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EFFECT OF EARLINESS OF MAIZE CULTIVARS (*Zea mays* L.) ON DAMAGE CAUSED BY *Ostrinia nubilalis* HBN. (LEP., CRAMBIDAE)

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Abstract. Early-maturing maize cultivars identified with index FAO 190-220 were more susceptible to damage caused by caterpillars of the European corn borer (*Ostrinia nubilalis* Hbn.) than medium-late maturing cultivars with index FAO 270-280. The conducted analysis of coefficients of correlation and regression demonstrated that the cultivars earliness had a significant effect on the number of caterpillars found on a plant, the percentage of damaged plants and grain yield. The increase in the FAO index was correlated with a significant decrease in the number of ECB caterpillars inside the plant ($r = -0.87$; $p < 0.001$), reduction in the number of damaged plants ($r = -0.64$; $p < 0.001$) and with an increase grain yield ($r = 0.62$; $p < 0.001$). The formulated regression equations demonstrated that the increase in the FAO index for maize cultivars by 100 units results in a decrease in the number of caterpillars in the plant, on average by 2.6 caterpillars, decrease in the number of damaged plants on average by 24.38%, and increase in the grain yield by 5.07 $t \cdot ha^{-1}$.

Key words: earliness of cultivars, FAO, harmfulness, *Ostrinia nubilalis*, susceptibility of cultivars, *Zea mays* L.

INTRODUCTION

The European corn borer (ECB) (*Ostrinia nubilalis* Hbn.) is one of the major maize (*Zea mays* L.) pests in Europe, North America, North-Western Africa and Western Asia [Mutuura and Munroe 1970]. According to Manson *et al*. [1996] and Calvin and Van Duyn [1999] in North America loss in maize yield caused by the feeding caterpillars of *O. nubilalis* and the cost for their control is estimated at 1 billion USD annually.

In Poland ECB caterpillars has been causing damage in maize cultivations since the 1950s. [Kania 1962]. Up to the end of 2008 *O. nubilalis* was recorded in 14 out of 16 provinces of Poland, which accounts for over half of the country's area [Bereś and Konefał 2010]. Currently, this is one of the most serious maize pests, which in regions

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with intense maize growing damages from 50 to 80, and locally up to 100% of plants, causing a 30-40% loss in maize grain yield [Lisowicz and Tekiela 2004].

ECB in Poland is controlled using agrotechnical, biological and chemical methods, as well as the cultivation of GMO cultivars [Lisowicz and Tekiela 2004, Bereś 2008, 2010]. In the integrated program for maize protection against *O. nubilalis* special emphasis is put on the use of non-chemical methods, particularly the choice of maize cultivars which are less susceptible to damage caused by caterpillars [Bereś and Pruszyński 2008].

According to Dąbrowski [1976] there are many factors decisive for the plant resistance to pests, which may affect the cultivated plant or a certain pest. Gallun and Khush [1980] indicated that the resistance level of plants to pests depends, for example, on the specific morphological or biochemical defence reactions of plants, and particularly on plant genotype, pest genotype and plant-pest interactions.

The available literature reports many studies on short-term resistance of juvenile maize plants to the European corn borer, which is determined by the high tissue level of 2-4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA) [Klun *et al*. 1967, Barry and Darrah 1991, Bergvinson *et al*. 1995].

On the other hand, Lisowicz [2004] found that the earliness of cultivated maize cultivars may be a factor differentiating the harmfulness of ECB caterpillars. The available literature provides relatively limited information on this subject, particularly because the earliness of individual cultivars defined by the FAO index may differ by country. For example, the maize cultivars grown in Poland belong to three earliness categories: early (FAO 180-220), medium-early (FAO 230-250) and medium-late (FAO 260-290) [Janiak *et al*. 2011]. In other countries located in a different geographical zone, e.g. Hungary, the earliness of cultivated cultivars is expressed by an FAO index over 300, which would not be grown successfully under Polish soil and climate conditions due to the insufficiently long vegetation period.

The objective of the conducted studies was to evaluate the effect of earliness of maize cultivars on the extent and type of plant damage caused by *O. nubilalis* caterpillars under the soil and climate conditions of south-eastern Poland.

