Impact of Climate Change on Plant Diseases and IPM Strategies

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Abstract

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There has been a remarkable scientific output on the topic of how climate change is likely to affect plant diseases. Climate change will probably influence the occurrence, prevalence and severity of plant diseases. Projected atmospheric and climate change will thus affect the interaction between crops and pathogens in multiple ways. This will also affect disease management with regard to timing, preference and efficacy of chemical, physical and biological measures of control and their utilization within integrated pest management (IPM) strategies. As prediction and management of climate change effects on plant health are complicated by indirect effects and the interactions with global change drivers. There is a consensus that prediction and management of climate change effects on plant health are complicated by interactions between globalization, shifts in climate, pollution and increasing numbers of invasive plants, pests and pathogens. Prediction of future requirements in disease management is of great interest for agro-industries, extension services and practical farmers. A comprehensive analysis of potential climate-change effects on disease control is difficult because current knowledge is limited and fragmented and due to the complexity of future risks for plant disease management, particularly if new crops are introduced in an area. Uncertainty in models of plant disease development under climate change calls for a diversity of management strategies, from more participatory approaches to interdisciplinary science. Involvement of stakeholders and scientists from outside plant pathology shows the importance of trade-offs. All these efforts and integrations will produce an effective crop protection strategies using novel technologies appropriate tools to adapt to altered climatic conditions.

Introduction

Climate change is a major concern for agricultural communities worldwide. Changes in climatic parameters greatly affect crop production and susceptibility to pests as well as insect pest longevity. Climate change affects crop pests and disease susceptibility which in turn affects crop health and these changes cause deviations in farming practices as to cope with the effects of these changes and to prevent a decline in productivity.

There are four different future scenarios regarding climate change including A1, A2, B1 and B2. The A1 scenario focuses on rapid increases in global economic development, A2 focuses on rapid regional economic development instead of the global one in A1 scenario, B1 focuses on rapid global environmental development regarding agriculture and B2 focuses on rapid environmental sustainability at the regional and local levels.

Effect of Climate Change on Plants and Plant Diseases

A major example for the devastating effects of climate change is floods caused by rising of sea level that can cause the disappearance of low level lands and major crop losses. Another example is drought, where reduced water levels in the soil cause plants to lose their biological functions and even become more susceptible to diseases and pests. Climatic conditions contribute to the disease triangle, which involves the presence of a susceptible host, a pathogen and suitable environmental conditions for infection to occur, and climate change affects environmental conditions whether it be in favor of the host or the pathogen. Examples of these conditions include dew, rain, relative humidity, temperature, aeration (wind), soil moisture and sunlight intensity.

Climate change parameters can have effects on both the host and the pathogen (Figure 1), for example certain temperature levels promote pathogen growth and other temperature levels can cause the host to have higher resistance to pathogenic infections. Wheat and oats, as an example, become more susceptible to rust diseases with increased temperature; whereas some forage species become more resistant (1). Moreover, changes in temperature, as little as 2°C, could cause certain pests to undergo from 1 to 5 additional lifecycles per season, which increases the ability of the pests to overcome plant resistance.

Certain mycotoxin concentrations (such as those produced by *Fusarium* sp.) are often increased at harvest due to high humidity and temperature. Humid conditions also increase proliferation of weeds and weed biomass increases with increasing temperatures.

Certain parameters can have different effects depending on plant physiology. For example, increased CO_2 levels can cause a decrease in plant decomposition rates, which results in higher fungal inoculum levels and these concentrations may induce the production of more fungal spores. On the other hand, high CO_2 concentration may cause physiological changes to plants, causing them to acquire higher resistance to certain pathogens.

