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CPM-CAST: An Early Warning Computerized Model for Cucumber Powdery Mildew in Egypt

Hebat Allah H. Morsi*; E.A.M. Gado and Sahar A.M. Zayan***

* *Early Warning Unit, Pl. Pathol. Res. Inst., Agric. Res. Centre, Giza, Egypt.*

***Plant Pathol. Dept., Fac. Agric., Ain Shams Univ., Egypt.*

Powdery mildew caused by *Podosphaera xanthii* (Syn. *Sphaerotheca fuliginea*) is considered one of the most devastating diseases which can causes complete loss of the crop and poses a major threat to the Egyptian`s cucumber production. The first Egyptian early warning computerized model CPM-CAST, is an integral linking system based on short-term observations over several cucumber growing seasons. It analyzes real time, 24 hours microclimate and data collected automatically by an advanced Agro-weather station (Adcon Telemetry A733). CPM-CAST was designed and validated under both computers' Labs and field conditions to forecast the cucumber powdery mildew disease daily infection potential (DDIP). Subsequently, it was evaluated as an advisory system to reduce number of fungicides application compared with the fundamental applications during 2008 and 2009. The basic roles of system analysis for model validation and evaluation are discussed. On the other hand, the positive performance for using CPM-CAST to forecast powdery mildew infection was detected in decreasing number of fungicide application (2 sprays) and disease severity in comparison with the traditional fungicides application (4 sprays).

Keywords: Early warning, computerized model, CPM-CAST, cucumber, daily disease infection potential (DDIP), *Podosphaera xanthii*, powdery mildew and system analysis.

Cucumber (*Cucumis sativus* L.) is considered one of the most common vegetable crops in Egypt. Total production quantity was 595,732 tons during 2008 (Anonymous, 2008). Cucumber cultivation throughout the world and also in Egypt is affected by various disease problems.

Powdery mildew, caused by the fungus *Podosphaera xanthii* (Syn. *Sphaerotheca fuliginea*), *Golovinomyces cucurbitacearm* (syn. *Erysiphe cichoracearum)* and *Golovinomyces orontii* (syn. *Erysiphe cichoracearm*) (Vakalounakis and Klironomou 1995 & 2001), is one of the most ubiquitously damaging disease of cucumber worldwide, where temperature is relatively high and moisture occurs as heavy dews rather than as dashing rains. Also, powdery mildew was found in Egypt as the major disease threat to cucumber was powdery mildew (Metwally and Wehner, 1990).It was most important yield-reducing factor in cucumber, all aerial plant parts, mostly affected by the disease (*e.g.* leaves, stems and fruits) and showed considerable reduction of quantity and quality of cucumber yields (Dik *et al.*, 2004). In Egypt, *Podosphaera xanthii* was found on different varieties causing considerable

losses in crop yield (Mahdy *et al.*, 2006). However, the intensive management of high value crops such as cucumber has relied increasingly in recent years on synthetic fungicides to sustain production. The negligent use of chemicals can cause diseases for humans, environmental disasters and pollution. The international concern about environmental and human health risks, due to pesticide overuse, raises the necessity of production of food free from chemical substances. There are many noteworthy efforts to improve sustainability and environmental stewardship among cucumber powdery mildew management. In the early 1990s, plant pathologists worldwide began to develop powdery mildew growth models that could provide growers with forecasts or early warning advisory system and help them foresee outbreaks in order to time more precisely their preventative powdery mildew treatments (Sall, 1980; Kast, 1994; Gadoury *et al.*, 1994; Seem & Gadoury, 1996; Gubler *et al.*, 1999; Carroll *et al.*, 2002 and Austin *et al.*, 2006). If effective, the computerized early warning model simulates the development of cucumber powdery mildew on the basis of short-term observation of microclimatic factors. The inputs variables to the model are: temperature, RH, precipitation, wind speed, global radiation and leaf wetness for the primary disease infection potential (PDI) and the secondary daily disease infection potential (DDIP).

