Predicting the occurrence of alate aphids in Brassicaceae

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Abstract – The objective of this work was to predict the occurrence of alates of *Brevicoryne brassicae*, *Lipaphis erysimi*, and *Myzus persicae* (Hemiptera, Aphididae) in Brassicaceae. The alate aphids were collected in yellow water traps from July 1997 to August 2005. Aphid population peaks were predicted using a degree-day model. The meteorological factors, temperature, air relative humidity, rainfall, and sunshine hours, were used to provide precision indexes to evaluate the best predictor for the date of the first capture of alate aphids by the traps. The degree-day model indicated that the peak population of the evaluated aphid species can be predicted using one of the following biofix dates: January 1st, June 1st, and the date of the first capture of the alate aphid species by the yellow water traps. The best predictor of *B. brassicae* occurrence is the number of days with minimum temperature >15°C, and of *L. erysimi* and *M. persicae*, the number of days with rainfall occurrence.

Index terms: *Brassica oleracea*, pest management, population dynamics, thermal requirements.

Previsão da ocorrência de pulgões alados em Brassicaceae

Resumo – O objetivo deste trabalho foi prever a ocorrência de formas aladas de *Brevicoryne brassicae*, *Lipaphis erysimi* e *Myzus persicae* (Hemiptera, Aphididae) em Brassicaceae. Os pulgões foram coletados com armadilhas tipo bandeja amarela com água, no período de julho de 1997 a agosto de 2005. Os picos populacionais dos pulgões foram previstos com uso de modelo de graus-dias. Os fatores meteorológicos temperatura, umidade relativa do ar, precipitação pluvial e insolação foram utilizados para a obtenção de índices de precisão para determinar o melhor previsor da data da primeira captura de pulgões alados pelas armadilhas. O modelo de graus-dias indicou que o pico populacional dessas espécies de pulgões pode ser previsto ao se utilizar uma das seguintes datas biofix: primeiro de janeiro, primeiro de junho e data da primeira captura de alados das espécies de pulgão por armadilha tipo bandeja amarela com água. O melhor previsor da ocorrência de *B. brassicae* é o número de dias com temperatura mínima >15°C, e de *L. erysimi* e *M. persicae*, o número de dias com ocorrência de chuvas.

Termos para indexação: *Brassica oleracea*, manejo de pragas, dinâmica populacional, exigências térmicas.

Introduction

The aphids *Brevicoryne brassicae* (Linnaeus), *Lipaphis erysimi* (Kaltenbach), and *Myzus persicae* (Sulzer) (Hemiptera, Aphididae) are worldwide distributed and can damage several crops, and transmit viruses to plants (Emden & Harrington, 2007). *Brevicoryne brassicae* is associated to plants of the Brassicaceae family (Dixon, 1998). *Lipaphis erysimi* has been observed in several plant species, such as lettuce (Stoltz et al., 1996), potato (DiFonzo et al., 1997), watercress (Blackman & Eastop, 2000), and Brassicaceae (Blande et al., 2004), whereas *M. persicae* is a generalist species infesting more than 400 plant species (Francis et al., 2006). The control of these aphids has often been done using insecticides (Dewar, 2007).

Meteorological factors, especially temperature, are the main environmental variables acting on aphids, associated to the occurrence of population peaks (Dixon, 1998; Tang et al., 1999; Asin & Pons, 2001). Several authors (Chattopadhyay et al., 2005; Zamani et al., 2006; Klueken et al., 2009) have predicted aphid occurrence by meteorological factors.

Degree-day models relate insect development to environmental temperature and do not operate on a calendar-day basis but on physiological time, which considers a degree-day as a unit (Gomez et al., 2009).

Degree-day models have been used to predict the occurrence of insects, such as aphids (Hanula et al., 2002; Chakravarty & Gautam, 2004; Gomez et al., 2009), helping to improve the decisions associated with pest control in integrated pest management programs (Day & Knight, 1995).