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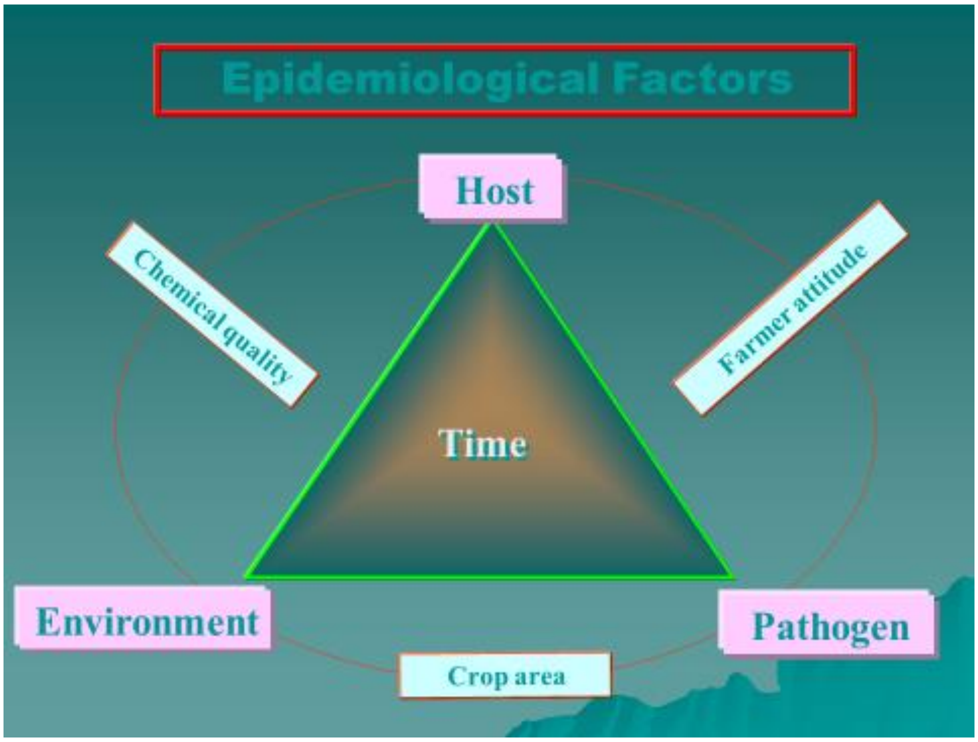

Figure 1. The relation between the pathogen, host and environmental conditions which are the main factors required for infection with plant pathogens to occur.

Other extreme conditions may include low water levels and soil erosion which causes a decline in soil fertility and hence plant health.

Fungicide activity is also a major determinant factor. Climate change may highly affect fungicide efficiency. Highly frequent rainfalls greatly impact the efficiency of contact fungicides, as rain has the ability to sweep and eliminate contact fungicides from the hosts' surface, rendering them ineffective. However, plants with high metabolic rates have increased intake of fungicides and aren't highly affected by this parameter.

In 2008, the International Food Policy Research Institute estimated that due to climate changes, by 2050 twenty five million additional children will have malnutrition due to increased consumption of food products with little efforts done to adapt to and deal with these changes. In addition, the yearly costs to deal with the issue by reducing its impacts by 2050 will be seven billion US dollars. It will generally be difficult to deal with international trade of crops due to the more frequent appearance of unexpected pathogens (2).

Integrated Pest Management

Integrated pest management (IPM), according to the Food and Agricultural Organizations in the United States (FAO), is an ecosystem approach involving crop protection which combines different strategies and practices towards growing more healthy crops and minimizing the use of pesticides to protect the environment. It is based on analyzing the agro-ecosystem and its different elements in order to manage these elements in such a way to minimize damage caused by pests while protecting the environment and human health.