The goal of this investigation was to evaluate and to facilitate validation of CPM-CAST, the first Egyptian computerized early warning model, to allow direct use of the model in an experimental cucumber over two successive cucumber-growing seasons in Egypt. To detect the optimal time for the first spray and lead the fungicides application for perfect disease control compared with standard fungicide schedule, for each season of testing. Finally, to establish an advisory system for cucumber powdery mildew early warning model in Egypt.

Materials and Methods

Weather monitoring:

Automated, portable and solar powered in-crop weather stations (Adcon Telemetry A733) (Fig.1) were used to monitor the microclimatological conditions.

High technology, sensitive sensors transmitted the digital data up to 20 km in distance, on average every 15 minutes, via a personal computer using radio waves. In this way, data on temperature, relative humidity, wind speed, leaf wetness, precipitation and global radiation were collected from cucumber field. The station is equipped with central base station (Fig.2) which served as a: data collection centre (receiver) to receive and save the collected data up to 50 days and to run advantage software which allowed simple interpretation of the readings using a graph and detailed list of chosen items.

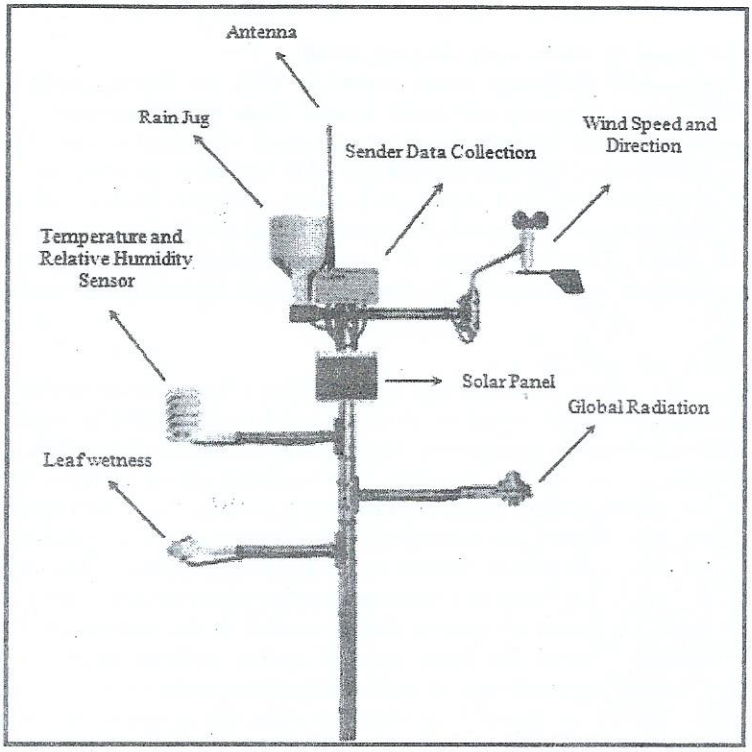


Fig.1. Automated in crop weather station (Adcon A733).

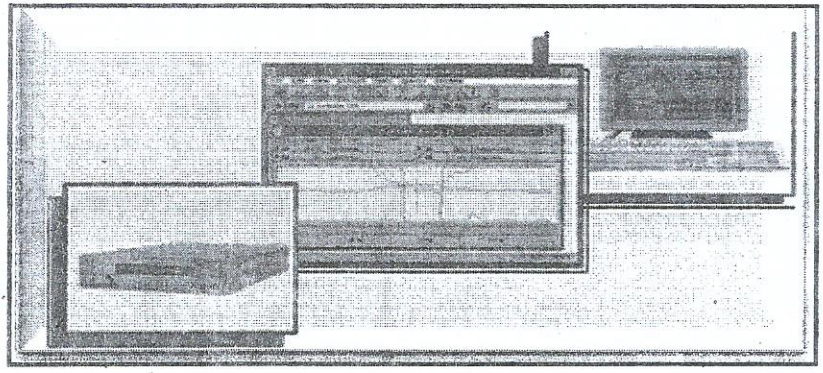


Fig. 2. The base station (Receiver, PC, and Advantage Software) where the data are instantly plotted for easy examination of weather.

