# RELATIONSHIPS BETWEEN CLIMATIC CONDITIONS AND POTATO LATE BLIGHT EPIDEMIC IN EGYPT DURING WINTER SEASONS 1999–2001

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**Abstract.** Late blight is a disease of potatoes caused by *Phytophthora infestans* (Montagne) de Bary, the fungus can destroy virtually 100% of the above-ground parts of susceptible cultivars under favourable environmental conditions and in the absence of any control measures. Sever epidemics of late blight have emerged in both 1999/2000 and 2000/2001 growing seasons. An indicator variable for the occurrence of outbreak during the season based on the number of favourable days in terms of temperature and relative humidity during November to January was used to describe the disease status throughout the tested period. Weather conditions prevailing during potato-growing winter seasons were studied and compared in three potato-growing areas during 1998/1999 and in five growing areas during 2000/2001. Infection efficiency is a function of the environmental conditions and the potato cultivars. Mild and warm nights allow the disease to become established on first-early cultivars. This build-up of inoculums early in the year leads to a tendency for blight to appear in later-planted potato crops in the area sooner than it does in other regions. Wet warm winter seasons were identified as important factors influencing development of the recent late blight epidemics in Egypt. Most of the nights minimum temperature in November and December 1998/1999 were relatively cool in all of potato-growing areas, so, the disease had not built up the inoculums which are needed to start epidemic. While in November and December at 1999/2000 and 2000/2001 growing seasons at Badrashin, Kom Hamada, and Salhia which had relatively warm nights and the rainfall fairly early in November and December 2000/2001 and this occurred again on following days. So, the disease had built up the inoculums for starting epidemic. However, Bosaily and Kafr El-Zayat had cool nights during both seasons.
**Keywords:** *Phytophthora infestans, epidemic disease, environmental conditions*

## Introduction

Potato (*Solanum tuberosum* L.) is one of the most important economic crops in Egypt concerning the production, farm income and exportation.

Potato late blight caused by *Phytophthora infestans* (Mont.) de Bary is still among the most destructive of all plant diseases. Under favourable environmental conditions and in the absence of any control measures, this disease can destroy virtually 100% of the above-ground parts of susceptible cultivars [8]. Infection efficiency is a function of the environmental conditions and the potato cultivars. During periods of favourable weather, many such cycles occur, resulting in an explosive epidemic [6].

Late blight progresses more rapidly under cool, moist conditions than hot dry weather since its spores require water and an appropriate temperature range to germinate. Also, if the conditions for blight are right for extended periods of time earlier in the season there can be a high risk of late blight at that time. The role of the


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environment in the development of late blight epidemics has been well documented [8, 16, 19]. Cool, wet weather with rainfall and ambient relative humidity (RH) above 90% and temperature of 7 to 21 °C favour late blight development [1, 16, 19].

The aim of this study is to attempt to derive the weather conditions during epidemic 1999/2000–2000/2001 growing seasons, which were favourable to potato late blight outbreak in potato-growing areas, where the disease was observed as an epidemic. Also, comparison of the weather conditions during the studied period in different locations.

## Materials and methods

### *Potato planting dates*

Potato was planted in winter (Mehira) season from September to first of October in Badrashin region and from November to first of December in Kafr El-Zayat, Kom Hamada, Bosaily and Salhia.

### *Survey of potato late blight*

General survey in potato fields for late blight disease was carried out during three successive seasons, 1998/1999–1999/2000–2000/2001, in the main potato growing governorates in Egypt i.e. Giza, Behaira, Gharbia and Ismailia (*Fig. 1*). Different locations in each governorate were selected and various potato fields in each location were surveyed using the disease assessment keys, as described by James [10].

#### *Disease assessment as foci*

The average area of the foci was determined as the number/feddan and expressed as percentage acreage affected, when the primary stages of epidemic development as foci. The key presented in *Fig. 2* was used and surveyed the crop for foci of infection as follows: 1 = survey the crop and estimate the average number of foci per feddan (N), 2 = determine the average area of the foci (A), 3 = express (1) and (2) as percentage of acreage affected, 4 = use key presented in *Fig. 2* to assess percentage of leaf area affected within the foci, 5 = assessment of late blight by percentage of acreage affected = N × A ($m^2$)/4200 × 100, and 6 = step 4 × 5 (the output percentage affected with an average infection% within the foci).

#### *Disease assessment as widespread*

The key showed in *Table 1* was used when the disease was widespread in the crop. The growth stages were 40–50 days and disease assessment at regular intervals (7–10 days) after the epidemic had started.

### *Weather data collection*

There were several meteorological and agrometeorological weather stations located in potato-growing areas. Over the three seasons, data of environmental conditions in potato areas were collected automatically (electronically) and manually from weather stations in fields of agricultural research stations.

The study areas were covered by 5 weather stations: Badrashin, Kom Hamada, Kafr El-Zayat, Salhia and Bosaily. The equipment and procedure for collecting pertinent environmental data is similar to that described for Blitecast [12].


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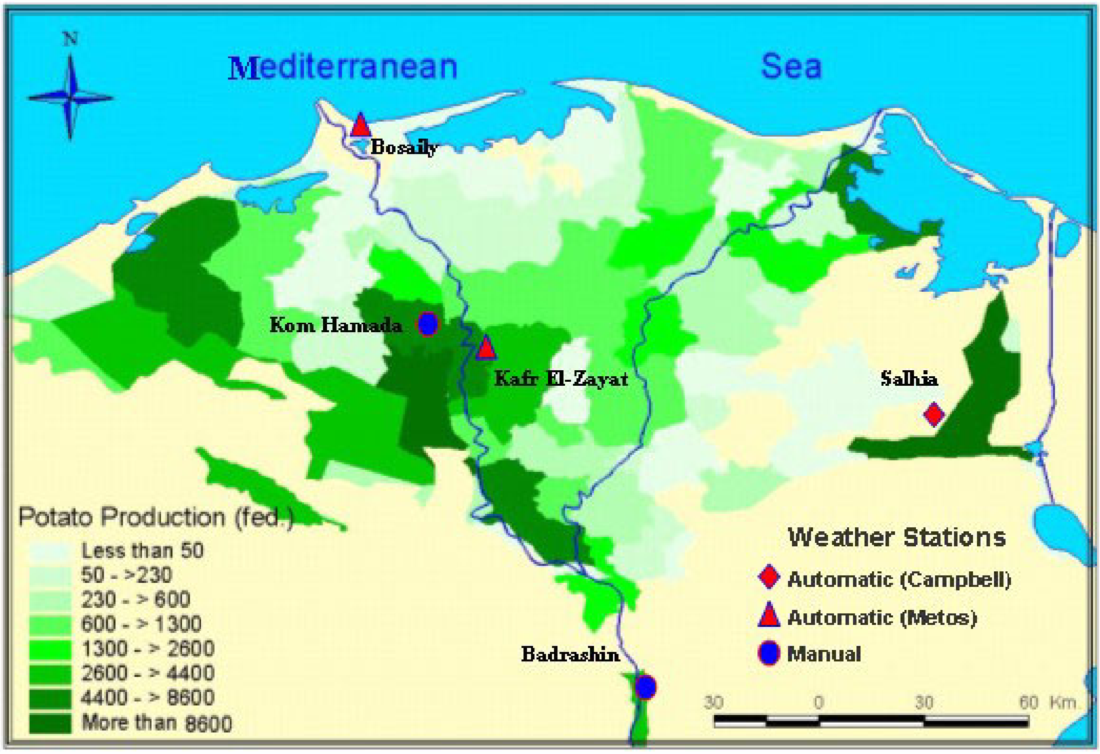


