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EGG LAYING AND CATERPILLAR HATCHING DYNAMICS OF *OSTRINIA NUBILALIS* HBN. ON MAIZE (*ZEA MAYS* L.) IN SOUTH-EASTERN POLAND

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Abstract: During the study years, the European corn borer (ECB) (*Ostrinia nubilalis* Hbn.) females began depositing eggs on maize plants between the last ten days of June and the first ten days of July. A maximum number of eggs on plants was found at the beginning of the second ten days of July and at the beginning of the third ten days of July. The last egg clusters were recorded in August. During the five years of the study period, the female oviposition period lasted from 4.5 to 8 weeks. The shortest oviposition period took place during the warm and dry years, while the longest period was during the rainy and relatively cold years. During the study years, within the entire flight period, *O. nubilalis* females deposited from 1,564 to 3,393 eggs on 200 observed plants. The average number of eggs per cluster in the study years was from 10.0 to 15.2. The beginning of caterpillar hatching, based on the observation of empty egg clusters, was recorded in the last ten days of June or in the first and second ten days of July. Mass hatching of the caterpillars was observed in the second and third ten days of July, and only in 2004 was it in the first ten days of August. The last empty egg clusters were recorded in the second and in the third ten days of August.

Key words: *Ostrinia nubilalis* Hbn, ECB, maize, dynamics, egg laying, caterpillar hatching

INTRODUCTION

The European corn borer (ECB) (*Ostrinia nubilalis* Hbn.) has been found on maize (*Zea mays* L.) in Poland since the 1950s. (Kania 1961; 1962a, b). Currently it is one of the most significant maize pests in many regions in Poland (Lisowicz 2001; 2003a, b; Wałkowski and Bubniewicz 2004; Żołnierz and Hurej 2005; Haliniarz and Bojarczyk 2007; Bereś and Konefał 2010). In regions where maize is intensely cultivated, caterpillars of this moth damage from 50 to 80%, and sometimes up to 100% of plants, causing up to a 40% loss in maize grain yield (Lisowicz and Tekiela 2004).

Caterpillars must be controlled because of the great harm they cause. Control of this pest is based on non-chemical and chemical methods, as well as the cultivation of the Genetically Modified Organisms (GMO) maize (Bereś and Pruszyński 2008). However, any control activities should be based on detailed investigation of selected elements of ECB biology which will allow for defining the optimal time for plant protection intervention. The timing for introducing control methods which intervene against *O. nubilalis* is crucial. Such methods include biological preparations and chemical insecticides and plant spraying. The objective of the conducted study was to investigate the dynamics of egg laying by ECB females, and caterpillar hatching, to indicate optimal times for the control of eggs and caterpillars of this species.

MATERIALS AND METHODS

The studies were conducted during the time period of 2004–2008 in the Plant Cultivation Station in Krzeczowice (49°59′ N; 22°27′ E) near Przeworsk (south-eastern Poland). Observations on the dynamics of oviposition by *O. nubilalis* and the dynamics of caterpillar hatching were conducted on the San maize variety (FAO 240) on a 5–7 ha field.

To investigate the dynamics of oviposition by *O. nubilalis* females, 50 consecutive maize plants in a row were observed in four places of the maize field (in total 200 on the field). Twice a week, observations were carried out on the oviposition by ECB females. Observations were always carried out on the same plants. The following data were recorded:

– number of egg clusters on 200 plants,
– number of eggs in individual clusters.

Observations were carried out in the first ten days of June. At the moment the last egg cluster was found and when there were no new egg clusters of the pest found

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on investigated plants for three weeks, the observations were discontinued. To prevent duplicate counting, each newly found egg cluster was marked with a waterproof marker. A magnifying glass with 4X magnification was used for egg counting in individual clusters.