Cucumber powdery mildew early warning model:

A computerized simulation model named by Afifi and Zayan (2008) as CPM-CAST (Fig.3) was designed and tested several times under laboratory conditions before switching to the validation experimental phase conducted at Yousef El-Sdeek (Fayoum Governorate) throughout 2008 and 2009 cucumber growing seasons. This allowed us to figure out how well such a model predicted disease incidence and facilitated revision and refinement of the model based on these findings. Frequently, disease control (timing of sprays) of cucumber treated according to the model recommendations was compared to disease managed by traditional routine spray schedules.

The model system analysis:

CPM-CAST model, presented as a flowchart (Fig.4) is a creation and designation of a computerized model, based on short-term observations (hourly weather data) analyzing the correlation between the input variables of microclimatological factors such as: temperature, relative humidity, leaf wetness, global radiation and wind speed. The model uses these factors to calculate the actual time of Primary Disease Infection Potential (PDIP) and Secondary Daily Disease Infection Potential (SDIP) of cucumber powdery mildew caused by *Podosphaera xanthii.* Then, the model outputs a daily announcement as a warning message (spray or don't spray) to guide the fungicides application for perfect disease control in the appropriate time. The model evaluation follows the basic rules of system analysis to identify events (A and B). The model is activated at pre-budding phase, and tries to detect the event A, which is defined as: Event A is triggered when the model detects at least X accumulated dynamic summation hours of relative humidity (RH) between 50–90 % and temperature between Y and Z according to the data tabulated in (Table 1). Then the model looks for event B which is continues hours of RH > 60%, and/or leaf wetness > 50 U. Moreover, using the model system analysis brings an extension to the model, that applies the same rules not only to identify the first critical phase of the season (correct time for primary infection), but also to issue warnings for secondary disease infection potential (SDIP) throughout the whole growing season.

Table 1. The basic rules of system analysis to identify events A

Y = Temp from:	Z = Temp to:	X = 8 hours of RH	X = 10 hours of RH	X = 12 hours of RH
24°	28°	Event A detected		
20°	23°		Event A detected	
15°	19°			Event A detected

Model validation:

Field experiments were conducted in big plots at Yousef El-Sdeek (Fayoum Governorate) throughout September, October and November of the 2008 and 2009 cucumber-growing seasons. Commercial cultivars of cucumber, Beit Alpha f1 and Amira II, were used. Both cultivars are always susceptible to powdery mildew infection. Designed experiments in the area of 350 m^2 at a rate of 5 lines per transaction and used four replicates 175 m^2 per treatment and untreated plots

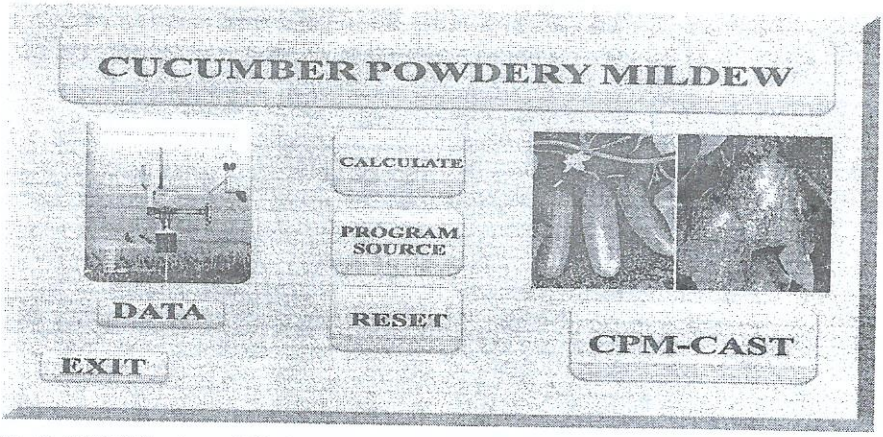


Fig.3. CPM-Cast model's interface for cucumber powdery mildew in Egypt.

