007/2008to 2015/2016					
	Simple Correlation		Partial Regression			%
factors	r	P	b	S.E.	P	E .V.
Temp. MAX °C	-0.011	0.99	8.71	4.17	0.075	45%
Temp. MIN C◦	-0.3208	0.35	-12.18	6.25	0.092	
Avg RH %	-0.3008	0.37	0.29	0.39	0.486	
F=1.90						
Ismailia Early blight Tested	**Seasons from 2007/2008to 2015/2016**					
	Simple Correlation		**Partial Regression**			**%**
factors	**r**	**P**	**b**	**S.E.**	**P**	**E .V.**
Temp. MAX °C	0.31	0.36	8.66	6.19	0.2	44%
Temp. MIN C◦	0.36	0.63	-5.42	5.77	0.37	
Avg RH %	-0.41	0.21	-0.30	0.2	0.182	
F= 1.85						
Assute Early blight Tested factors	**Seasons from 2007/2008to 2015/2016**					
	Simple Correlation		**Partial Regression**			**%**
	r	**P**	**b**	**S.E.**	**P**	**E .V.**
Temp. MAX °C	-0.52	0.098	8.2	3.24	0.039	68%
Temp. MIN C◦	-0.69	0.018	-9.19	3.72	0.043	
Avg RH %	0.96	0.0001	-1.72	0.16	0.0003	
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 $Y= b_0+b_1x_1+b_2x_2+.......... b_qx_q$ **(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 an min temperature and humidity during the seasons resulted in the following relationship:

(1) Beheira $y = -236.1 + 6.03\ x1 - 3.59\ x2 + 2.723\ x3$ $R^2= 93.1\%$

(2) Ismailia $y= -289.6 + 13.25\ x1 - 2.84\ x2 – 0.389\ x3$ $R^2=82.4\%$

(3) Assuit $y =186.8-12.96\ x1 - 14.82x2 + 0.896\ x3$ $R^2= 82.5\%$

Where:

Y = prediction of disease severity (%)
X1= average max temperature (°C)
X2= average min temperature (°C)
X3 =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 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) 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 20.0and 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, 33.5and 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 Assuit 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. **Abolmaaty, (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.

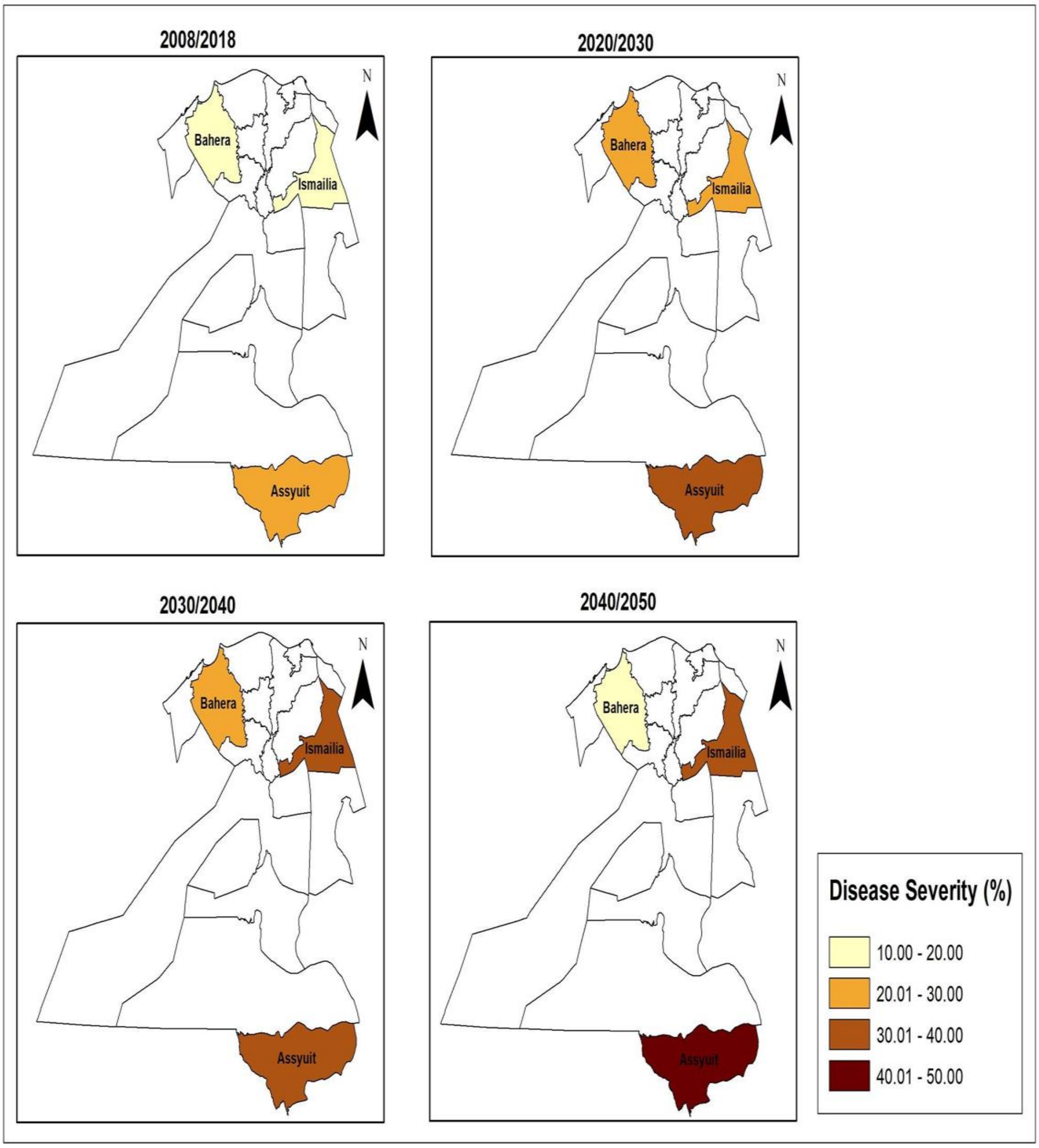

Fig. 3. Distributive maps for forecasting severity of early blight disease of tomato, under climate change in Egypt, during 2020/2030,2030/2040 and 2040/2050s growing seasons using estimated diseases severity in 2008/2018s seasons, at three different governorates