MATERIAL AND METHODS

The study was conducted in 2005-2008 in the Plant Cultivation Station in Krzeczowice (49°59’ N; 22°27’ E) near Przeworsk (south-eastern Poland). 11 maize cultivars classified to three earliness groups were used in the experiment:

- early-maturing: KB1902, Wilga, Fido and Prosna,
- medium-early maturing: Glejt, San, Blask, Monumental and Moncada,
- medium-late maturing: Gavott and Chambord.

Each cultivar was sown in four-row 50 m^2 plots using the random block method in four replications. The standard grain sowing density was 80,000 grains·ha^{-1}. Sowing was carried out on 16 May (2005), 27 April (2006), 24 April (2007) and 28 April (2008).

The level of damage to maize plants caused by caterpillars of the European corn borer was evaluated twice during the vegetation season:

- on: 8-9 September (2005), 28-29 August (2006), 20-22 August (2007) and 21-22 August (2008), when maize plants were at the developmental stage BBCH 83-85 [Adamczewski and Matysiak 2002]. The percentage of plants and cobs damaged

by caterpillars and the percentage of broken tassels was calculated. Observations were carried out on 2 x 50 plants from two central rows on each plot (together 100 per plot). Additionally, 5 consecutive plants from 4 rows were cross-sected (20 per plot in total) and the following was calculated:
- the number of holes and ECB caterpillars below and under the cob, and inside the cob,
- the number of feeding tunnels and their average length per plant;

- on: 17 October (2005), 10 October (2006), 21 September (2007) and 22-23 September (2008), directly before grain harvest, when plants were at stage BBCH 87-97 the following parameters in per cent were calculated: stems broken below and above the cob, and cobs gnawed on the base. Analysis was carried out on 2 x 50 plants growing in two central rows on each plot (100 in total).

Grain was harvested from 100 plants growing in two central rows on each plot with a harvesting machine. Grain yield from plots was weighted and calculated to yield in tonnes per hectare at 15% water content.

Results obtained in years 2005-2008 were statistically analysed based on variance analysis for the random block system. The analysis was based on a mixed variance analysis design which assumed a constant result for a cultivar and random effects for year and year-to-cultivar correlation. The significance of differences between mean values was analysed using the Tukey test, at a significance level of $P < 0.05$.

The significance of correlations between the analysed parameters and cultivar earliness expressed as an FAO index was estimated based on the analysis of coefficients of simple correlation and linear regression. Mean values from four study years ($N = 44$) were used for calculations, and the significance of coefficients of correlation and regression equations was evaluated at the significance level $P < 0.001$.

Calculations were performed in Statistica© 9.0. software, ARM 8© (Agriculture Research Manager) and Microsoft® Office Excel 2007.

RESULTS AND DISCUSSION

The obtained results concerning the level of damage in individual parts of maize plants caused by *Ostrinia nubilalis* caterpillars are presented in Tables 1 and 2.

In 2005-2008 the harmfulness of the European corn borer in the study region was at a very high level, comparable to that observed in the same location by Lisowicz [2003] in 2002. The quoted author found during that period that ECB caterpillars damaged 96.0% of maize plants. During the analysed four-year period the percentage of plants damaged by *O. nubilalis* caterpillars was from 72.7% to 93.9%, depending on the cultivar. The highest number of damaged plants was recorded in early and medium-early cultivars, while the lowest was recorded in two medium-late cultivars, i.e. Gavott and Chambord (Table 1).

According to Lisowicz [2003] the number of cobs damaged by ECB caterpillars also increases along with the increase in the number of damaged plants. In our studies the percentage of cobs damaged by *O. nubilalis* ranged from 39.2% to 66.5%. The highest number of damaged cobs was recorded in early cultivars and in two medium-early cultivars, i.e. Glejt and San. On average, during the four-year period the lowest number of damaged cobs was recorded in the medium-early maturing cultivar Moncada, and in two medium-late maturing cultivars, i.e. Gavott and Chambord (Table 1).

From the economic point of view, gnawing of the cob base by caterpillars created a high risk to the grain yield. During the analysed four-year period the highest number of such damage was found in early cultivars, especially in the Wilga cultivar, where the average percentage of cobs gnawed at the base was 16.0%. The lowest number of cobs gnawed at the base was recorded in cultivars with FAO index 270-280 (Table 1).