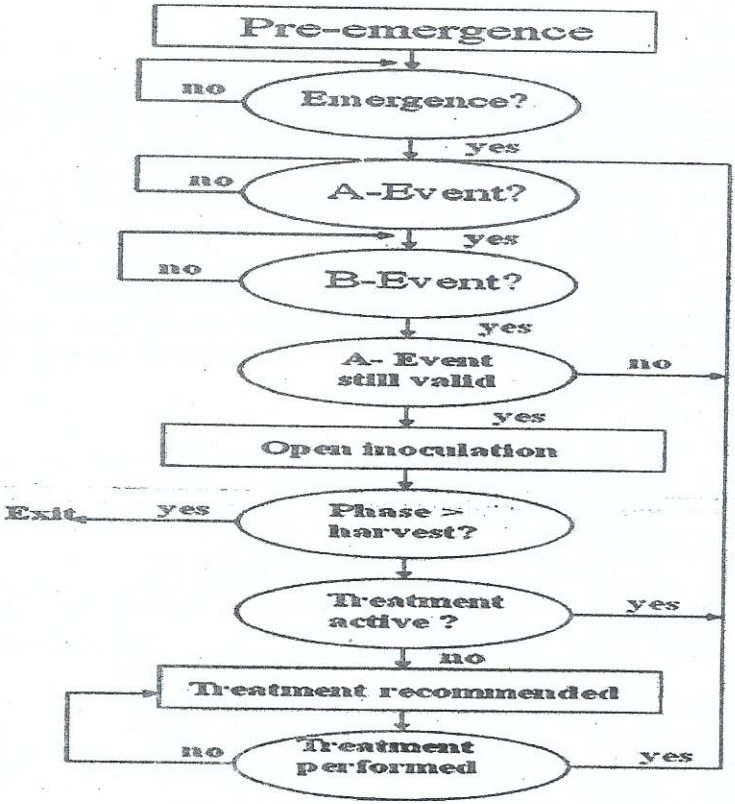


Fig. 4. Flowchart of CPM-Cast model's system analysis for cucumber powdery mildew in Egypt

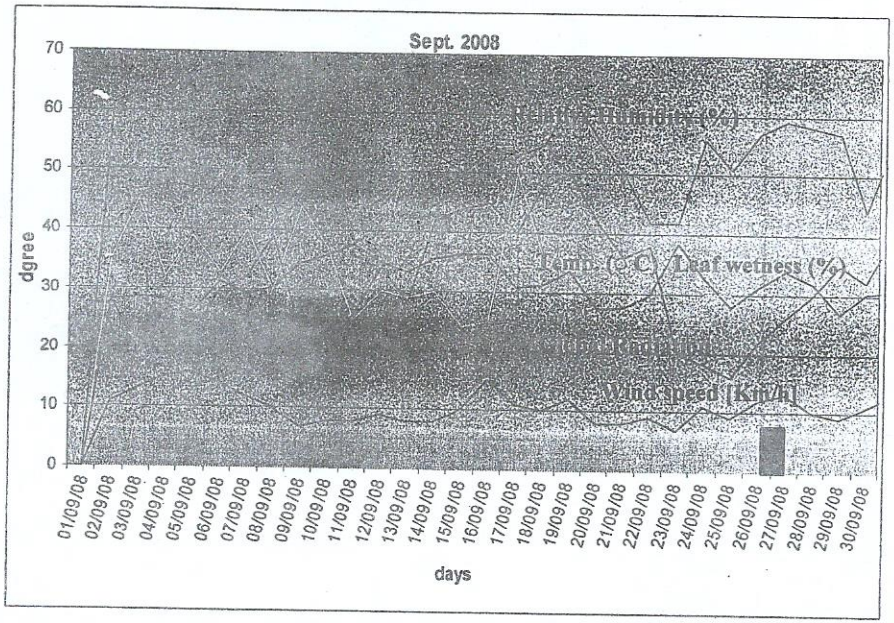
sprayed with water only were served as control. Each year, the following two treatments were tested: (i) a full-schedule fungicide program, in which plants were sprayed every 10 to 14 days and (ii) spraying when the advisory system of early warning model CPM-CAST indicated that a spray application was needed and at least 14 days, had elapsed since the previous fungicide application. Generally, Sumi-8 50% (35 ml/100 l water) in alternate with Microtheol special 80% (250g /100 l water) are considered effective for controlling powdery mildew, therefore they were used with both the advisory - system treatment and the full - schedule program. Cucumber plants were carefully inspected at least one time per week to point out the time of appearance of disease symptoms. The effect of each treatment was evaluated by calculating the severity of powdery mildew. It was determined on a 0 to 4 scale, with 0 indicating no infection and 1 to 5 indicating leaf surfaces covered with powdery mildew as follows: 1= less than 5%, 2= 6 to 25%, 3= 26 to 50% and 4= > 50%, according to Morishita *et al.* (2003). Data were measured by automatic weather stations (Adcon Telemetry A733), installed within the cucumber plants.