According to Chattopadhyay et al. (2005), for an efficient, economical, and ecological control of aphids, it is necessary to determine the right timing of attack in relation to weather factors, which may enable the prediction of insect occurrence and allow growers to take timely action for efficient crop management.

The objective of this work was to predict the occurrence of alates of *B. brassicae*, *L. erysimi*, and *M. persicae* using a degree-day model and meteorological indexes.

Materials and Methods

The experiment was carried out at the College of Agrarian and Veterinary Sciences (FCAV) of the Universidade Estadual Paulista (Unesp), Jaboticabal, SP, Brazil (21°15'22"S, 48°18'58"W). The traps were set up in an area composed of a fodder plant collection and were located at least 200 m from Brassicaceae plants.

The population survey was done at weekly intervals from July 1997 to August 2005. The alate aphids were captured using two yellow water traps, spaced 10 m apart and kept at 120 cm above ground level, according to Gutierrez et al. (1974). The traps were 36 cm in diameter and contained approximately 12 L of water, 5.0 mL of detergent, and 50 mL of formaldehyde. The insects were removed from the traps using a thin mesh screen and transported to the laboratory where the alate aphids were preserved in 80% ethanol for later identification.

At the beginning of the experiment, winged specimens of *B. brassicae*, *L. erysimi*, and *M. persicae* were used to identify, by comparison, the aphid specimens captured during the experiment.

The occurrence of population peaks was predicted using a degree-day model, according to Silveira Neto et al. (1976). This model requires the lower developmental thermal threshold (Tb) of the insect and the maximum and minimum temperatures of the environment to calculate the number of degree-days. The following thermal requirements of the aphid biological cycles (nymph to adult) were considered in the model: *B. brassicae*, Tb = 4.5°C and K (thermal constant) = 176.1 degree-day (Cividanes, 2003); *L. erysimi*, Tb = 3.04°C and K = 132.2 degree-day (Godoy & Cividanes, 2001); and *M. persicae*, Tb = 2.23°C and K = 165.6 degree-day (Cividanes & Souza, 2003). The counting of degree-days by the model was started on the following biofix dates: date of the first capture of the alate aphid species by the yellow water traps, January 1st, and June 1st. This last biofix date was chosen because the cultivation of Brassicaceae plants is concentrated from June to September in the region of Jaboticabal, SP, Brazil.

The prediction of aphid occurrence was evaluated by comparing the dates of population peaks predicted by the model to dates of peaks observed in the field (Cividanes & Santos-Cividanes, 2010). The differences in days (lags) between the dates of the predicted peaks and the ones observed in the field indicate the accuracy of the prediction. Only lags common to the three biofix dates were used to compare predictions. Results were subjected to analysis of variance, and means were compared by the Tukey test, at 5% probability.

Daily meteorological factors collected at the weather station of FCAV/Unesp, located at approximately 500 m from the yellow water traps, were used to investigate the capacity of several meteorological indexes to predict the capture date of the first alate aphid species by the yellow water traps between 1998 and 2005, according to Zhang et al. (1997). The variables used were: day of the year; accumulated degree-days from January 1st of each year using the base threshold temperatures of the aphid species; number of days in which the maximum daily temperature was greater than 20, 25, and 30°C from January 1st to the date of the catch; number of days in which the average daily temperature was greater than 15, 20, and 25°C from January 1st to the date of the catch; number of days in which the minimum daily temperature was greater than 10, 15, and 20°C from January 1st to the date of the catch; number of days in which the air relative humidity was greater than 60, 70, and 80% from January 1st to the date of the catch; number of days in which sunshine hours were greater than 2, 6, and 10 hours from January 1st to the date of the catch; number of days with rainfall from January 1st to the date of the catch; and number of days without rainfall from January 1st to the date of the catch.

For the eight-year evaluation period, the mean and standard error were calculated for each of the variables, and the standard error:mean ratio was used as an index of precision to evaluate the best predictor.