Studies on the dates of ECB caterpillar hatching were carried out on the same marked plants where observations on the dynamics of egg laying by females were carried out. Observations were carried out on 4x50 consecutive plants in a row. The observations began in the first ten days of June and ended in the first ten days of September. To prevent duplicate counting, each newly found empty egg cluster was marked with a waterproof marker. A cluster was considered empty if caterpillars hatched from 95% or more eggs. Egg clusters which had spontaneously fallen onto the soil, or were infested by *Trichogramma* spp., or destroyed by other natural enemies or weather conditions were not included in the total number of empty egg clusters.

RESULTS

Changes in weather conditions during the study period (from June to September) in 2004–2008 are presented in table 1.

In the studied five-year period, the most favourable conditions for moth flight and oviposition were recorded in 2006–2007. The least favourable conditions resulting from low temperature and intense rainfall were recorded in 2008.

2004

On 5 July 2004, the first egg clusters of the European corn borer on maize plants were found. This was the period when maize was at growth stages BBCH 32–33 (Adamczewski and Matysiak 2002) (Fig. 1). During the next several days, the number of egg clusters increased dynamically. A maximum of 35 clusters per 200 plants was reached on 22 July, when plants were at growth stages BBCH 59–63. Then, a gradual decrease in the number of clusters was observed until 9 August. From 12 to 16 August there was a break in oviposition, but new clusters occurred on 19 and 23 August. Despite a relatively high number of egg clusters in 2004, oviposition was significantly affected by weather conditions. Prolonged intensive rainfall in July disturbed moth flight and oviposition. For this reason, the last two egg clusters were found on plants at the latest time within the analysed five-year period, *i.e.* on 23 August, when maize was at growth stages BBCH 75–83.

Our observations demonstrated a highly diversified number of eggs in individual clusters. Clusters found on the plants ranged from very large; containing 48 eggs to very small; containing 2 eggs (Table 2). The largest difference in the number of eggs in individual clusters was found during their mass occurrence on plants, particularly between 16 and 26 July. In 2004, a total of 161 egg clusters were found on 200 observed plants. In the same year, *O. nubilalis* females deposited a total of 2,558 eggs. The average number of eggs per cluster in the entire studied period was 10.0.

The first empty egg shells demonstrated caterpillar hatching. These shells were found on 12 July, when plants were at stage 51, *i.e.* 7 days after the first egg clusters of ECB were recorded (Fig. 1). Their number gradually increased to reach a maximum of 38 clusters/200 plants on 2 August, when plants were at growth stages BBCH 67–71. After that period the number decreased rapidly. The last empty egg clusters were recorded on 30 August, when plants were at stage BBCH 83. In 2004, a total number of 154 empty egg clusters were found. This total indicates that from among all 161 egg clusters deposited by females, 7 were completely destroyed by natural enemies or by other factors, *e.g.* weather conditions.

2005

In 2005, the first four egg clusters of *O. nubilalis* were recorded on plants on 30 June, when plants were at growth stage BBCH 53 (Fig. 2). Weather conditions in the last ten days of June and in July of this year were favourable for moth flight and oviposition. Therefore, the number of eggs on plants gradually increased to reach a maximum of 37 clusters/200 plants on 21 July, when plants were at growth stages BBCH 59–61. After this period, egg numbers decreased rapidly. The last empty egg cluster was recorded on 8 August, when plants were at stages BBCH 67–71.

Further diversification in the number of eggs in individual clusters was observed in 2005. Between 14 and 21 July very large egg clusters, containing up to 79 eggs, were recorded on plants (Table 2). Much smaller clusters, containing 2 eggs were also found. As in 2004, the largest difference in the number of eggs in clusters was found during periods of mass oviposition. Although in 2005, a lower number of clusters was found than the year before, the total number of eggs deposited by females was significantly higher. In 2005, 139 egg clusters with a total number of 2,798 eggs were recorded on 200 plants. In 2005, one cluster contained, on average, 14.7 eggs.