Results

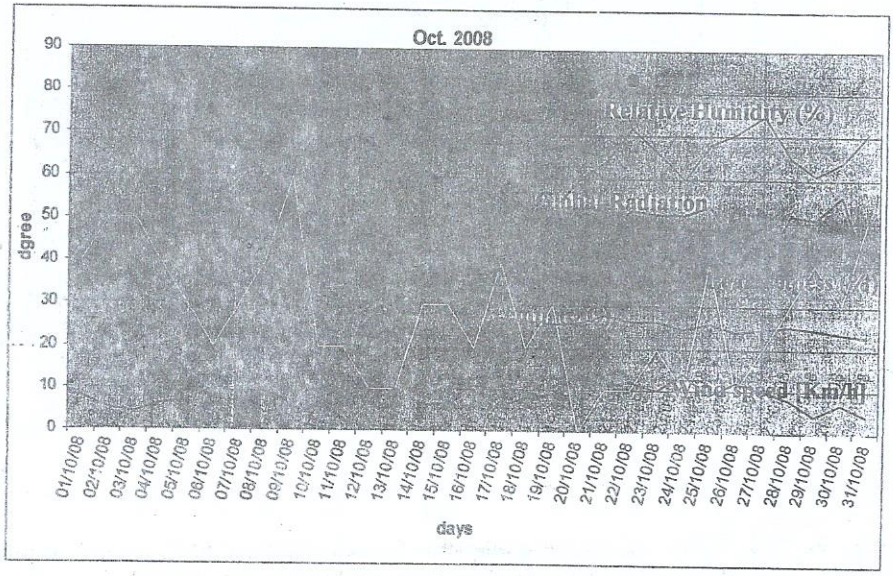
The application of a designed early warning computerized model named by the author CPM-CAST for cucumber powdery mildew which was adopted with the role of system analysis has been evaluated successfully for the first time in Egypt. Results presented in (Fig.5) showed that the CPM-CAST model has accurately determined the correct time for the first application (PDIP) in 27th of September and the second application in 15th of November 2008 with disease severity 2.47^{b} after the second spray which was tabulated in Table (2). On the other hand, results shown in (Fig.6) prove that the CPM-CAST model has accurately estimated the correct time for the first application (PDIP) in 25th of September and the second application in 26th of November 2009 with disease severity 2.20^{b} after the second spray which was tabulated in Table (2).

Table 2. Effect of early warning system and time table of fungicides on the severity of powdery mildew disease on cucumber cv. Amira II, in Fayoum Governorate during two successive autumn seasons of 2008 and 2009

No. of fungicide sprays	Disease severity (%)			
	Spraying using time table of fungicides application		Spraying using the early warning system	
	Autumn 2008	Autumn 2009	Autumn 2008	Autumn 2009
1st spray	4.20 ^{b}	4.06 ^{b}	3.33 ^{b}	3.77 ^{b}
2nd spray	3.50 ^{bC}	3.47 ^{b}	2.47 ^{b}	2.20 ^{b}
3rd spray	3.30 ^{bC}	2.00 ^{C}	---	---
4th spray	2.23 ^{C}	1.63 ^{C}	---	---
Control	16.67 ^{a}	13.63 ^{a}	16.67 ^{a}	13.63 ^{a}
L.S.D. at 5 %	1.71	1.37	2.41	3.00