***Figure 1**. Locations in Egypt, where potato fields were surveyed for occurrence of late blight disease during winter growing seasons 1999–2001.*

*Collecting weather data automatically*

During the three seasons, data of environmental conditions in potatoes fields were collected automatically from weather stations in potato areas. Temperature, relative humidity, leaf wetness in the plant canopy and rainfall were recorded hourly and the data were forwarded via phone-modem connection daily to the Central Laboratory for Agricultural Climate (CLAC) in Dokki. There were automatic weather stations in some regions: Metos electronic weather stations (Metos® Compact, Pessl instruments GmbH., A-8160 Weiz, Austria) in Bosaily and Kafr El-Zayat, Campbell auto station (Campbell Scientific Ltd, CR10X Measurement & Control, USA) in Salhia region. Each weather station consisted of relative humidity sensor, temperature sensor, tipping bucket rain gauge, portable stand, data logger with battery and solar panel, modem and phone. All sensor signals were sampled at 10-min intervals in Campbell Scientific electronic weather station and at 12-min in Metos electronic weather station.

*Collection of weather data manually*

A thermohygrograph was sheltered in a white wooden house, that recorded temperature (˚C) and relative humidity (%) daily, and the thermohygrograph papers were collected weekly. In Badrashin and Kom Hamada regions, some potato fields were furnished with thermohygrograph, and the thermohygrograph papers were collected weekly.


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***Estimation of disease characters***

The disease severity was used to measure the development of late blight. The degree-day calculation, which called physiological-environmental time scale used as an environmental quality or combination of quantities (environmental units).

*Disease progress curves*

The progress of late blight in potatoes was estimated by the observations of epidemics, as exemplified by Fry [7]. The graph paper, statistics and computers, were used for fitting the disease progress curves [11]. Simple and polynomial regression models are common forms of this type of model. Statistical modelling of disease progress data for potato late blight was represented as $Y = f(t)$, where $y$ is disease severity, $t$ is time, $f(t)$ is some function of time.

## Results and discussion

***Survey of potato late blight***

Survey of potato for incidence of late blight was carried out in several fields in three locations in Egypt (Badrashin, Kafr El-Zayat and Bosaily) during three consecutive winter seasons 1998/1999, 1999/2000 and 2000/2001, and in two locations (Kom Hamada and Salhia) during two winter seasons 1999/2000 and 2000/2001. There were some differences between disease severities at those locations. The obtained result indicated that the disease severity was very low in all surveyed localities at Badrashin, Kafr El-Zayat, and Bosaily, where severities were ranged from 9–20%, in 1998/1999. The highest severities of blight were at Badrashin, Kom Hamada and Salhia, where severities ranged from 85–97% and 97–100% in 1999/2000, 2000/2001, respectively. However, disease severity was low in Kafer El-Zayat and Bosaily, where severities ranged from 10–25%.

The results of the present study showed that disease incidence varied between the three seasons and different locations. In most areas surveyed, the most affected area by late blight was at Giza, Behaira and Ismailia. The highest severity of late blight in many fields indicated that these fields were grown under favourable weather conditions [5, 8, 14, 15].

***Monitoring of weather conditions***

The weather data was plotted in *Figs. 3–7*. Daily total rainfalls are included in each figure. In all figures, horizontal lines were included to indicate the thresholds of temperature (min. 10 °C, max. 25 °C), relative humidity (85%) and rainfall (2 mm).

Most of the nights (minimum temperature) in November and December 1998/1999 were relatively cool in all of potato-growing areas, so, the disease had not built up the inoculums which are needed to start epidemic [3, 4]. There was a big contrast in this regard with November and December 1999/2000-2000/2001 at Badrashin, Kom Hamada and Salhia, which had relatively warm nights. However, Kafr El-Zayat and Bosaily had cool nights during both seasons. We note also that the rainfall came fairly early in November and December 2000/2001 and occurred again on following days. De Weille [2] reported that after three or four days from infection at the first leaf spot occur, the number of diseased leaves will soon begin to increase. Thus for a period extending from November and December 1999/2000-2000/2001, warm and humid nights were the usual occurrence at most of stations in growing areas which had