In 2005, the first empty egg clusters were recorded on 4 July, when plants were at growth stages BBCH 53–55, *i.e.* 4 days after the first egg cluster was found on marked plants (Fig. 2). Initially the number of hatching caterpillars increased slowly until 18 July. Then, the dynamics of hatching intensified, reaching a maximum of 34 empty egg clusters on 200 plants on 29 July, when plants were at stage BBCH 67. After that period, the number of empty egg clusters decreased. The last empty egg clusters were found on 19 August, when plants were at stages BBCH 75–83. Caterpillars hatched from 127 out of 139 egg clusters deposited by ECB. This figure means that 12 egg clusters were destroyed by natural enemies or other factors.

2006

The year 2006 was very favourable for moth flight and oviposition, and therefore this process lasted for a relatively short time but was very intensive (Fig. 3). The first two egg clusters of ECB on plants were found on 4 July, when maize was at growth stages BBCH 33–34. During the following days, the number of newly deposited egg clusters increased dynamically to reach a maximum of 48 clusters/200 plants on 14 July, when plants were at stages

Table 1. Weather conditions in Krzeczowice in 2004–2008

Month	Decade	Mean air temperature [°C]					Sum of precipitation [mm]					Number of days with precipitation					Number of windy days (average wind speed over 6 m/s)				
		2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
June	I	16.3	13.8	11.5	18.6	17.9	10.7	84.4	37.1	28.4	1.4	3	5	6	3	1	4	4	4	1	3
	II	16.6	17.9	18.0	20.4	16.2	28.7	20.0	6.7	13.7	40.0	8	4	1	4	3	4	4	1	3	2
	III	16.5	18.4	21.3	17.7	19.7	24.9	5.2	47.4	28.4	45.3	5	1	5	6	6	5	3	2	6	5
	mean/ sum monthly	16.4	16.7	16.9	18.9	17.9	64.3	109.6	91.2	70.5	86.7	16	10	12	13	10	13	11	7	10	10
July	I	17.8	18.4	18.8	17.5	17.8	26.7	59.3	2.7	40.0	35.9	5	2	1	7	5	4	2	2	6	6
	II	17.9	19.4	20.5	21.8	19.2	13.6	20.2	7.6	19.3	43.3	5	6	3	3	4	3	5	4	5	3
	III	19.5	21.3	23.2	20.4	19.0	139.3	29.6	5.6	14.3	38.4	7	5	3	4	5	4	2	2	8	4
	mean/ sum monthly	18.4	19.7	20.8	19.9	18.6	179.6	109.1	15.9	73.6	117.6	17	13	7	14	14	11	9	8	19	13
August	I	18.1	17.2	19.2	18.2	19.6	22.9	81.6	31.0	36.8	21.2	8	7	6	5	3	4	4	2	1	5
	II	19.6	17.3	19.7	19.3	19.9	9.5	25.5	29.8	51.1	18.2	3	3	8	5	3	5	2	4	2	5
	III	19.3	17.9	16.2	19.5	17.3	66.4	16.9	42.7	0.0	15.9	7	4	7	0	4	2	2	6	3	4
	mean/ sum monthly	19.0	17.4	18.3	19.0	18.9	32.9	124.0	103.5	87.9	55.3	18	14	21	10	10	11	8	12	6	14
September	I	14.3	16.8	16.0	12.8	19.3	0.1	0.0	22.1	115.6	5.0	1	0	4	8	2	1	3	7	7	6
	II	14.6	14.4	15.7	12.0	9.0	1.9	44.0	1.3	18.5	84.1	2	6	1	4	9	5	4	1	7	3
	III	10.9	13.2	13.3	12.7	10.7	20.5	18.4	1.2	7.6	14.1	4	2	1	2	4	5	3	1	3	2
	mean/ sum monthly	13.2	14.8	15.0	12.5	13.0	22.5	62.4	24.6	141.7	103.2	7	8	6	14	15	11	10	9	17	11

Table 2. Number of *O. nubilalis* eggs in clusters in 2004–2008

Year	2004	2005	2006	2007	2008
Number of eggs clusters	161	139	141	109	90
Total number of eggs in clusters	2,558	2,798	3,393	2,130	1,564
Average number of eggs per cluster	10.0	14.7	15.2	13.9	14.2
Minimum number of eggs per cluster	2	2	6	3	5
Maximum number of eggs per cluster	48	79	83	59	38

