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# Changing of Flight Phenology and Ecotype Expansion of the European Corn Borer (*Ostrinia nubilalis* Hbn.) in Hungary

## Part 1. Biomathematical evaluation

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The studies aimed to acquire the widest possible information on the annual flight in Hungary of the European corn borer (ECB), *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae). The investigations used biomathematical (Part 1) and graphical (Part 2) evaluation to document changes in the individual population number.

The study was conducted in Hungary using ECB moth capture records from the Plant Protection Information System black light trap system (1991–2004). We have drawn conclusions on the appearance of annual flights and the tendency of alterations in flight direction by means of light trap results in four different areas in Hungary. We calculated the flight peak quotients, the individual population numbers of the second flight peak, the distinctions of individual numbers of two flight peaks in this part.

As previously published, alterations in flight direction of ECB flights began at different times in Hungary. In the current study, a gradual disappearance of the univoltine ecotype and gradual appearance of the bivoltine ecotype ECB in Hungary is confirmed by the data obtained between 1991–2004. Flight peak quotients and data concerning the second flight peak have confirmed change this process, too: the appearance of a second flight peak in Northwestern Hungary from 1995–1996 (FP = 1.27), the more significant appearance of flights in August in Western Hungary (FP = 1.05) and Northeastern Hungary (FP = 1.45), and a three and four times more individual number of the second flight peak in Southeastern Hungary (FP = 3.44). Flight peak quotients, individual population numbers of the second flight peak, the tendency towards a difference in population number of the two peaks, and size of increase of these values demonstrates the southeastern-northwestern presence of the bivoltine ecotype in Hungary.

**Keywords:** European corn borer, flight

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## Introduction

*Entomological indicators of climate change*

We are currently undergoing a worldwide change of climate, which in the last century resulted in a considerable rise in average temperature in Eastern Europe. The causes of global warming have not yet been adequately established: it might be due to the cyclic nature of the climate history of the Earth, or it may be of anthropogenic origin (Gordon and Davies 1975; Thompson 1975; Jolánkai 2005). Global climate change has a great effect on the elements of the biosphere (Schwartz 1992; Woodward and Lomas 2004), of which one is the distribution and propagation of insect pests (Fuhrer 2003; Strand 2000; Yamamura and Kiritani 1998). The first relevant Hungarian analysis was published by Kozár and Nagy Dávid (1985).

From a comparison of agro-ecosystem models, Gourdiaan and Zadoks (1993) drew the conclusion that climate change has a great influence on insect pests and their host plants.

The first climatological studies concerning the distribution of the ECB are linked to the work of Porter et al. (1991) and Stollár et al. (1993) who found the northern limit of the distribution of the species to shift northward by more than 100 km with a 1 ºC rise in the average temperature. A significant increase of 1.1 ºC in the average winter temperature can be seen to have occurred over the last 110 years in Hungary (Stollár et al. 1993; Jolánkai 2005). The rise of average temperature was especially high in the last decades (Fig. 1).

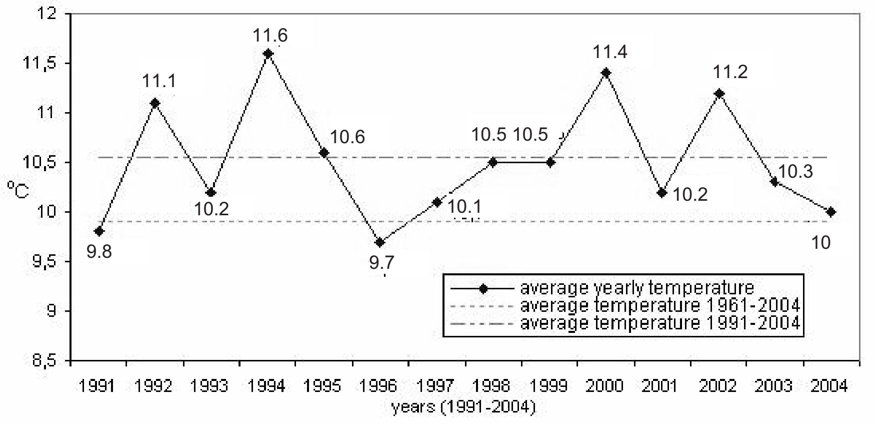

*Figure 1*. Average yearly temperature in Hungary in 1991–2004
[by Hungarian Meteorological Service (HMS); www.met.hu]