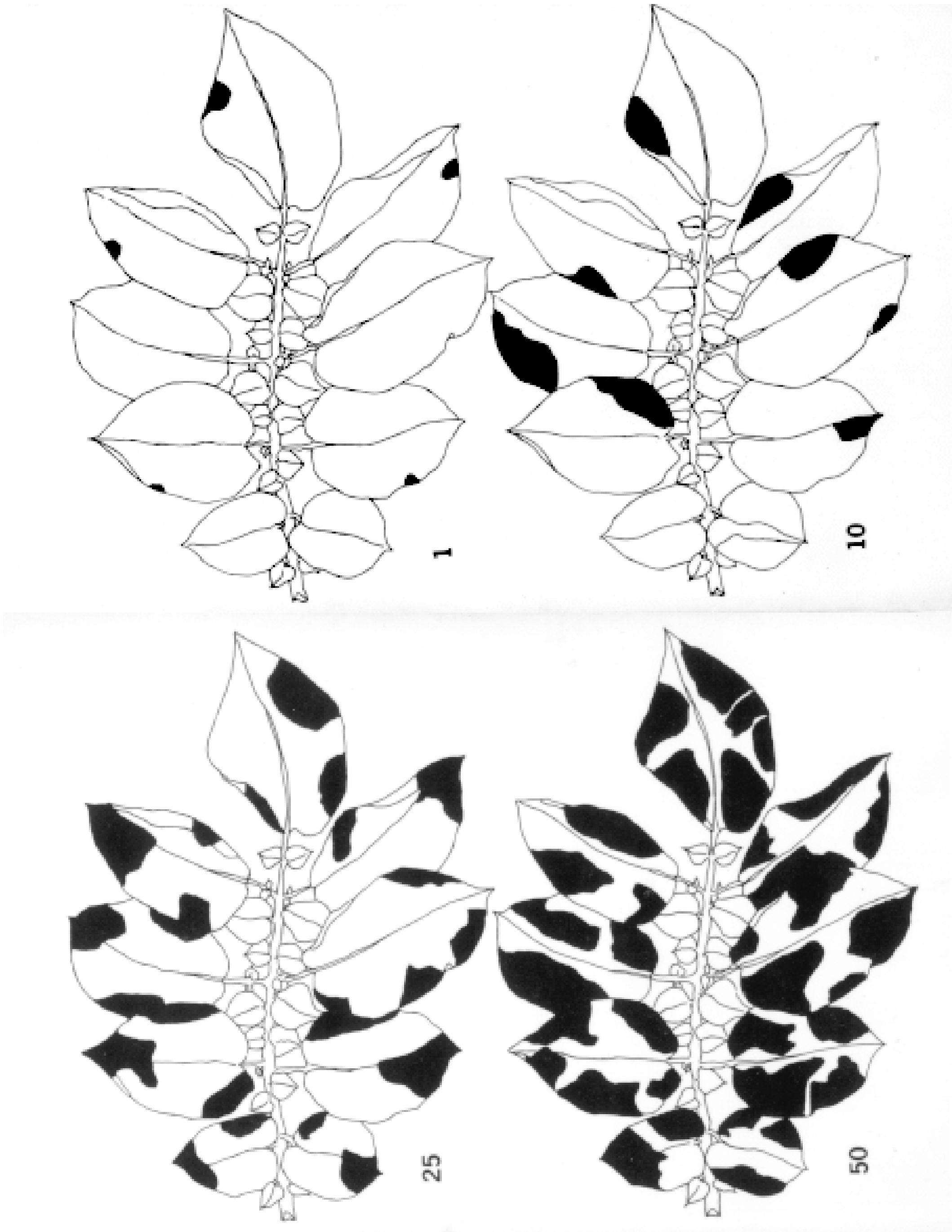


***Figure 2**. Assessment of percentage of leaf area affected by late blight within the foci, it scaled as 1, 10, 25 and 50% (James, 1947* [10]*).*

outbreak of late blight. An important part of the climatological model for the development of *Phytophthora infestans* is the continuation of high humidity into each morning after sunrise. Such a continuation would normally be most favoured by the presence of complete fog or cloud cover. Then it is reasonable to expect that, in the potato crops themselves, leaf surfaces would have been wet for at least a few hours during most nights in this period [2]. Similar results were obtained by Ullrich [17]


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***Table 1**. Assessment key* for the last stages of late blight epidemic when infection is widespread.*

| Blight (%) | Nature of infection |
|---|---|
| 0 | No disease observed. |
| 0.1 | A few scattered plants blighted; not more than 1 or 2 spots in 12-yard radius. |
| 1 | Up to 10 spots per plant; or general light infection. |
| 5 | About 50 spots per plant; up 1 to 10 leaflets infected. |
| 25 | Nearly every leaflet infected, but plants may smell of blight; field looks green although every plant is affected. |
| 50 | Every plant affected and about 50% of leaf area destroyed; field appears green, flecked with brown. |
| 75 | About 75% of leaf area destroyed; field appears neither predominantly brown nor green. |
| 95 | Only a few leaves on plants, but stems are green. |
| 100 | All leaves dead, stems are dead or dying. |

* Disease assessment keys, which described by James (1947) [10] in British Mycological Society Manual.

found from the laboratory investigations that 50% infection result was obtained in 4.5 hours of leaf wetness. In the temperature interval between 10°C and 21°C, obtained about equal degree of infection. However, Hyre [9] considered temperature below 7.2 °C or above 25.5 °C to be unfavourable for blight development.

### *Estimation of disease progress curves*

Late blight epidemic started shortly after the rainy season started and progressed steadily in most of potato-growing areas in Egypt during winter seasons 1999–2001 (*Figs. 8–9*). The progress of late blight in potato fields, the $x$ (disease severity) increased from $0 \leq x_0 \leq 0.1$–1.0% after 70 days during non-epidemic year, while during epidemic year, the $x$ increased from $0 \leq x_0 \leq 40$–45% after 70 days from planting date. Obviously $x_0$ locates the curve at time zero.

***Table 2.** Polynomial models* for analysis of disease progress data for different potato-growing areas during winter seasons 1999–2001.*

| Locality | Growing season | Polynomial model | $R^2$ |
|---|---|---|---|
| Badrashin | 1999 | $y = -0.0021\,x^6 + 0.0648\,x^5 - 0.7391\,x^4 + 3.7252\,x^3 - 7.5435\,x^2 + 4.8013\,x$ | 0.9931 |
| | 2000 | $y = -0.0167\,x^5 + 0.2984\,x^4 - 1.3962\,x^3 + 1.7216\,x^2 + 0.3354\,x$ | 0.9882 |
| | 2001 | $y = -0.0187\,x^5 + 0.4707\,x^4 - 4.5362\,x^3 + 21.649\,x^2 - 38.598\,x + 20.933$ | 0.996 |
| Kom Hamada | 2000 | $y = -0.0004\,x^6 + 0.0011\,x^5 + 0.1015\,x^4 - 0.7938\,x^3 + 2.0318\,x^2 - 1.5881\,x$ | 0.9989 |
| | 2001 | $y = 4E\text{-}05\,x^6 + 0.0002\,x^5 - 0.0246\,x^4 + 0.0761x^3 + 2.4781\,x^2 - 3.847\,x$ | 0.997 |
| Kafr El-Zayat | 1999 | $y = -1E\text{-}05\,x^6 + 0.0005\,x^5 - 0.0096\,x^4 + 0.0804\,x^3 - 0.2268\,x^2 + 0.1732\,x$ | 0.9842 |
| | 2000 | $y = 0.0003\,x^6 - 0.0074\,x^5 + 0.0573\,x^4 - 0.1333\,x^3 + 0.0224\,x^2 + 0.1161$ | 0.9773 |
| | 2001 | $y = -0.0007\,x^6 + 0.0226x^5 - 0.2607\,x^4 + 1.2986\,x^3 - 2.3776\,x^2 + 1.3166\,x$ | 0.9875 |
| Bosaily | 1999 | $y = -0.0001\,x^6 + 0.0037\,x^5 - 0.0404\,x^4 + 0.2169\,x^3 - 0.4949\,x^2 + 0.3514\,x$ | 0.9829 |
| | 2000 | $y = -0.0002\,x^6 + 0.0062\,x^5 - 0.0853\,x^4 + 0.5492\,x^3 - 1.4162\,x^2 + 1.1327\,x$ | 0.9639 |
| | 2001 | $y = -0.0003\,x^6 + 0.0108\,x^5 - 0.1277\,x^4 + 0.6224\,x^3 - 0.8596\,\mathrm{x}^2 + 0.1744\,x$ | 0.9776 |
| Salhia | 2000 | $y = -0.0004\,x^6 + 0.0011\,x^5 + 0.1015\,x^4 - 0.7938\,x^3 + 2.0318\,x^2 - 1.5881\,x$ | 0.9989 |
| | 2001 | $y = 4E\text{-}05\,x^6 + 0.0002\,x^5 - 0.0246\,x^4 + 0.0761\,x^3 + 2.4781\,x^2 - 3.847\,x$ | 0.997 |

*Statistical analysis with polynomial regression using MINITAB statistical program.
$y$: disease severity, $x$: days after planting, $R^2$: coefficient of determination between $x$ and $y$ variables.