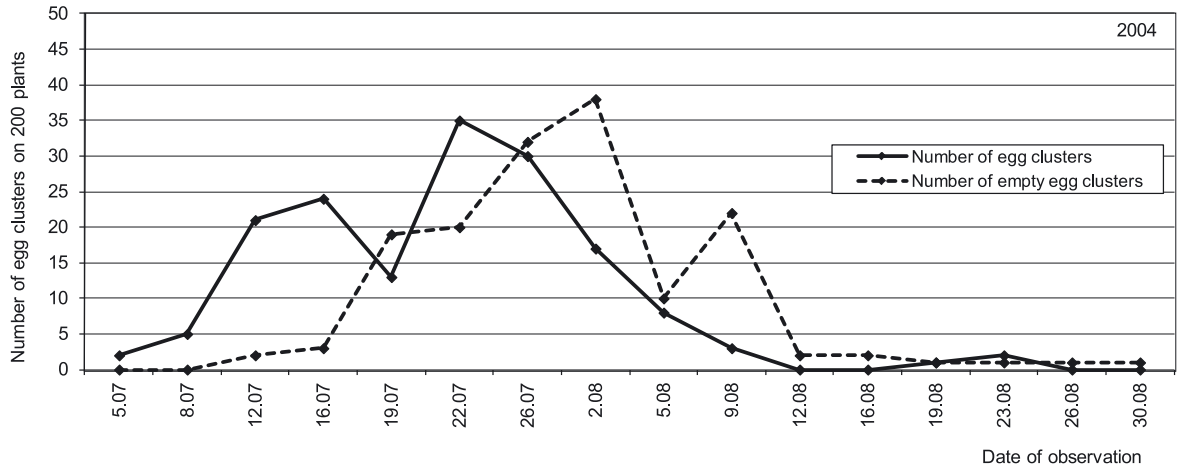

Fig. 1. The dynamics of oviposition and hatching of *O. nubilalis* caterpillars on maize in 2004

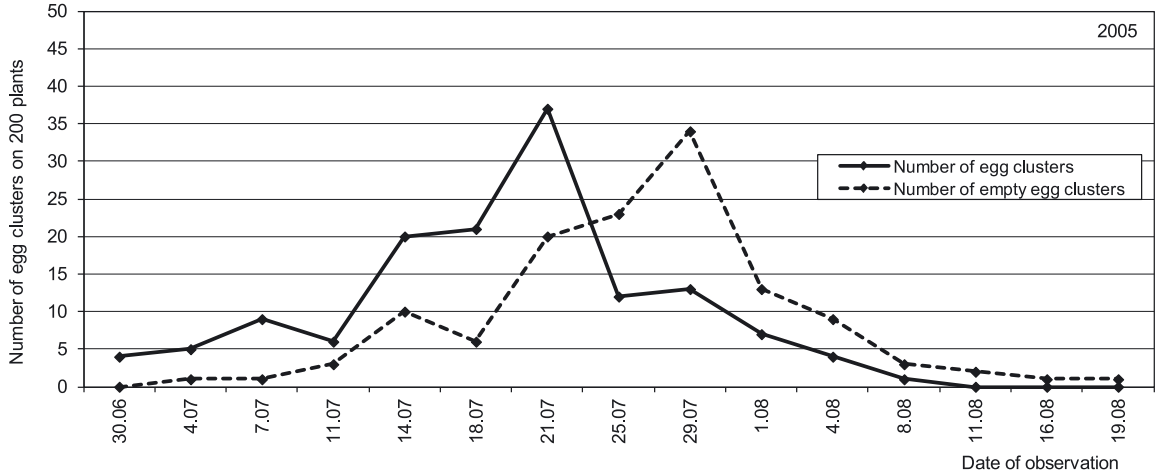

Fig. 2. The dynamics of oviposition and hatching of *O. nubilalis* caterpillars on maize in 2005