Besides global warming, the meteorological extremities also have a great influence on the spread of insects (Kozár 1995). In recent decades, periods that were cooler and warmer than average alternated in the summers (Stollár et al. 1993; Kozár 1997), which has largely contributed to the more frequent regional fluctuation of insect species (Székács et al. 2005).

## Materials and Methods

We examined changes in the temporal patterns of ECB moth flights by processing the data from the Hungarian light trap system [Plant Protection Information System (NIR) of the Hungarian Central Plant Protection and Soil Conservation Service].

The examination was carried out between 1991 and 2004. The choice of the period was justified by two factors. (1) Since the 1990s an ever growing number of publications have been dealing with the effects of global climate change on Hungary (Székács et al. 2005), which reflects the importance of this phenomenon, and (2) it is for that time interval that a more or less uniform series of ECB trap data were available from various parts of the country. Unfortunately, the data were available only from 1995 in District 1, because of the light traps were out of order in Northwestern Hungary between 1991–1994.

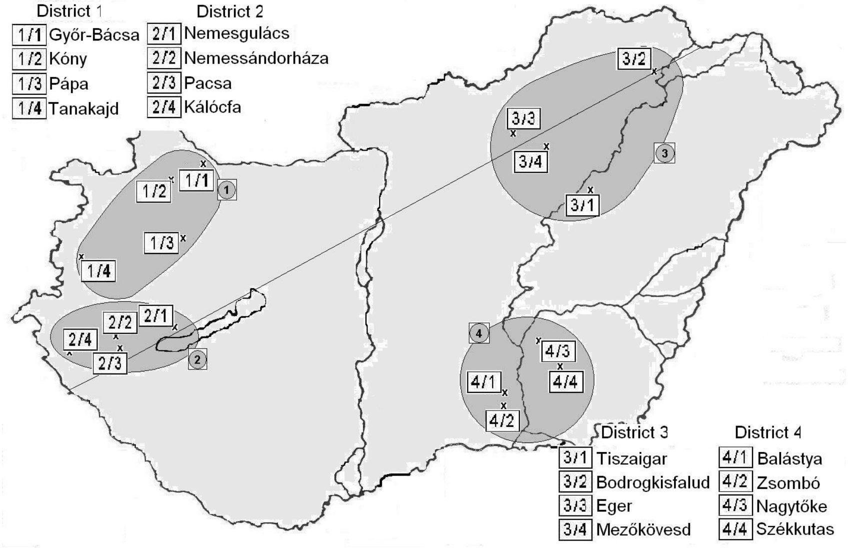

*Figure 2*. Location of light traps of four districts in Hungary. Explanation: The stripe is the borderline between uni- and bivoltine ecotype of ECB by Mészáros (1969)

We have processed ECB light trap catches originating from 4 sites in each of four different districts of Hungary. Moths were recovered from trap daily, and the representation of catches happened on traps every fifth day. The different districts determined by us and the location of light traps can be seen in Figure 2.

Climatic features of the four districts examined (Péczely 1979) and their annual generation numbers of ECB (Mészáros 1969) are the following:

District 1: Northwestern Hungary. The climate "moderately warm, moderately dry" in the northern part, and "moderately warm, moderately humid" in the southern part of the district. The precipitation is higher than the national average, and half of it falls during the growing season in the northern part. The mean water shortage in summer is 10–30 mm in northern part of district (climatic features of the southern part of district can be seen in District 2). The distribution of ECB univoltine ecotype shown is based on earlier data.

District 2: Western Hungary. A "moderately warm, moderately dry" climate prevails in this district. Precipitation is higher than the national average, and 60% of it falls during the growing season. Despite of this, the mean water shortage is still 15–20 mm in the summer period. The 3200 ºC isotherm dividing the uni- and bivoltine ecotypes is based on earlier data.