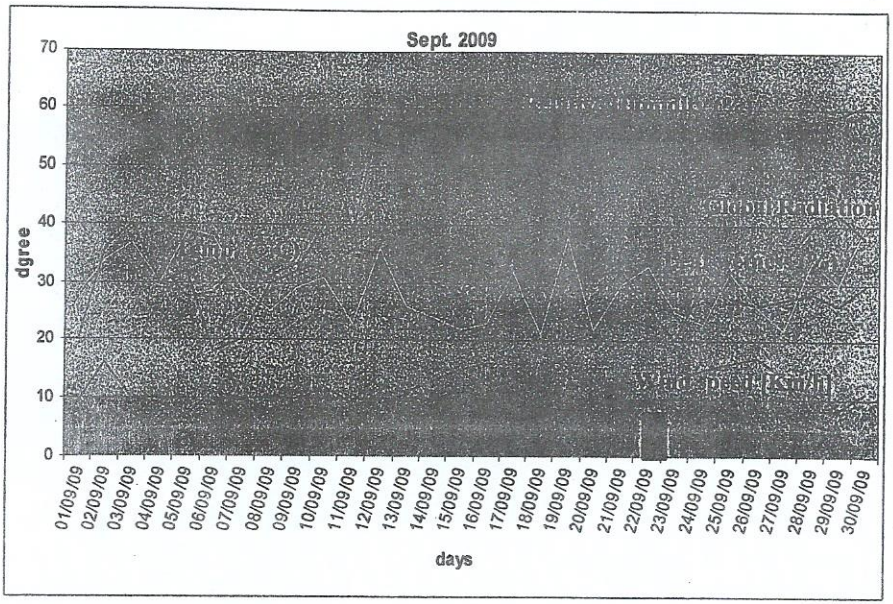


(a)

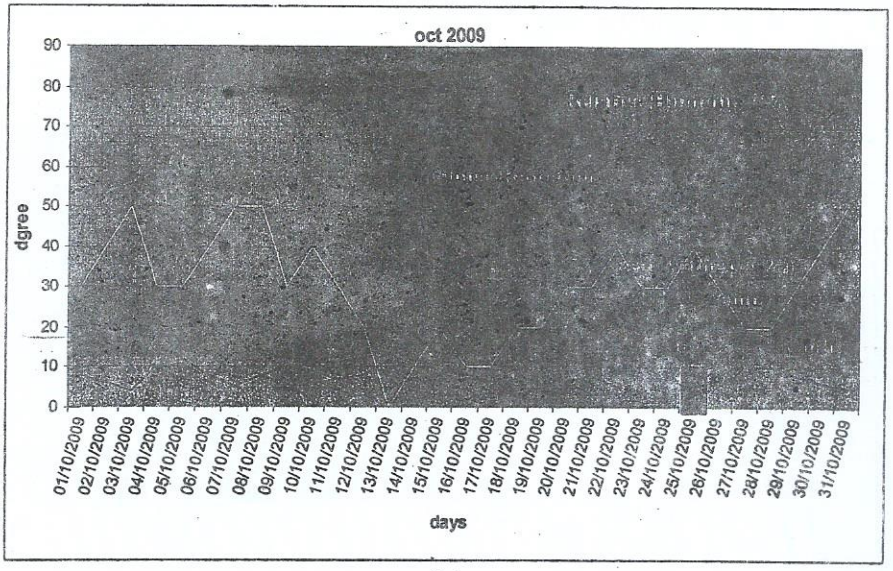


(b)

Fig. 5. The daily microclimatological factors (CPM-CAST model input variables) during September (a) and October (b) of 2008 cucumber growing seasons indicate the early warning system spray recommendations.



(a)



(b)

Fig. 6. The daily microclimatological factors (CPM-CAST model input variables) during September (a) and October (b) of 2009 cucumber-growing seasons indicate the early warning system spray recommendations.

The disease severity in the two seasons was compared to the disease severity under control which was 16.67[a] in the first season and 13.63[a] for the second one. Therefore, two sprays were applied in each season of evaluation according to the recommendation of CPM-Cast warning system, instead of four sprays in 2008 and 2009 following a full-schedule fungicide program (routine application) with disease severity 2.23[c] in the first season and 1.63[c] in the second one, with a reduction percentage of chemical applications by 50% during 2008 and 2009. Moreover both of the experimental treatments successfully controlled powdery mildew in 2008 and 2009 cucumber successive growing seasons.