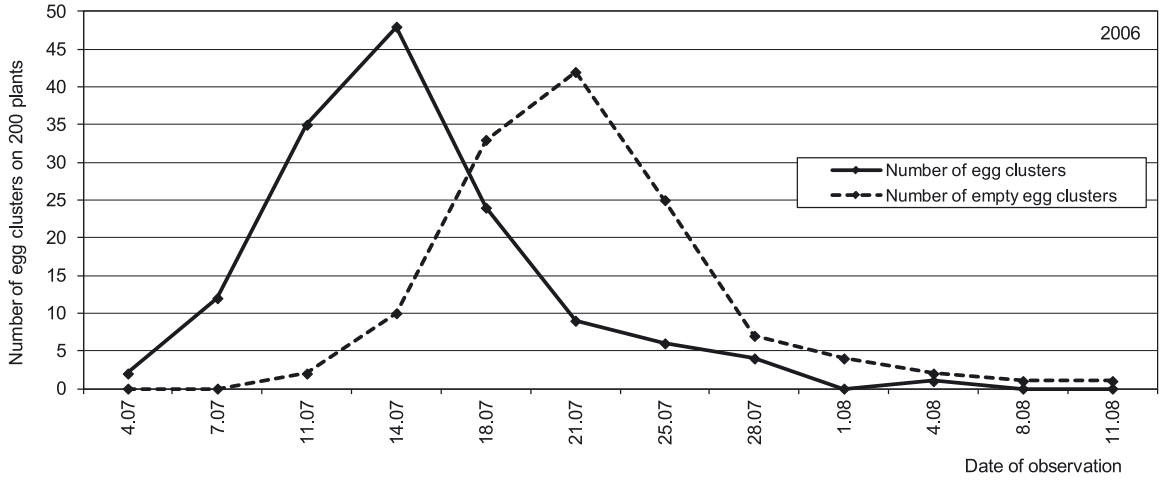

Fig. 3. The dynamics of oviposition and hatching of *O. nubilalis* caterpillars on maize in 2006

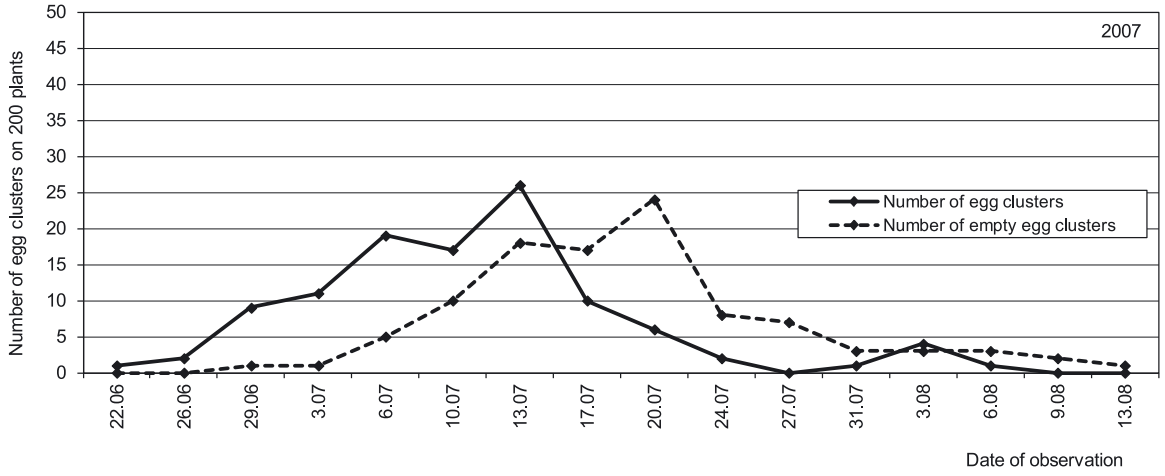

Fig. 4. The dynamics of oviposition and hatching of *O. nubilalis* caterpillars on maize in 2007