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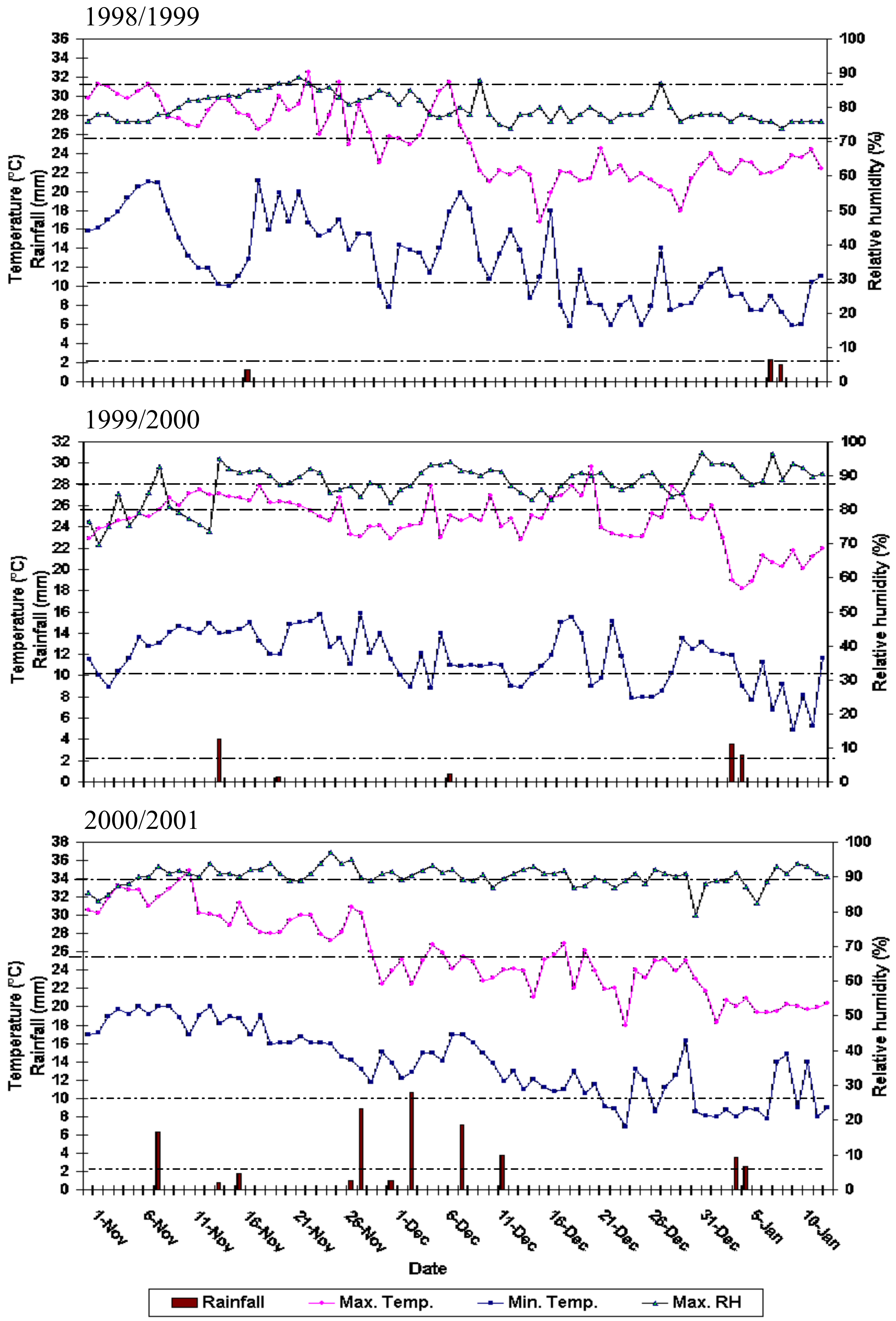


***Figure 3.*** *Daily rainfall (mm), maximum and minimum daily temperature (°C), and maximum daily relative humidity (%) during winter seasons 1999–2001 in Badrashin region.*