Particularly high and statistically significant differences between early and medium-late cultivars were found in respect to the number of broken tassels and stems broken below and above the cob. The highest amount of such damage was found in cultivars with FAO index from 190 to 240, while the lowest was found in medium-late cultivars (Table 2). The number of plants with stems broken below the cob was highly important for the grain yield. Early-maturing cultivars (KB1902, Wilga and Fido) were particularly susceptible to this type of damage, and the average percentage of stems broken below the cob in the four-year period in their case was over 20% (Table 2).

The nature of the damage caused by *O. nubilalis* in studied maize cultivars of different earliness was associated with the number of caterpillars feeding on plants, the number of holes bored by them in tissues, and the number and length of feeding tunnels. The values of these parameters are presented in Tables 3 and 4.

The carried out analyses demonstrated that in the stems of individual maize cultivars ECB caterpillars gnawed over four years on average from 0.38 to 1.63 holes below the cob and from 0.97 to 2.0 holes above the cob. On average from 0.37 to 0.93 holes were found in the cobs. Statistical analysis demonstrated differences in the number of holes depending on the cultivar. Statistically significant differences were mainly found between early and medium-late cultivars (Table 3).

Detailed analysis of plants also demonstrated large differences in the number of caterpillars feeding on tissues of individual maize cultivars. In 2005–2008 on average from 0.30 to 1.35 ECB caterpillars fed on one plant below the cob, from 0.82 to 1.80 above the cob and from 0.51 to 1.01 inside the cob (Table 4). A statistically higher number of caterpillars was found on cultivars with FAO index from 190 to 240 than on cultivars with FAO index 270-280.

Depending on the cultivar and its earliness, *O. nubilalis* caterpillars gnawed on average from 1.25 to 2.80 feeding tunnels inside the plant. The highest number of tunnels was recorded in early cultivars (from 2.23 to 2.80). In medium-early cultivars the average number of feeding tunnels ranged from 1.75 to 2.25. In cultivars with FAO index 270-280 from 1.25 to 1.32 feeding tunnels were found on average in one plant (Table 5).

During the analysed four years, statistically significant differences were found in the length of feeding tunnels in the studied maize cultivars differ in earliness. The longest feeding tunnels (from 30.69 cm to 21.15 cm on average) were found in early maturing cultivars. In medium-early cultivars the average length of tunnels ranged from 14.04 cm to 19.16 cm, while in medium-late cultivars it was from 9.75 cm to 9.87 cm (Table 5).

The number of ECB caterpillars feeding on maize plants of individual cultivars and the nature of resulting damage had a significant effect on grain yield. Year 2006 was particularly unfavourable, and from 2.12 $t \cdot ha^{-1}$ to 5.09 $t \cdot ha^{-1}$ was harvested from early cultivars. Such a low yield resulted from the high number of stems broken below the cobs, and cobs gnawed at the base. On average, in four years the grain yield obtained from individual cultivars of differing earliness was from 4.91 to 10.12 $t \cdot ha^{-1}$ (Table 5).

Table 1. Percentage of damaged plants, cobs and cobs gnawed at the base in 2005-2008
Tabela 1. Procent uszkodzonych roślin, kolb oraz kolb podgryzionych u nasady w latach 2005-2008