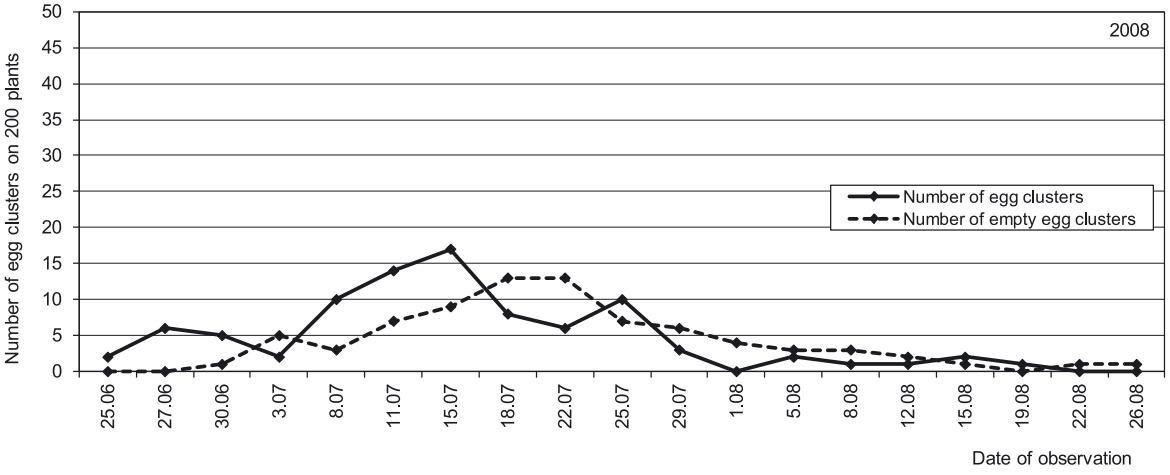

Fig. 5. The dynamics of oviposition and hatching of *O. nubilalis* caterpillars on maize in 2008

BBCH 51–53. This was the peak number of egg clusters observed during the five-year study period. Moreover, the peak of moth mass oviposition was about one week sooner in comparison to 2004–2005. This may have resulted from the relatively high temperatures and the absence of other unfavourable factors, such as intense rainfall or gusty winds hindering moth flight. The last egg cluster was found on plants on 4 August, when maize was at growth stages BBCH 71–73.

In 2006, *O. nubilalis* females deposited 141 egg clusters containing 3,393 eggs on 200 plants (Table 2). In comparison to previous years, the number of eggs per cluster increased significantly. Under favourable weather conditions, females deposited up to 83 eggs in a single cluster. The largest egg clusters were recorded on plants between 11 and 18 July. The smallest egg cluster contained 6 eggs. On individual observation dates, the average number of eggs per cluster ranged from 8.0 to 30.8, and for all of 2006, the average was 15.7.

In 2006, the first two empty egg clusters showing the beginnings of caterpillar hatching were found on 11 July, when plants were at stage BBCH 51, *i.e.* 7 days after the egg clusters of ECB were recorded on marked maize plants (Fig. 3). Caterpillar hatching was very dynamic and reached its maximum at the end of the second ten days and the beginning of the third ten days of July. The highest number of empty egg clusters was recorded on 21 July, when plants were at stage BBCH 61. The last empty cluster was recorded on 11 August, when plants were at stage BBCH 75. From among 141 of all egg clusters deposited by the ECB females in 2006, caterpillars hatched from 127 egg clusters, while 14 clusters were destroyed.

2007

In 2007, the first egg cluster of *O. nubilalis* was recorded on 22 June, when plants were at stage BBCH 32 (Fig. 4). This was the earliest date during the five-years of the study period. Moth flight and the oviposition process were undisturbed because of favourable weather conditions. The number of deposited eggs increased dynamically from the third ten days of June and reached a maximum on 13 July, when plants were at stages BBCH 55–59. Starting from mid-July, the number of deposited egg clusters decreased gradually and continued until 27 July, followed by a slight increase in number on 3 August. The last egg cluster was found on 6 August, when plants were at stages BBCH 71–73. As in 2006, the peak in the number of egg clusters on plants was reached at the beginning of the second ten days of July and occurred 8–9 days earlier than in 2004–2005.