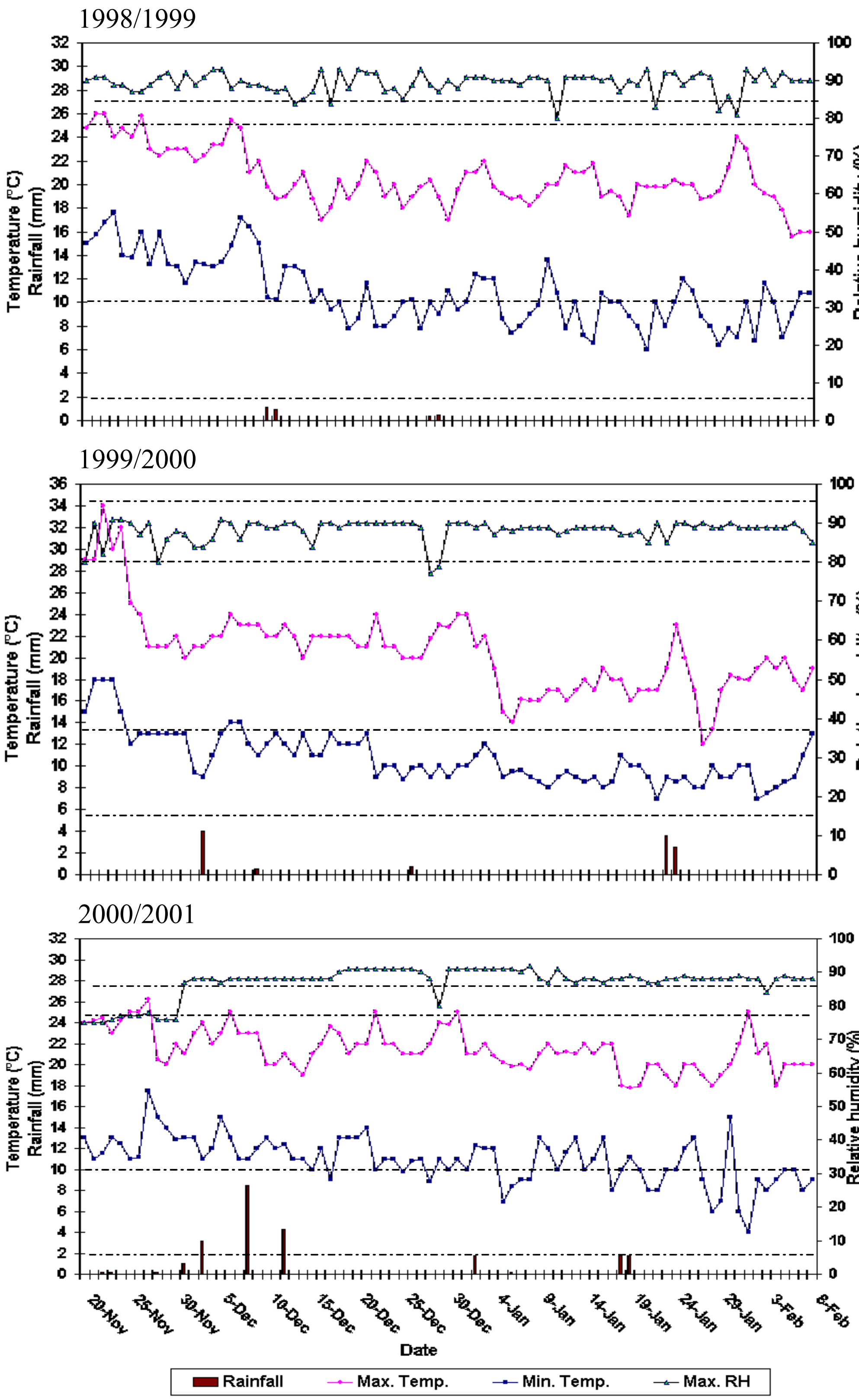


***Figure 4**. Daily rainfall (mm), maximum and minimum daily temperature (°C), and maximum daily relative humidity (%) during winter seasons 1999–2001 in Kafr El-Zayat region.*


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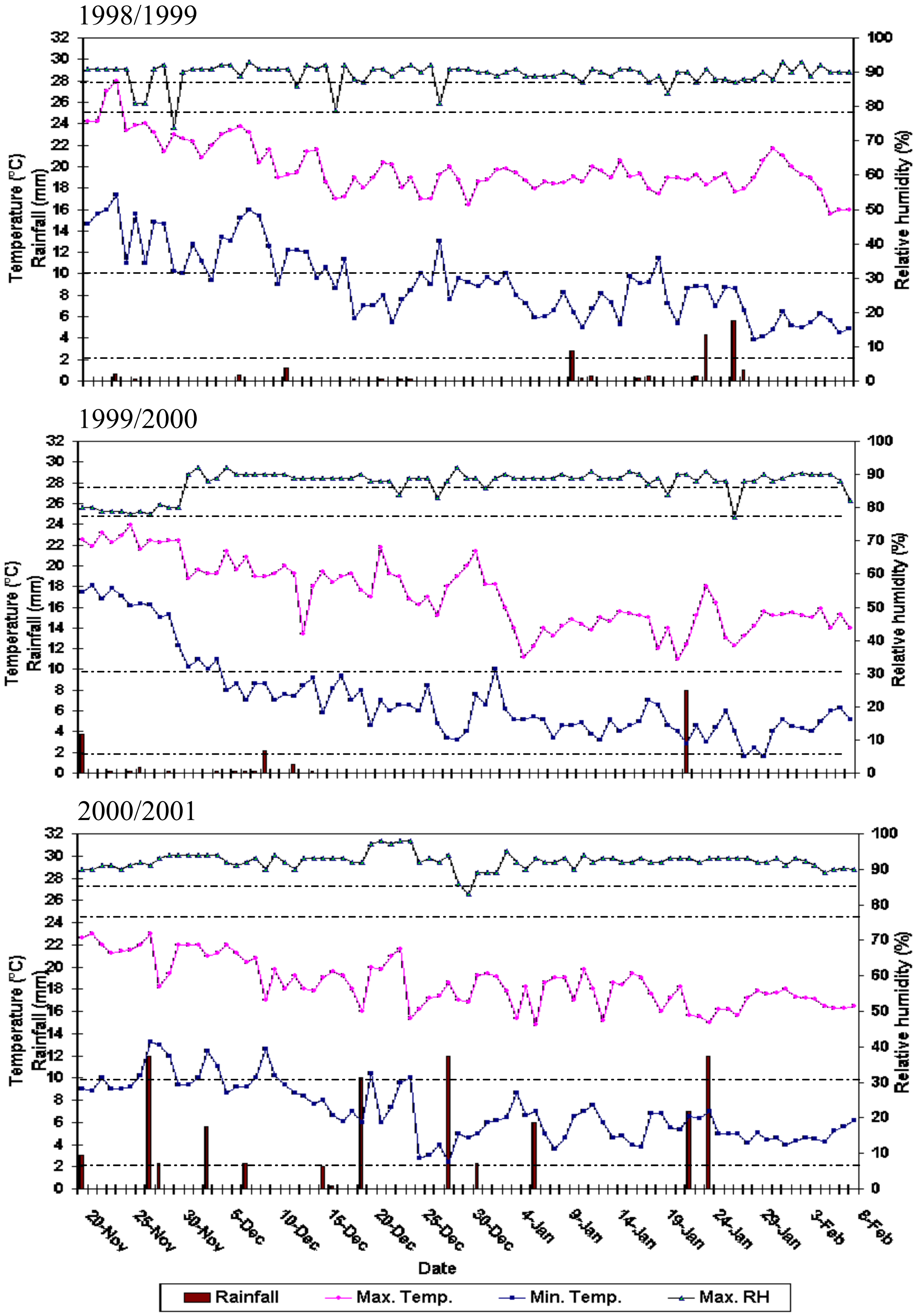


***Figure 5.*** *Daily rainfall (mm), maximum and minimum daily temperature (°C), and maximum daily relative humidity (%) during winter seasons 1999–2001 in Bosaily region.*