The IPM pyramid consists of three main processes which include preventive or indirect crop protection, risk assessment or monitoring and responsive or direct crop protection. The three processes aim to increase the efficiency of each step involving crop breading and maintenance. Preventive crop protection involves the use of certified seeds, cultivars which have high tolerance to pathogens and enhancement of natural enemies of plant pathogens such as microbiological competitors. Risk assessment and monitoring is the most crucial process in IPM, based on the use of an early warning system which provides information related to current climate and how it could affect plant health and by using such information and good understanding of plant pathogen interaction, one can determine time frames where plants are most susceptible to pathogens and take countermeasures to prevent or minimize pathogen severity (through the use of fungicides for example). Direct crop protection basically involves the counter measures taken to deal with unfavorable conditions, which include the use of antagonistic microorganisms or application of fungicides.

Decision Support System (DSS)

Decision support system is an informatics tool which uses mathematical models such as equations and statistics to help the decision maker take appropriate action. The three main phases of a decision making system include intelligence, design and choice, with two other subsequent phases which include implementation of the decision and monitoring of its effect and outcomes. The decision making process in IPM is highly complex and dynamic, it requires a high level organization and constant update of operators. It also requires the presence of databases and means to collect data and information as well as tools to handle data. The decision making process generally provides the capability to identify when difficulties may occur and how to deal with these difficulties depending on data provided.

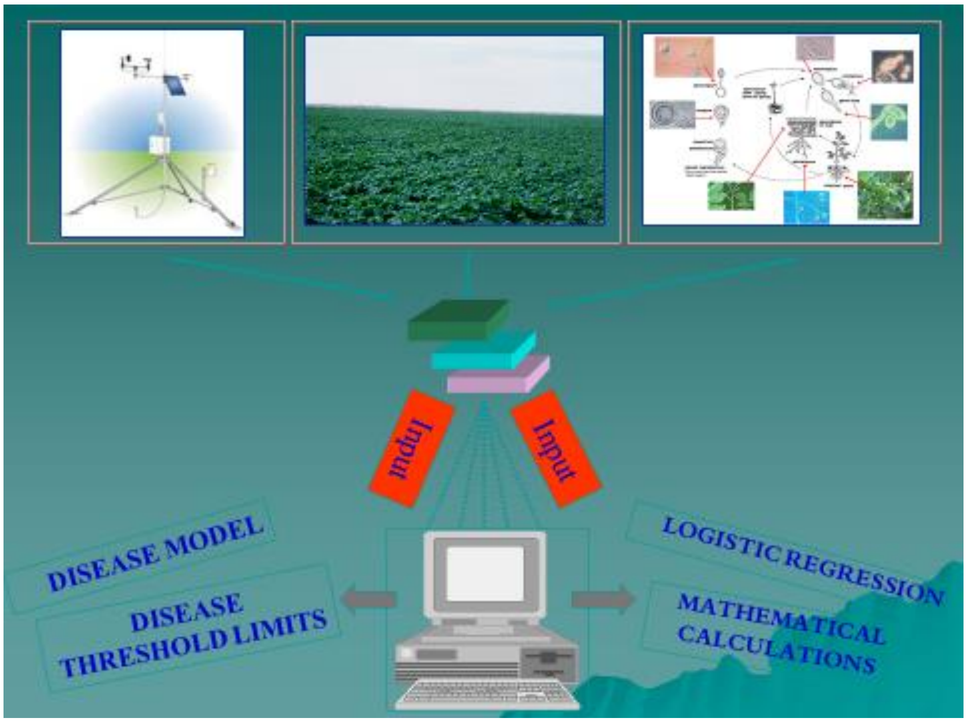

Figure 2. The correlation between forecasting data input, pathogen studies and environmental conditions as input and disease modeling to develop preventive measures as an output.