Cultivar Odmiana	FAO	Percentage of damaged plants Procent roślin uszkodzonych					Percentage of damaged cobs Procent kolb uszkodzonych					Percentage of gnawed cobs at the base Procent kolb podgryzionych u nasady				
		2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia
KB1902	190	91.50a-d	97.30ab	92.50a	84.80a	91.53ab	51.75e	61.00abc	50.50a	43.80ab	51.76d	9.75ab	12.00b	8.30abc	9.00a	9.76bc
Wilga	190	97.50a	99.00a	90.80a	88.50a	93.95a	93.50e	73.80a	51.80a	47.00ab	66.53ab	16.25a	28.50a	11.50a	8.00a	16.06a
Fido	210	95.75ab	95.80ab	88.00ab	88.00a	91.89ab	89.75ab	63.50ab	55.50a	49.50a	64.56ab	9.75ab	23.50a	9.30ab	9.00a	12.89b
Prosna	220	87.58bcd	96.00ab	90.00ab	76.80ab	87.60bc	48.42ef	54.00b-e	49.30ab	42.00ab	48.43d	9.67ab	12.30b	9.80ab	7.00ab	9.69c
Glejt	230	96.00a	93.50ab	85.50abc	79.00ab	88.50bc	92.25a	54.50bcd	42.80bcd	43.50ab	58.26c	6.00bc	7.80bcd	5.80abc	4.00a-d	5.90de
San	240	93.50abc	94.30ab	88.80ab	74.50ab	87.78bc	86.25ab	60.80abc	48.30abc	40.80ab	59.04bc	6.75bc	9.00bc	8.30abc	5.00a-d	7.26cd
Blask	240	84.25de	89.50bc	86.30abc	77.00ab	84.26cd	46.17ef	53.30b-e	42.80bcd	42.50ab	46.19d	5.00bc	2.30cd	6.50abc	6.30abc	5.03def
Monumental	250	92.25a-d	80.80de	82.00bc	63.30bc	79.59de	80.75bc	45.80de	39.80d	34.80ab	50.29d	2.50c	5.80bcd	4.50bc	2.50bcd	3.83efg
Moncada	250	76.50e	85.00cd	79.00cd	65.50bc	76.50ef	39.25f	40.30e	41.00cd	36.50ab	39.26e	3.67bc	4.50cd	4.00bc	2.50bcd	3.67efg
Gavott	270	86.25cd	81.30de	69.30e	54.30c	72.79f	69.50d	49.00cde	40.80cd	30.50b	47.45d	1.50c	1.80cd	2.50c	1.00d	1.70g
Chambord	280	87.00cd	76.30e	71.50de	56.50c	72.83f	72.75cd	44.30de	38.50d	33.80ab	47.34d	1.25c	1.30d	3.80bc	1.50cd	1.96fg
$LSD_{0.05}$ – $NIR_{0,05}$		8.40	7.89	8.71	16.46	5.16	9.99	14.21	7.58	16.57	5.93	7.16	7.33	6.65	5.03	3.11

means followed by the same letter do not differ at 5% level of significance (Tukey's multiple range test) – średnie oznaczone tą samą literą nie różnią się na poziomie istotności 5% (test wielokrotnych porównań Tukeya)

Table 2. Percentage of stems broken above and below cob and broken tassels in 2005-2008
Tabela 2. Procent łodyg złamanych powyżej i poniżej kolby oraz złamanych wiech w latach 2005-2008

Cultivar Odmiana	FAO	Percentage of stalks broken above the cob Procent łodyg złamanych powyżej kolby					Percentage of stalks broken below the cob Procent łodyg złamanych poniżej kolby					Percentage of broken tassels Procent złamanych wiech				
		2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia
KB1902	190	21.58bc	16.80ab	24.80a	23.30a	21.62a-d	27.92a	51.00ab	22.80a	10.00abc	27.93a	16.67cd	17.30bcd	18.50ab	14.30ab	16.69cd
Wilga	190	39.75a	25.00ab	26.30a	20.00ab	27.76a	15.25bc	57.80a	20.50ab	15.00a	27.14a	33.50a	36.30a	18.80ab	17.00a	26.40a
Fido	210	23.00bc	24.50ab	23.30ab	23.80a	23.65ab	10.75b-f	43.80bc	15.30abc	13.00ab	20.71b	29.00ab	25.00abc	20.30a	17.30a	22.90ab
Prosna	220	23.17bc	26.00ab	21.80abc	21.80ab	23.19abc	17.67b	24.30def	20.00ab	8.80bc	17.69bc	16.92cd	23.50abc	17.50abc	9.80ab	16.93cd
Glejt	230	25.25ab	26.50ab	17.00abc	19.30ab	22.01a-d	8.25c-f	30.50de	15.00abc	9.30abc	15.76cde	19.25cd	29.00ab	15.00abc	13.50ab	19.19bcd
San	240	21.25bc	28.00a	21.80abc	16.50ab	21.89a-d	7.50c-f	34.80cd	16.00abc	9.80abc	17.03bcd	21.50bc	26.30abc	18.80ab	15.50a	20.53bc
Blask	240	19.75bc	24.00ab	17.30abc	18.00ab	19.76bcd	12.75bcd	10.80g	19.00ab	8.50bcd	12.76def	15.09cd	17.30bcd	14.80abc	13.30ab	15.12de
Monumental	250	13.00bc	17.50ab	21.00abc	17.50ab	17.25cde	6.75def	21.80efg	12.00bc	8.80bc	12.34def	12.50cd	27.00ab	10.80abc	11.50ab	15.45de
Moncada	250	16.67bc	17.00ab	19.80abc	13.30ab	16.69def	11.58b-e	15.80fg	11.00bc	8.00bcd	11.60ef	11.75d	13.00cd	11.50abc	10.80ab	11.76e
Gavott	270	7.50c	15.30b	9.80c	11.50b	11.03f	3.00f	13.50fg	7.00c	2.80d	6.58g	2.25e	7.50d	6.30c	6.80b	5.71f
Chambord	280	9.75bc	15.50b	11.00bc	11.00b	11.81ef	3.75ef	13.80fg	8.50c	6.30cd	8.09fg	1.50e	4.30d	8.00bc	9.50ab	5.83f
$LSD_{0.05} – NIR_{0,05}$		16.37	11.70	13.36	11.42	6.30	7.96	12.73	9.62	5.82	4.42	9.26	13.44	11.45	8.19	5.08