District 3: Northern and Northeastern Hungary. Both "moderately warm, dry" and "moderately cool, moderately dry" climatic conditions can be found in this district. Level of precipitation varies throughout this district. It is higher than the national average in the northern part of the district; while in the south it is lower than average. There is significant mean water shortage in summer of about 30–50 mm between May and September. The isotherm of 3200 ºC dividing the uni- and bivoltine ecotypes is in this case, too, based on earlier data.

District 4: Southeastern Hungary. "Warm, dry" climate area, where precipitation is close to the national average and more than half of it falls during the growing season. The mean water shortage is 30–40 mm. This district falls within the distribution area of area of the bivoltine ecotype of ECB.

We drew up diagrams of flight phenology. Based on the generation quotient (Mészáros 1969) [G=B/A; where G = generation quotient, B = individual number of the second generation, A = individual number of the first generation], from the light trap data we were able to calculate the flight peak quotient [FP=B/A; where FP = flight peak quotient, B = individual population number (cumulative moth catch during the period) of the second flight peak, A = individual population number of the first flight peak], and the propagation quotient (E=U/M; where U = individual population number of the year in question, M = individual population number of the preceeding year), and this allowed us to draw conclusions about flight phenology for each of the above districts above. Establishment of the border between first and second peak of flights shown below in results.

We tabulated the flight peak quotients for each year, the individual population numbers of the second flight peaks, and the distinctions of individual numbers of two flight peaks (DFP) (DFP = B–A; where: B = individual population number of the second flight peak, A = individual population number of the first flight peak) in a coordinate system. By means of the linear trends shown we were able to establish the directional tendency from year to year. Annual changes in the aforementioned values were statistically analysed by one-way analysis of variance (ANOVA) by means of SPSS 10.0 software.

## Results

In the past 15 years the two peak type of flight appeared in four different areas of Hungary (Table 1). In Northwestern Hungary (District 1), the light traps began to register the appearance of the late summer flight peak of ECB in 1995–1996. A comparison of the peaks indicates that – with the exception of four years (1995, 1998, 2002, and 2004) – the August peak was lower than the first peak with regard to the individual population number.

*Table 1.* Average flight peak quotients of four districts between 1991–2004

| | Average flight peak quotients (FP) | | | | | | |
|---|---|---|---|---|---|---|---|
| Years | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
| District 1 | – | – | – | – | 3.1 | 0.06 | 0.09 |
| District 2 | 1.24 | 0.35 | 0.32 | 0.65 | 0.19 | 4.4 | 0.12 |
| District 3 | 0.96 | 0.26 | 0.14 | 1.80 | 0.85 | 1.99 | 0.25 |
| District 4 | 1.84 | 1.25 | 1.02 | 2.43 | 5.54 | 1.2 | 1.52 |

| | Average flight peak quotients (FP) | | | | | | |
|---|---|---|---|---|---|---|---|
| Years | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
| District 1 | 2.31 | 0.51 | 0.3 | 0.86 | 2.74 | 0.93 | 1.85 |
| District 2 | 1.75 | 0.43 | 1.82 | 0.76 | 0.77 | 0.72 | 1.15 |
| District 3 | 1.02 | 1.88 | 0.29 | 0.84 | 6.06 | 2.2 | 1.74 |
| District 4 | 1.67 | 2.18 | 5.78 | 8.36 | 4.94 | 4.49 | 6.02 |

| Average flight peaks quotients (FP) of districts (n = 14) | | | |
|---|---|---|---|
| District 1 | District 2 | District 3 | District 4 |
| 1.27 | 1.05 | 1.45 | 3.44 |

Explanation: – = one peak of ECB flight in given year

In the case of light traps to the west of Lake Balaton (District 2), the change in flight phenology occurred earlier, before 1991. The western and northwestern expansion of the two-peak flight is demonstrated by the light trap data from Kálócfa, where the August peaks appeared later, only after 1995. The one peak (1991, 1992, 1993) and the two peaks (2003, 2004) flight phenology in Kálócfa can be seen in Figure 3. The emergence of the peaks was the most explicit in these years. Apart from that, 65% of the flight traps of District 2 showed a more significant appearance of the early summer flight.