In 2007, female of ECB deposited 109 egg clusters containing 2,130 eggs on 200 marked plants (Table 2). The number of eggs varied from cluster to cluster. The maximum number of eggs found in a single cluster was 53 and the lowest was 3. The average number of eggs per cluster in the entire analysed period was 13.9.

In 2007, the first empty egg cluster was recorded on 29 June, when plants were at stage BBCH 51 (Fig. 4). Caterpillars began hatching one week after the first egg cluster was found on plants. The number of empty egg clusters increased gradually from 3 July reaching a maximum on 20 July, when plants were at stages BBCH 61–65. The last egg cluster was found on 13 August, when maize was at growth stages BBCH 73–75. From all 109 egg clusters deposited by *O. nubilalis* females in 2007, caterpillars hatched from 103 clusters; 6 others were destroyed.

2008

Weather conditions in 2008 were unfavourable for moth flight and oviposition. Prolonged rainfall and relatively low temperatures extended the oviposition period but also caused a decrease in the number of eggs.

The first two egg clusters of *O. nubilalis* were found on plants on 25 June, when maize was at stages BBCH 32–33 (Fig. 5). Precipitation that occurred in the last ten days of June disturbed oviposition. A clear increasing trend in the number of egg clusters on plants was recorded late, after 8 July. The maximum number of egg clusters on plants (17 clusters/200 plants) was observed on 15 July, when maize was at stages BBCH 55–61. From 18 July the number of deposited egg clusters decreased, with a single increase observed on 25 July. Because of rainfall at the end of July and the beginning of August, the last egg cluster deposited by the ECB was found on plants on 19 August, when maize was at stages BBCH 79–83.

In 2008, female ECB deposited 90 egg clusters containing 1,564 eggs on 200 identified plants (Table 2). This was the lowest number of egg clusters observed during the five-year study period. The maximum number of eggs found in a single cluster was 38, and 5 was the lowest. In 2008, one cluster contained, on average, 14.2 eggs.

In 2008, the first empty egg clusters were recorded on 30 June, when plants were at stage BBCH 34, i.e. 5 days after the first egg cluster was found on identified plants. The number of empty egg shells increased gradually from 8 July, reaching a maximum of 13 empty egg clusters on 18 and 22 July, when maize was at stages BBCH 61–65. The number of empty egg clusters decreased gradually after 25 July. The last cluster with empty egg shells was found on 26 August, when maize was at stages BBCH 83–85. Detailed observations demonstrated that from all 90 egg clusters deposited by the ECB female caterpillars, 79 hatched, which means that 11 egg clusters were destroyed (Fig. 5).

DISCUSSION

The conducted study demonstrated that oviposition by the European corn borer females in the soil and climate conditions of south-eastern Poland lasts from 4.5 to 8 weeks. Birova (1962) observed in the former Czechoslovakia, that the occurrence of individual developmental stages of *O. nubilalis* are significantly extended in time. Results from our study are partly in agreement with the results obtained by Mazurek *et al*. (2003), who found clusters of pest eggs for 3–5 weeks on sweet corn cultivated in south-western Poland. Another study, by Tancik and Cagan (1998), showed that in Slovakia, oviposition by the ECB lasts for 3 to 4.7 weeks. Our own study demonstrated that the oviposition period of the pest may be shorter or longer, depending on changes in weather conditions.

In this study, the first egg clusters of ECB on fodder maize were recorded in the third ten days of June and first ten days of July, which is partly confirmed by Birova's studies (1962). These dates, however, are different from the observations by Pieprzyk and Romankow (1960), who recorded the first eggs of *O. nubilalis* as late as in mid-July. However, in Slovakia, the first eggs of the pest were recorded on maize slightly earlier than in our own study, *i.e.* in the second and third ten days of June (Tancik and Cagan 1998).