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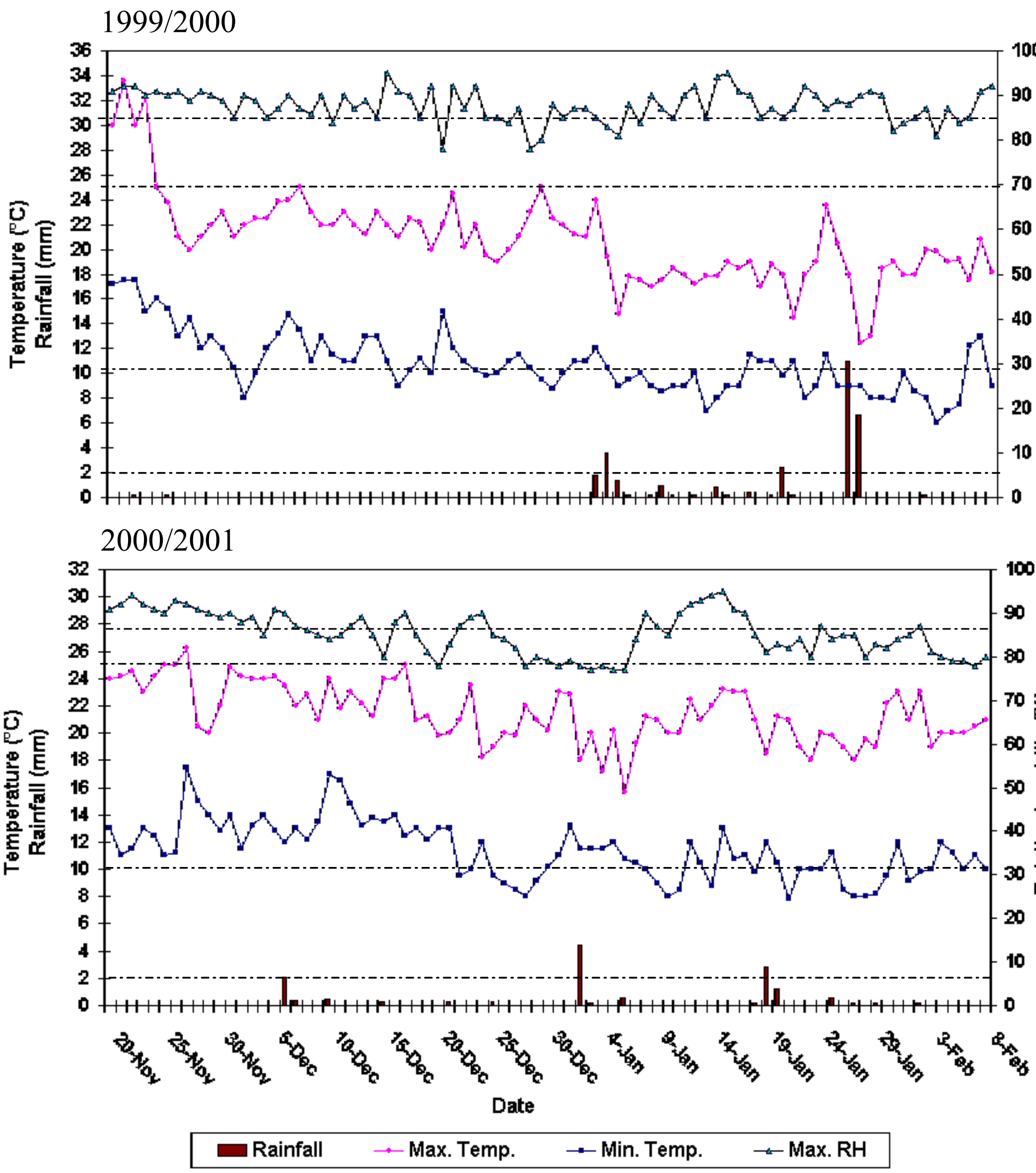


***Figure 6.*** *Daily rainfall (mm), maximum and minimum daily temperature (°C), and maximum daily relative humidity (%) during winter seasons 2000–2001 in Kom Hamada region.*

A plot of potato late blight values vs. time – a disease progress curve – summarizes the effect of host, pathogen, and environment on epidemic development. Thus the same pathogen in the same environment and in the same host species produced both positively and negatively skewed progress curves [11, 18].

***Statistical analysis of disease progress curves***

MINITAB statistical program was used for fitting the best model to describe the relationships between time (days after planting) and observing disease severity. The model based on the observed set of data about the mechanism of disease increase. Polynomial regression models are common forms of this type of model.