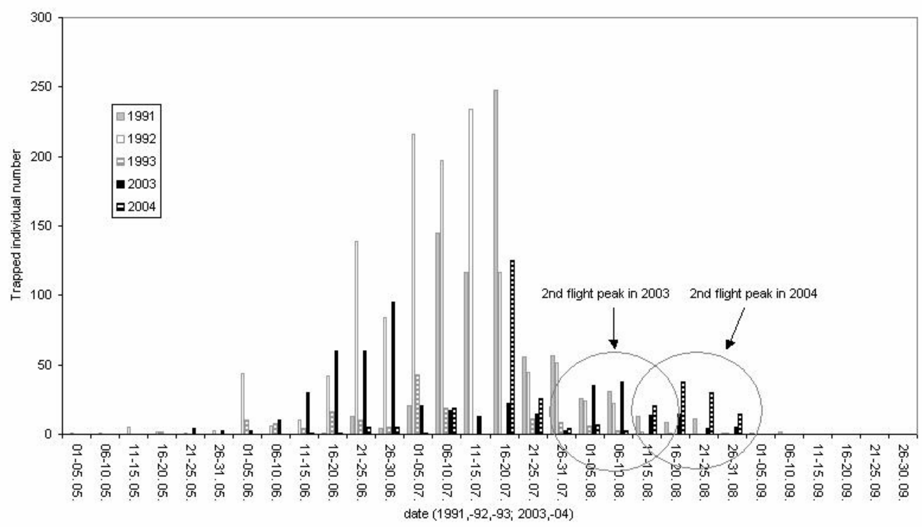

*Figure 3*. Flight of ECB in Kálócfa in 1991, 1992, 1993 and 2003, 2004

In Northwestern Hungary (District 3), since the turn of the millennium, the second flight peak has become definitive. This phenomenon was particularly remarkable in Mezőkövesd in 2002 (FP = 11.56) and Bodrogkisfalud (FP = 7.68). The pattern of flight observed for the last 4 years has shown increasing similarity to the data from Southeastern Hungary.

The quotients of the average flight peak in District 4 show values above 1 only. A higher measure of increase in the individual population number of the second peak has been especially remarkable since 2000.

Table 2 contains the values for the univoltine populations in comparison to the previous year. It can be seen that in the Northwestern areas of Hungary the two-peak flight appeared later. In the light traps of District 2 in the early 1990s, the univoltine (one-peak flight) ecotype was recorded only in the case of Kálócfa. From the values of the propagation quotients we cannot, however, establish facts concerning the multiplication and ecotype change of the ECB.

*Table 2.* The propagation quotients of places of occurrence and years of univoltine ecotype between 1992–2002

| District 1 | Propagation quotients (E) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
| Győr-Bácsa | 7.33 | 0.59 | 5.11 | 1.15 | 1.5 | 1.59 | 0.55 | 0.84 | 0.93 | 0.5 | ** |
| Kóny | * | * | * | 1.31 | 0.36 | 1.34 | 0.53 | 3.54 | 0.42 | 0.33 | ** |
| Tanakajd | 5.5 | 0.5 | 0.45 | 1.72 | 0.08 | 2.8 | 0.78 | 2.54 | 0.61 | 1.9 | ** |
| Kálócfa | 1.63 | 0.11 | 0.8 | ** | ** | ** | ** | ** | ** | ** | ** |

Explanation: * = Trapped result of ECB was not available; ** = Flight of ECB has appeared already in two peaks