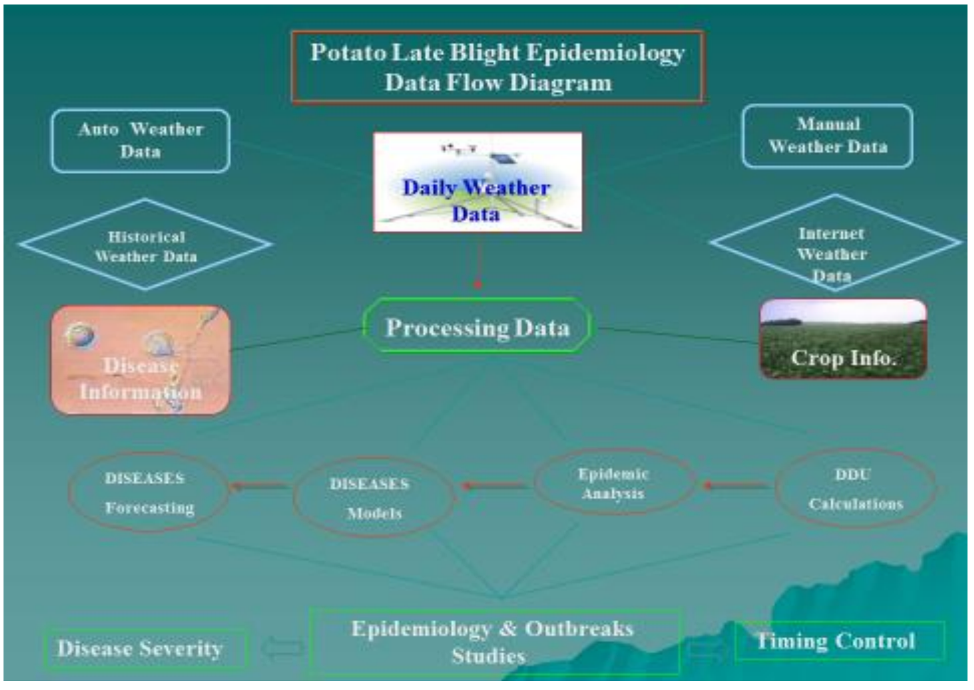

Figure 3. Example of Pathogen epidemiology system in potato late blight and its integrated components.

A system is defined as an integration of certain components and interacting factors with a common objective. A pathogen monitoring system would basically receive input based on environmental factors and properties and the output is expressed in the form of maps, information and graphs (Figure 2).

Forecasting and Early Warning System

The idea of forecasting and early warning system has been introduced in 1926, with the appearance of computers and information technology software which produced convenient warning systems (Figure 3). Currently in Egypt, early warning systems are being used to deal with pathogens of certain crops such as faba bean chocolate spot disease (licensed in 2016) (4) (Figure 4). The main concept involves the use of a mobile telemetry automated weather station system to monitor environmental conditions and software to interpret the input. Based on the information provided, a decision can be made regarding the protection and maintenance of plant health (3).

A set of computer programs have been successfully produced by the unit's work team and some of them were applied on crop databases in different governorates in Egypt. These programs have proven to be successful early warning systems, as they predicted the appearance of diseases before infection and before they reached a damaging level as well as the reduction of the amount of fungicides used for disease control.

With the appearance of climate change phenomena, farmers and decision makers will need more decision support systems especially plant disease forecasting systems