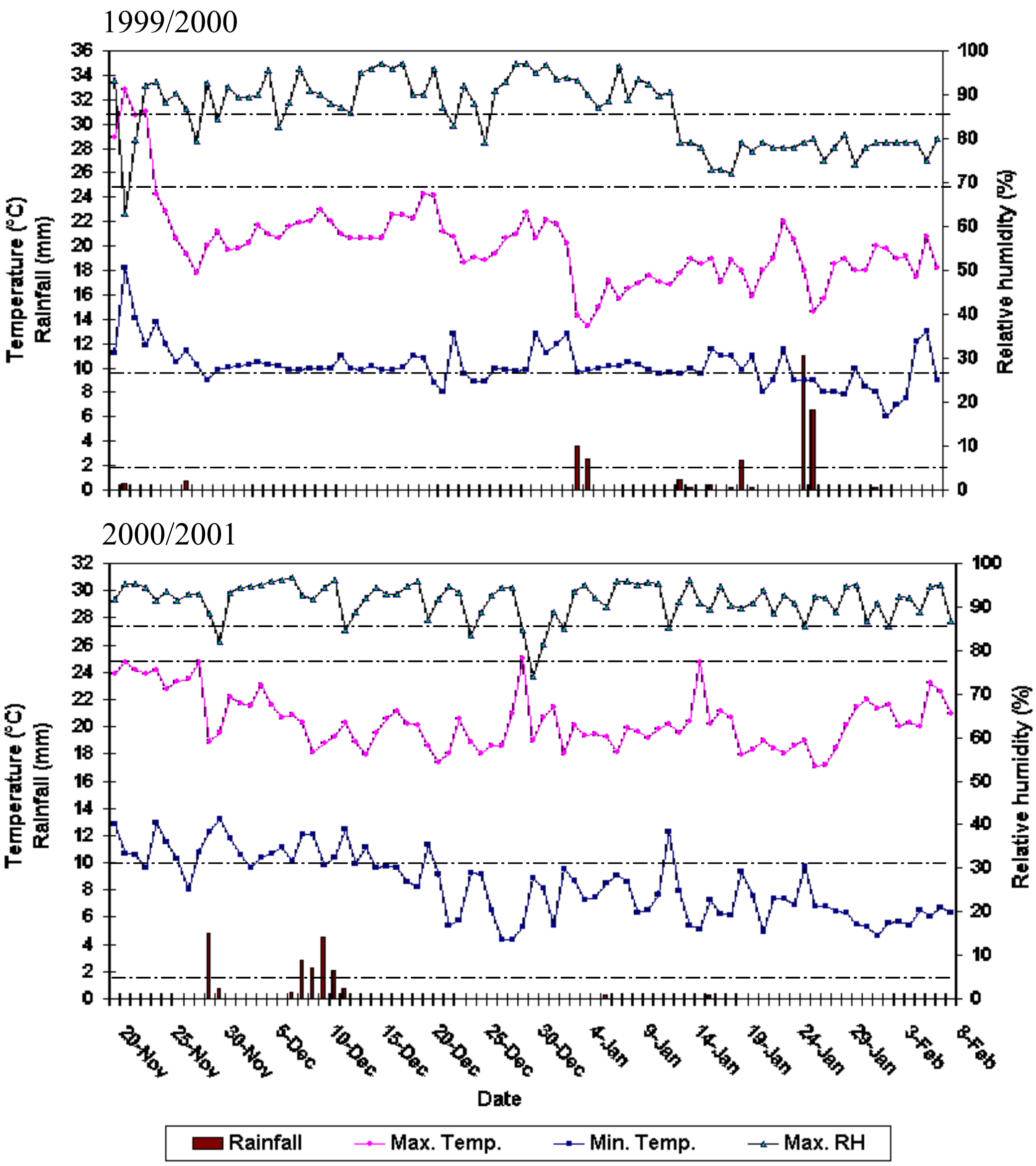


***Figure 7.*** *Daily rainfall (mm), maximum and minimum daily temperature (°C), and maximum daily relative humidity (%) during winter seasons 2000–2001 in Salhia region.*

Statistical modelling of disease progress data for potato late blight represented as $y = f(x)$, where $y$ is disease severity, $x$ is time (days after planting); $f(x)$ is function of time. The function of time has been described as $y = b_0 + b_1 x + b_2 x^2 + \ldots + b_q x^q$, in which the $b$'s are unknown parameters estimated from the data and $x$ is days after potato planting. The equations of disease progress curves for the growing area have been shown in *Table 2*. Models of this type are called polynomials. Although parameters are constants, their estimates are random variables; the estimated parameters characterize epidemics.

The increase in blight in a field of potatoes during epidemic years follows a compound-interest pattern of development [18], resulting in a sigmoid-shape disease progress curve. All models are simplification of reality.

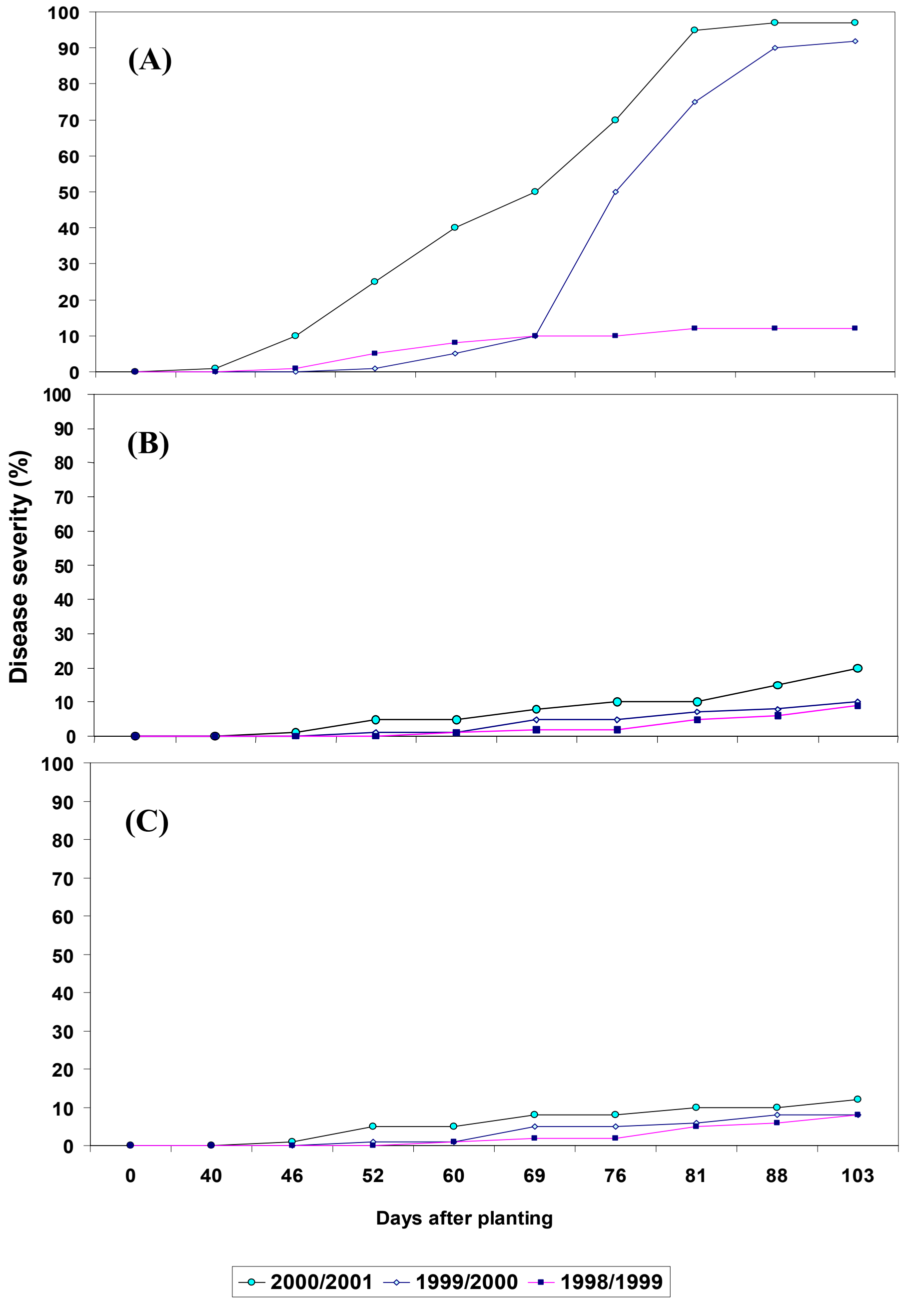


***Figure 8.*** *Late blight progress curves on potato in* (A) *Badrashin,* (B) *Kafr El-Zayat and* (C) *Bosaily growing area during three winter seasons 1999–2001. Visual disease severity assessments weekly.*

## Conclusion

Late blight epidemic started shortly after the rainy season started and progressed steadily in most of potato-growing areas in Egypt during winter seasons 1999–2001.