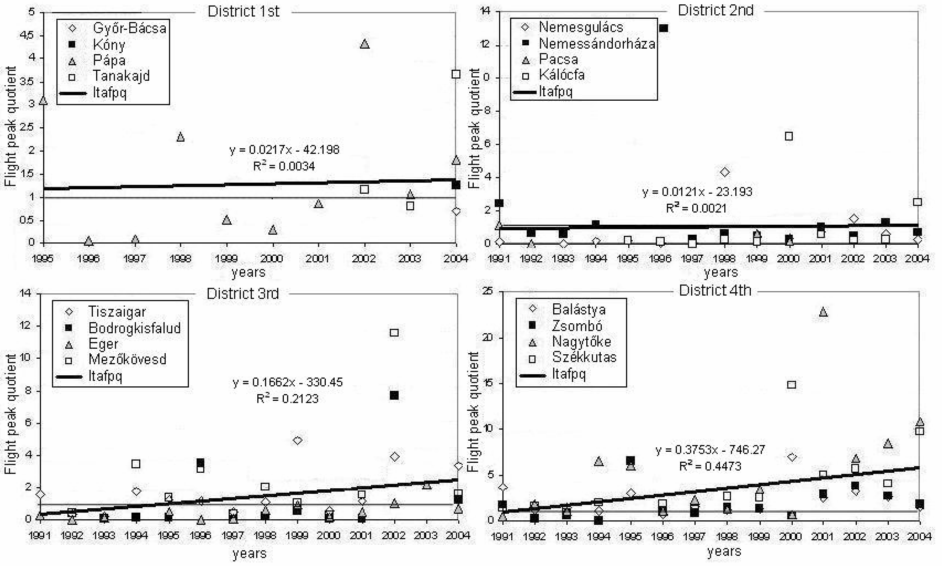

*Figure 4*. Flight peak quotients of four examined districts between 1991–2004
Explanation: ltafpq = linear trendline of average flight peak quotients; the horizontal line through 1 represents the equality of two peaks' individual number

Figure 4 shows the annual flight peak quotients for the four districts in question. The linear trends indicate the changes in the ratio of the two peaks during the course of successive years. In the areas of southeastern (District 4) and northern Hungary (District 3), a gradual strengthening of the August swarm as compared to the early summer one is remarkable.

From the average individual population number of the second flight peak (Fig. 5) and from the linear trends of changes in individual population number be-

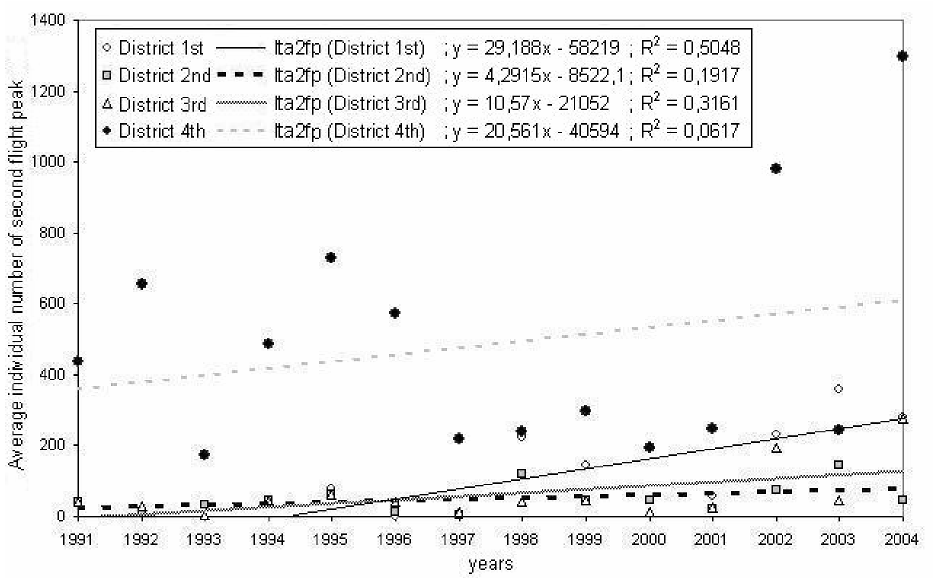

*Figure 5*. Average trapped individual numbers of second flight peaks in four examined districts between 1991–2004. Explanation: lta2fp = linear trendline of average individual number of $2^{nd}$ flight peak

tween the two flight peaks (Fig. 6), also the above conclusion can be drawn. In the values of the second flight peak, an increasing tendency can be observed irrespective of the districts (Fig. 5). The year-by-year increase in the number of trapped adults is particularly conspicuous in Southeastern and Northwestern Hungary.