Results and Discussion

The differences in number of days (lags) between the prediction by the degree-day model and the population peak of *B. brassicae*, *L. erysimi*, and *M. persicae* in the field were not significant between the three biofix dates (Table 1). These results indicate that the occurrence of alates can be predicted with equal accuracy using any of the biofix dates to start the counting of degree-days.

Although degree-day models are used to predict the occurrence of aphids and other insect pests (Zou et al., 2004; Hansen, 2006), the time lags observed between the prediction and actual occurrence can range from zero to nine days (Hickel et al., 2003; Jiao et al., 2006). Differences between prediction and occurrence dates of an insect population peak in the field can be related to the difficulty of determining the biofix date, which is considered important to get an accurate prediction by the model (Knight & Light, 2005).

The prediction of the occurrence of an aphid population peak with the degree-day model can be obtained using preferentially June 1st as a biofix date for *B. brassicae*, January 1st for *L. erysimi*, and the date of the first capture of alates by traps for *M. persicae* (Table 1). However, since the lags between the predictions by the degree-day model and the population peaks observed in the field were not significant among the three biofix dates, it is possible to use any of the biofix dates to predict the occurrence of population peaks of *B. brassicae*, *L. erysimi*, and *M. persicae*.

The dates of the first capture of the alate *B. brassicae* by the yellow water traps occurred on May, June, and September, whereas for *L. erysimi* and *M. persicae* the dates were concentrated in the beginning of the year, i.e., January and February. According to Cividanes & Santos-Cividanes (2010), the occurrence of the alate *B. brassicae* was restricted from May to October-November, and no specimens were captured from December to April of the following year. However, the alates *L. erysimi* and *M. persicae* were observed for a longer period than *B. brassicae*, especially *L. erysimi*, which was captured in most of the evaluated months.

The number of days with minimum temperature greater than 15°C was the best predictor of *B. brassicae*, and the standard error:mean ratio was 0.0413 (Table 2). The mean number of days with minimum temperature above 15°C for the first catch over the eight-year period was 138 with a range of 113–159. The next best predictor (standard error: mean ratio = 0.0545) was the number of days with an average temperature greater than 20°C (number of days = 147, range = 120–178).

The best predictor (standard error:mean ratio = 0.0793) for the date of the first capture of the alate *L. erysimi* by yellow traps was the number of days with rainfall (Table 2), and the mean number of days with this environmental feature was 43 (range = 26–57 days). The second best predictor (standard error:mean ratio = 0.1094) was the number of days with air relative humidity greater than 80% (number of days = 39, range = 20–51). The prediction of *L. erysimi* related to environmental humidity is in agreement with Chattopadhyay et al. (2005), who linked the appearance of *L. erysimi* in Brassicaceae with the occurrence of air relative humidity above 75%.

Table 1. Mean±standard error of the difference between the dates of the prediction and occurrence of population peaks in the field by the degree-day model using three biofix dates for aphid species[(1)].

Species	Biofix dates			Mean
	1st capture of alates in traps	January 1st	June 1st	
Brevicoryne brassicae	3.03±0.28a	2.79±0.30a	2.21±0.23a	2.68±0.27
	(-5 to +5)[(2)]	(-5 to +5)	(-4 to + 4)	(-5 to + 5)
Lipaphis erysimi	1.61±0.16a	1.41±0.14a	1.76±0.17a	1.59±0.16
	(-4 to + 4)	(-4 to + 4)	(-4 to + 3)	(-4 to + 4)
Myzus persicae	2.05±0.20a	2.39±0.20a	2.25±0.22a	2.23±0.21
	(-4 to + 5)	(-5 to + 4)	(-5 to + 5)	(-5 to + 5)

[(1)]Means followed by equal letters, in the rows, do not differ by the Tukey test, at 5% probability. [(2)]Range, in days, between the dates of the prediction and occurrence of population peaks in the field. The signs (-) or (+) indicate, respectively, the date before or after a population peak occurrence.