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الموجــــــز

يعتبــر مــرض اللفحــة المبكــرة المتسـبب عـن فطر *Alternaria solani*) من اهم الامراض التى تصيب محصول الطماطم خلال مواسم النموالمختلفة تحت الظروف المصرية مما يسبب اضرار كبيرة للمحصول و جودته تضمنت هذه الدراسة دراسة مدى أنتشار المرض فى محافظات البحيرة والأسماعيلية بالوجه البحرى وأسيوط بالوجة القبلى خلال العروات الصيفية والخريفيـة والشـتوية لموسم 2017/2019 وتأثير بعض العوامل المناخية (حرارة عظمى وصغرى – رطوبة نسبية) على شدة الاصابة بمرض اللفحة المبكرة و كذلك تم الحصول على بيانات شدة الاصابة بـالمرض للأعـوام السـابقة 2007-2017 مـن وزارة الزراعة المصرية وتـم دراسـة العلاقـة بـين العوامل المناخية و شدة الاصابة المرضية من خلال معادلات احصائية بواسطة برنامج (MINITAB® program for window) وإمكانية الاستفادة منها للتنبؤ بالمرض تحت ظروف تغير المناخ مستقبلاً فى مصر 2030-2050 . سجلت أعلى شدة إصابة للمرض بمحافظة البحيـرة بـالعروة الخريفـى خــلال موسـم النمـو 2017/2016 واقل شدة اصابة كانت ايضاً بالعروة الخريفى خلال موسم النمو 2018/2017. سجلت أعلى شدة إصابة بمرض اللفحة المبكرة بمحافظة الاسـماعلية بـالعروة الخريفـى خــلال موسـم النمـو 2018/2017 واقل شدة اصابة كانت ايضاً بالعروة الخريفى خلال موسم النمو 2017/2016. وفى محافظة اسيوط سجلت أعلى شدة إصابة بالمرض بالعروة الخريفى خلال موسم النمو 2018/2017 وكانت اقل شدة اصابة كانت بالعروة الشتوية خلال موسم النمو 2017/2016. سجلت أعلى شدة إصابة بمـرض اللفحــة المبكـرة خــلال موســم النمــو 2018/2017 واقل شدة اصابة كانت فى موسم النمو 2017/2016. أيضا، تم تسجيل أعلى شدة اصابة خــلال العـروة الصـيفية مقارنـة بـالعروات الخريفيـة والشتوية، ولكن خلال العروة الشتوية سجلت أقل شدة أصـابة وشـدة أصـابة معتدلـة تـم تسـجيلها بـالعروة الخريفى. سـجلت اعلـى متوسـط شـدة إصـابة كـان ,محافظة اسيوط خلال مواسم النمو من 2008/2007 الـى 2015 /2016. وكـان متوسـط درجـة الحـرارة العظمـى و الصـغرى 31م° و 15.9م° علـى التـوالى وكـان متوسـط الرطوبـة النسـبية 50.8% . بالتحليـل الاحصائى كان تاثير درجة الحرارة العظمى والصغرى والرطوبــة النســبية ذات تــاثير غيــر معنــوى ســالب بمحافظة البحيرة وبينما بمحافظة الاسماعيلية كان تاثير درجة الحرارة العظمى و الصغرى غير معنوى موجب وكان تأثير متوسط الرطوبة النسبية غير معنوى موجب بينمـا فـى محافظـة اسـيوط كـان تـأثير متوسط درجـة الحرارة العظمى والصغرى معنوى سالب وتأثير متوسط الرطوبـة النسـبية معنـوى موجـب علـى شـدة الاصـابة بمـرض اللفحـة المبكـرة خــلال مواسـم النمـو. وامكـن الاستـفادة مـن دراسـة العلاقـة بـين العوامـل المناخيـة و

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شدة الاصابة خلال مواسم النمو من 2008/2007 الى 2016/2015 باستخدام برنامج (**MINITAB®**) لإيجاد العلاقة و التنبؤ بتطور و شدة مرض اللفحة المبكرة Y = b0 + b1x1 + b2x2 + ... bqxq تحت ظروف المستقبلية تحت الظروف البيئية فى المحافظات المصرية الثلاثة .تتوقع وجود اختلاف كبير بين شدة الاصابة بمرض اللفحة المبكرة تحت الظروف المستقبلية بمقارنة بالظروف الحالية، حيث ترتفع شدة الاصابة بمرض اللفحة المبكرة فى الطماطم من 18.8٪ مواسم 2018/2008 إلى20% موسم 2050/2040 بمحافظة البحيرة ، ومن 14.8 ٪ مواسم 2018/2008 إلى 36.0% مواسم 2040 / 2050 بمحافظة الإسماعيلية ومن 23.3٪ مواسم 2018/2008 إلى40% مواسم 2050/2040 بمحافظة أسيوط مع تغير طفيف في درجات الحرارة القصوى أو الدنيا و الرطوبة النسبية.

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