As to the change in individual population number between the two flight peaks (Fig. 6), some increase can be observed though it is a less clear correlation. The light traps of Zala county and Nemesgulács show a moderate increase in the difference between the individual population numbers of the two peaks (most of the data falls below the abscissa).

The three executed variance analysis confirmed a statistically significant correlation ($P < 0.0001$) between procession of the years and the flight characteristics (flight peak quotients of years, individual number of the second flight peak, trapped individual numbers of the two flight peaks).

## Discussion

As unequivocally seen from the flight diagrams, in the last years the two-peak flight pattern of the ECB became general in Hungary. Owing to different influencing factors, the rate of flight and ecotype change may vary with the area.

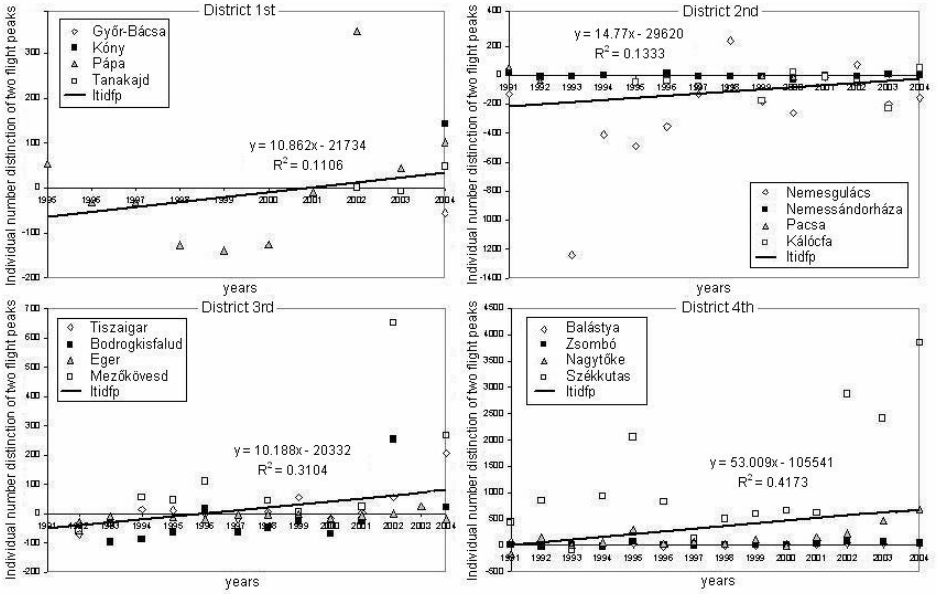

*Figure 6*. Individual number distinctions of two flight peaks of four examined districts between 1991–2004. Explanation: ltidfp = linear trendline of individual number distinction of two flight peaks

In Northwestern Hungary the sudden appearance and strengthening of the second flight peak observed in the last years can be traced back to a rise in the average annual temperature. In spite of this, the cooler and more rainy climate of this district allowed for a "prolonged conservation" of the univoltine ecotype.

The 3–4-fold dominance of a definite second peak in some places of Northeastern Hungary indicates the presence of the bivoltine ecotype.

The high flight peak quotients obtained for Southeastern Hungary indicates that in this area the ecological conditions necessary for the presence of the bivoltine ecotype, aroused in the preceding decades (Keszthelyi 2004a), had developed even earlier.

From the experiences of preliminary studies (Szeőke et al. 1996; Vörös 2002; Keszthelyi 2004b) we have drawn the conclusion that the change of flight is followed in time by a change of ecotype of the ECB. Therefore, the univoltine ecotype will be gradually displaced from Hungary and replaced by the bivoltine ecotype. This biological trend may cause increasing damage done by the ECB in maize growing areas, as a result of the appearance of a generation developing in summer without diapause.

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