In relation to the alate *M. persicae*, the best predictor (standard error:mean ratio = 0.0372) of the date of the first capture was the number of days with rainfall (number of days = 56, range = 42–60) (Table 2). The next best predictor (standard error:mean ratio = 0.0373) was the number of days with air relative humidity greater than 70% (number of days = 103, range = 85–113).

Considering the best predictors of alate aphids, predictors related to temperature prevailed for *B. brassicae* and to humidity for *L. erysimi* and *M. persicae*. These species also showed the same predictor, i.e., number of days with rainfall. This result is in accordance with Cividanes & Santos-Cividanes (2010), which reported that *L. erysimi* and *M. persicae* showed similar flight dynamics, differing from *B. brassicae*. These authors also found that *B. brassicae* showed a significant correlation with maximum and minimum temperatures, sunshine hours, and air relative humidity, whereas *L. erysimi* and *M. persicae* were only affected by sunshine and relative humidity.

The use of traps can enable the prediction of the appearance of alate aphids in Brassicaceae depending on weather conditions (Debaraj & Singh, 1996). The present study predicted the first capture of alates of *B. brassicae*, *L. erysimi*, and *M. persicae* with yellow water traps, which indicated that the early occurrence of alates can be predicted by the number of days with minimum temperature above 15°C (*B. brassicae*) and the number of days with rainfall (*L. erysimi* and *M. persicae*). These predictors are useful for the management of these aphid species, because they can indicate the best starting time for aphid sampling or even for control applications in Brassicaceae.

It should be emphasized that the degree-day model and the indicators selected in the present study should also be validated for use on other crops, besides Brassicaceae, and in different regions, other than Jaboticabal. This procedure is necessary since the variation between regions related to the occurrence of aphid biotypes and the specific conditions in the crop that favor the insect pest can alter meteorological factors for aphid prediction (Chattopadhyay et al., 2005).

Table 2. Indexes from standard error:mean ratio of variables calculated annually from January 1st until the date of the first capture of the alate aphid species by yellow traps.

Variable(1)	*Brevicoryne brassicae*	*Lipaphis erysimi*	*Myzus persicae*
N	0.0982	0.1285	0.0490
DD	0.0868	0.1238	0.0424
P	0.0608	0.0793	0.0372
A	0.1212	0.1948	0.0746
Tmax (°C)			
>20	0.0983	0.1495	0.0540
>25	0.0799	0.1510	0.0471
>30	0.0593	0.1731	0.0560
Tmed (°C)			
>15	0.0951	0.1495	0.0539
>20	0.0545	0.1376	0.0410
>25	0.1132	0.1739	0.1175
Tmin (°C)			
>10	0.0914	0.1469	0.0527
>15	0.0413	0.1334	0.0380
>20	0.0692	0.1283	0.1097
RH (%)			
>60	0.0843	0.1441	0.0494
>70	0.0847	0.1202	0.0373
>80	0.0772	0.1094	0.0534
Sunshine			
>2 hours	0.1037	0.1716	0.0531
>6 hours	0.1030	0.2137	0.0681
>10 hours	0.1394	0.2096	0.1232

(1)N, number of days of the year; DD, accumulated degree-days; P and A, number of days with and without rainfall, respectively. Tmax, Tmed, Tmin, maximum, average, and minimum temperatures; RH, air relative humidity; Sunshine, sunshine hours.

Conclusions

1. The prediction of the occurrence of alates of *Brevicoryne brassicae*, *Lipaphis erysimi*, and *Myzus persicae* can be obtained using a degree-day model and the following biofix dates: January 1st, June 1st, and the date of the first capture of the alates by the yellow water traps.
2. Considering the meteorological indexes, the best predictor of the alate *B. brassicae* is the number of days with minimum temperature >15°C, and of *L. erysimi* and *M. persicae*, the number of days with rainfall occurrence.

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