Discussion

Powdery mildew caused by *Podosphaera xanthii* (Syn. *Sphaerotheca fuliginea* auct. p.p.) is the most important disease affecting cucumber (*Cucumis sativus* L.) in Egypt. Most of the knowledge used to manage powdery mildew in Egypt is derived from studies that depended mainly on the fungicide management scheme of routine time-table spraying. Increasing the fungicide applications is very expensive causes environmental pollution has harmful effects on consumers and negatively affects the growth of the treated plants. Accordingly, there is a clear need to re-evaluate the previous research knowledge to know when to start control of powdery mildew with the effective fungicides during the growing season, in order to reduce, as possible, the number of fungicides applications. An advisory system presented as early warning computerized simulation model CPM-CAST (Afifi and Zayan, 2008) was validated and evaluated successfully for the first time during two successive cucumber growing seasons in Egypt to help the cucumber growers manage such disease with more precise use of fungicides. In this regard, many attempts have been made with success all over the world to forecast cucumber powdery mildew (Sall, 1980; Kast, 1994; Gadoury *et al.*, 1994; Chavan *et al.*, 1995; Seem and Gadoury, 1996; Gubler *et al.*, 1999; Carroll *et al.*, 2002 and Austin *et al.*, 2006). The obtained results were in agreement with aforementioned researches and suggest that powdery mildew of cucumber could be controlled effectively in Egypt with fewer fungicide applications using disease warning system compared with a standard calendar-based schedule. System analysis play an important role in designing and creating the study subjected model and was discussed here in details. It is noteworthy to record that a significant reduction percentage in fungicide applications was achieved. The number of sprays was reduced by 50% during 2008 and 2009 cucumber-growing seasons, respectively. Also, we were able to reach pretty good results in controlling the disease severity only using these two sprays used in CPM-CAST instead of four sprays used in full-schedule fungicide program.

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برنامج الكمبيوتر CPM-CAST المعد لمقاومة مرض البياض الدقيقي على الخيار في مصر

هبة الله حسين مرسى*، عماد الدين مصطفى جادو و سحر عبده زيان***

* وحدة الإنذار المبكر- معهد بحوث أمراض النباتات - مركز البحوث الزراعية- الجيزة- مصر.

** قسم أمراض النبات - كلية الزراعة - جامعة عين شمس- مصر.

يسبب الفطر *Podosphaera xanthii* (Syn. *Sphaerotheca fuliginea*) مرض البياض الدقيقي وهو من أكثر الأمراض خطوره حيث يؤدي لخسارة المحصول بالكامل مما يجعله أكثر تهديدا على إنتاج الخيار في مصر. ويعد برنامج CPM-CAST هو أول برنامج مصري للإنذار المبكر وهو نظام متكامل يعتمد على الملاحظات القصيرة خلال مراحل نمو الخيار المختلفة ، وهو يقوم بتحليل بيانات المناخ المحيطه بالمحصول خلال ٢٤ ساعة وهذة البيانات تجمع اتوماتيكيا بواسطة محطة الرصد الجوي الزراعي Adcon Telemetry A733.

وقد تم تصميم برنامج CPM-CAST والتاكد من صلاحية استخدامه تحت ظروف كلا من معامل الكمبيوتر والظروف الحقلية يوميا للتنبؤ باحتمال حدوث عدوى بمرض البياض الدقيقي للخيار ومن ثم تقييمه كنظام استشاري للتقليل من تكاليف مبيدات الفطريات مقارنة مع نظام الرش الدوري للمبيدات خلال موسم ٢٠٠٨/٢٠٠٩ ، وقد تم مناقشة القواعد الاساسية لوضع البرنامج بواسطة علم تحليل النظم وشرح كيفية عمل البرنامج من خلال هذا البحث.

من جهة أخرى فقد أظهر استخدام برنامج الكمبيوتر في التنبؤ بظهور العدوى لمرض البياض الدقيقي فعالية إيجابية في خفض كلا من عدد مرات الرش بالمبيد (رشتين) وشدة الإصابة بالمرض بالمقارنة ببرنامج الرش التقليدي بالمبيدات (٤ رشات).