Blight appeared consistently earlier in South-Delta (Badrashin) than elsewhere, because the potatoes had been planted 25–30 days before planting date of other potato-growing area in winter season.


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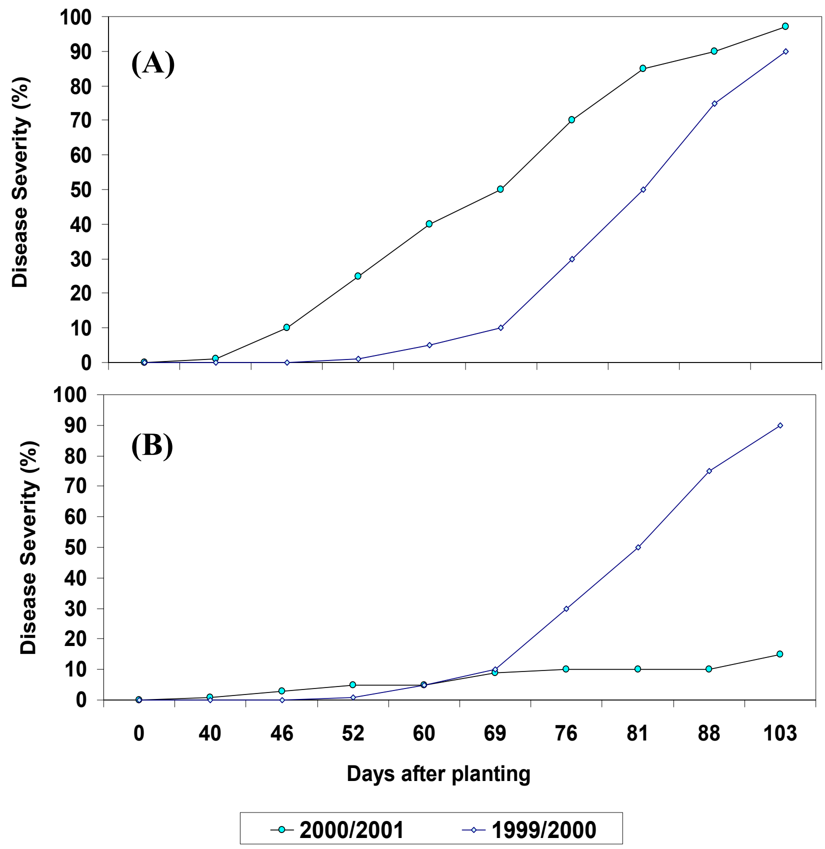


***Figure 9.*** *Late blight progress curves on potato in* (A) *Kom Hamada and* (B) *Salhia growing area during two winter seasons 1999–2001. Visual disease severity assessments weekly.*

From the disease progress curves it can be seen, late blight epidemic started shortly after rainy season and progressed steadily in most of potato-growing areas in Egypt during epidemic winter seasons 2000–2001.

Potato blight forecasting is important to protect the potato yield. If the favourable weather conditions can be forecast and communicated to the growers early with sufficient time for a control sprayed, the crop will be protected.

## REFERENCES

[1] Beaumont, A. (1947): The dependence on the weather of the dates of outbreak of potato blight epidemics. – Trans. Br. Mycol. Soc. 31: 45–53.

[2] De Weille, G.A. (1964): Forecasting crop infection by the potato blight fungus. – Koninklijk Nederlands Meteorologisch Institute, Mededlingen en Verhandelingen No. 82, 144 pp.

[3] El-Bakry, M.M. (1972): Meteorological conditions associated with potato late blight outbreak in the Nile Delta during November 1966. – Meteor. Res. Bull. 4(1): 29–43.

[4] El-Bakry, M.M., Saad, N.H. & Farahat, A.A. (1983): Relation between weather conditions and with potato late blight outbreak in Egypt. – Meteor. Res. Bull. 15: 43–53.

[5] Fry, W.E. & Doster, M.A. (1991): Potato late blight: forecasts and disease suppression. – In: Lucas, J.A., Shattock, R.C., Shaw, D.S. & Cooke, L.R. (eds.): Phytophthora. Cambridge University Press, New York, pp. 326–336.


ISSN 1589 1623

[6] Fry, W.E. & Goodwin, S.B. (1997): Resurgence of the Irish potato famine fungus. – Bioscience 47: 363–371.
[7] Fry, W.E. (1975): Integrated effects of polygenic resistance and a protective fungicide on development of potato late blight. – Phytopathology 65: 908–911.
[8] Harrison, J.G. (1992): The effect of aerial environment on late blight of potato foliage – a review. – Plant Pathology 41: 384–416.
[9] Hyre, R.A. (1954): Progress in forecasting late blight of potato and tomato. – Plant Disease Reporter 38: 245–253.
[10] James, C. (1947): Potato late blight scale. British Mycological Society Manual, 60 pp.
[11] Kranz, J. (1974): Comparison of epidemics. – Annu. Rev. Phytopathology 12: 355–374.
[12] Krause, R.A. & Massie, L.B. (1975): Predictive systems: modern approaches to disease control. – Ann. Rev. Phytopathology 17: 31–47.
[13] Lacey, J. (1965): The infectivity of soils containing Phytophthora infestans. – Ann. Appl. Biol. 56: 363–380.
[14] Minogue, K.P. and Fry, W.E. (1981): Effect of temperature, relative humidity and rehydration rate on germination of dried sporangia of Phytophthora infestans. – Phytopathology 71: 1181–1184.
[15] Raposo, R., Wilks, D.S. & Fry, W.E. (1993): Evaluation of potato late blight forecasts modified to include weather forecasts: a simulation analysis. – Phytopathology 83: 103–108.
[16] Rotem, J., Palti, J. & Lomus, J. (1970): Effects of sprinkler irrigation at various times of the day on development of potato late blight. – Phytopathology 60: 839–843.
[17] Ullrich, J.J. (1957): Die biologie und epidemiologie von Phytophthora infestans (Mont.) de Bary. – Nachrichtenblatt des deutschen Pflanzenschutzdienstes 9: 129–138. [c.f. Meteor. Res. Bull. 4(1): 29–43.]
[18] Van der Plank, J.E. (1963): Plant disease: epidemic and control. Academic Press, New York.
[19] Waggoner, P.E. (1986): Progress curves for foliar diseases: their interpretations and use. – In: Leonard, K.J. & Fry, W.E. (eds.): Plant Disease Epidemiology, Vol. 2. MacMillan, New York, pp. 3–37.
[20] Wallin, J.R. (1962): Summary of recent progress in predicting late blight epidemics in the United States and Canada. – Am. Potato J. 39: 306–312.
[21] Wishart, J. (1938): Growth Rate determination in nutrition studies with the bacon pig and their analysis. – Biometrika 30:16–28.


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