The maximum number of egg clusters of *O. nubilalis* on plants was in the second and third ten days of July, which is also supported in observations by Birova (1962). Our results differ from those presented by Tancik and Cagan (1998, 2004), who recorded the maximum number of egg clusters on plants to be earlier, i.e. in the last ten days of June and first ten days of July. The maximum number of egg clusters on sweet corn was recorded at a similar time by Mazurek *et al*. (2003).

In our study, the last egg clusters were observed in August, and females deposited eggs for the longest time in years with a high number of days with rainfall. In studies by Mazurek *et al*. (2003) the oviposition period on sweet corn usually ended in the last ten days of July, and only in some years did it last until mid-August. In contrast, studies by Tancik and Cagan (1998) conducted on fodder maize did not demonstrate the presence of egg clusters of *O. nubilalis* in August.

Detailed studies on the oviposition behaviour of the female ECB, demonstrated a highly variable number of eggs in clusters. Very small clusters containing only 2 eggs were found on plants as well as very large clusters with 83 eggs. The average number of eggs per cluster in the five-year period ranged from 10.0 to 15.2. The obtained results are similar to observations by other authors. Pieprzyk and Romankow (1960) in two localities (Wrocław and Oleśnica Mała), found clusters with 5 eggs as well as those with 92 eggs. The average number of eggs per cluster in these localities was from 13.9 (Oleśnica Mała) to 34.2 (Wrocław). Poss (1927) recorded from 2 to 69 eggs per cluster, with an average number of 15.5 eggs. Birova (1962) reported that one cluster usually contained 17 eggs.

Apart from the observation of oviposition behaviour by the female *O. nubilalis*, the number of empty egg clusters was also recorded, and dates of caterpillar hatching were established based on this. The first empty egg clusters were found from the last ten days of June to the second ten days of August, depending on the time when moths occurred on the maize. The maximum number was recorded in the second and third ten days of July, while the last empty shells were found in the second half of August. The time of mass caterpillar hatching noted in this study, was also confirmed by observations made by Mazurek *et al*. (2003).

Our study also demonstrated a clear shift in the date of mass pest hatching. Although in 2004–2005, this date was at the end of July or early August, in other years it was in the second ten days of July and in the ten last days of July. This shift in the time of mass hatching may be associated with the effect of the weather conditions, which in the most recent years were favourable for the development of ECB. Lisowicz and Tekiela (2004) reported that ECB caterpillars usually hatch 5–10 days after oviposition, while their incubation period depends on weather conditions, particularly temperature. Poos (1927), found that caterpillars hatch after 4–9 days (average 5.4 days).

CONCLUSIONS

1. During the study years in the south-eastern part of Poland, the European corn borer began oviposition on maize plants between the last ten days of June (2005, 2007–2008) and the first ten days of July (2004, 2006). One peak in the number of deposited eggs was found, which was at the beginning of the second ten days of July (2006–2008) and at the beginning of the third ten days of July (2004–2005). The last egg clusters were recorded in the first half of August (2005–2007) and in the second half of August (2004, 2008).
2. The oviposition period by females during these years lasted from 4.5 to 8 weeks. The shortest oviposition period was in warm and dry years, while the longest period was during rainy and relatively cold years.
3. During the study years, within the entire flight period, European corn borer females deposited from 1,564 (2008) to 3,393 (2006) eggs. The smallest found cluster consisted of 2 eggs while the largest consisted of 83 eggs. The average number of eggs per cluster in the study years was from 10.0 (2004) to 15.2 (2006).
4. The beginning of caterpillar hatching, based on the observation of empty egg clusters, was recorded in the last ten days of June (2007–2008) or in the first (2005) and second (2004, 2006) ten days of July. Mass hatching of ECB caterpillars was observed in the second and third ten days of July. Only in 2004 was mass hatvhing observed in the first ten days of August. The last empty egg clusters were recorded in the second (2005–2007) and in the last ten days of August (2004, 2008).

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