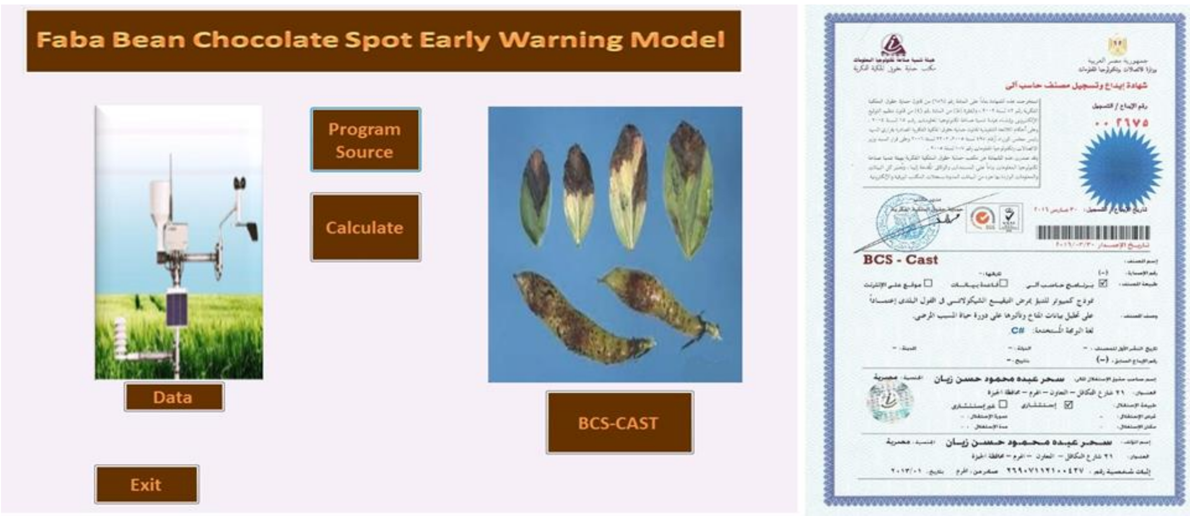

Figure 4. A certified early warning system for faba bean chocolate spot.

الملخص

زيان، سحر. 2018. آثار تغير المناخ في أمراض النبات واستراتيجيات المكافحة المتكاملة. مجلة وقاية النبات العربية، 36(1): 75-79.

أكدت نتائج البحوث العلمية الحديثة على أن تغير المناخ سيكون له تأثير واضح في أمراض النبات. يؤثر التغير المناخي في التفاعل بين العائل النباتي والمسبب المرضي من حيث حدوث المرض وانتشاره وشدة الإصابة المرضية، فضلاً عن الآفات الأخرى. ومن المرجح جداً أن يؤثر تغير المناخ في هذا التفاعل بطرائق متعددة. وسيؤدي هذا التأثير إلى تغيير فى استراتيجيات الإدارة المتكاملة للآفات (IPM) من حيث توقيت وتفضيل وفاعلية التدابير المتخذة للمكافحة سواء الكيميائية أو الفيزيائية أو البيولوجية. ومما هو جدير بالذكر أن التوقعات المتعلقة بآثار تغير المناخ في الصحة النباتية أمر في غاية التعقيد، نظراً لما يتطلبه من تآثرات بين العولمة والتغير الناتج عن تلوث المناخ وزيادة أعداد النباتات الغازية والآفات ومسببات الأمراض بصورة مباشرة وغير مباشرة. وتعتبر إدارة الأمراض في ظل الظروف المستقبلية ذات أهمية كبيرة للإنتاج الزراعي والصناعات الزراعية ومصالح الإرشاد والمزارعين الممارسين. في حين أن التحليل الشامل للآثار المحتملة للتغير المناخي في مكافحة الأمراض صعب ولا يزال يفتقر إلى الدقة نتيجة النقص الحالي في البيانات المطلوبة وتبعثر المعلومات المتوافرة ونقص الدراسات اللازمة التي تخدم هذا المجال. ويزداد تعقيد المخاطر المستقبلية لإدارة الأمراض النباتية نتيجة لإدخال أصناف نباتية جديدة أو التغيير في التوزيع المحصولي في المناطق المختلفة. ولازالت البرامج التي تربط عناصر المناخ مع تطور الأمراض بسيناريوهات تغير المناخ غير كافية وغير مكتملة وتحتاج إلى بذل المزيد من الجهود والتكامل المعرفي، الأمر الذي يؤدي إلى تجميع الجهود والتكامل بين الدراسات لوضع استراتيجيات فعالة لحماية المحاصيل باستخدام أساليب تكنولوجية حديثة ومناسبة للتكيف مع الظروف المناخية المتغيرة.

عنوان المراسلة: سحر زيان، معهد بحوث امراض النبات، مركز البحوث الزراعية، مصر، البريد الإلكتروني: drsahar.abdo@gmail.com

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