means followed by the same letter do not differ at 5% level of significance (Tukey's multiple range test) – średnie oznaczone tą samą literą nie różnią się na poziomie istotności 5% (test wielokrotnych porównań Tukeya)

Table 3. Mean number of holes in stems above and below cob and in the cob in 2005-2008
Tabela 3. Średnia liczba otworów w łodydze powyżej i poniżej kolby oraz w kolbie w latach 2005-2008

Cultivar Odmiana	FAO	Mean number of holes in the stem below the cob, pcs. – Średnia liczba otworów w łodydze poniżej kolby, szt.					Mean number of holes in the stem above the cob, pcs. – Średnia liczba otworów w łodydze powyżej kolby, szt.					Mean number of holes in the cob, pcs. Średnia liczba otworów w kolbie, szt.				
		2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia
KB1902	190	1.49a	2.00ab	1.39a	1.09ab	1.49a	1.76ab	1.48a-d	2.13a	1.69a	1.76abc	0.75abc	0.83a	0.83a	0.60a	0.75abc
Wilga	190	1.65a	2.38a	1.25ab	1.23ab	1.63a	2.15a	2.00ab	2.14a	1.73a	2.00a	1.01a	1.00a	0.90a	0.79a	0.93a
Fido	210	1.30ab	1.98ab	0.88abc	1.30a	1.36a	1.85ab	2.11a	2.01a	1.71a	1.92a	0.90ab	0.85a	0.96a	0.78a	0.87ab
Prosna	220	1.02bc	1.20cd	1.03abc	0.84abc	1.02b	1.80ab	1.74abc	1.93a	1.74a	1.80ab	0.69abc	0.69a	0.74a	0.65a	0.69a-d
Glejt	230	0.89c	1.33bcd	0.86abc	0.70abc	0.94bcd	1.93ab	1.83abc	1.79ab	1.68a	1.80ab	0.99a	0.50a	0.63a	0.61a	0.68bcd
San	240	0.83c	1.40bc	0.84abc	0.93abc	1.00bc	1.84ab	1.98ab	1.89ab	1.51a	1.80ab	0.64bc	0.78a	0.73a	0.73a	0.72a-d
Blask	240	0.72c	0.78cd	0.70abc	0.68abc	0.72cde	1.68ab	1.74abc	1.71ab	1.59a	1.68abc	0.62bc	0.65a	0.51a	0.70a	0.62cde
Monumental	250	0.69c	0.95cd	0.63bc	0.61bc	0.72cde	0.98c	1.26bcd	1.95a	1.46a	1.41c	0.58bcd	0.54a	0.45a	0.51a	0.52c-f
Moncada	250	0.68c	0.68cd	0.69abc	0.66bc	0.68de	1.48b	1.16cd	1.79ab	1.48a	1.48bc	0.50cde	0.46a	0.50a	0.54a	0.50def
Gavott	270	0.20d	0.58d	0.38c	0.36c	0.38f	0.50d	1.05cd	1.34ab	1.29a	1.04d	0.19e	0.50a	0.41a	0.38a	0.37f
Chambord	280	0.28d	0.61d	0.46c	0.45c	0.45ef	0.71cd	0.84d	1.01b	1.31a	0.97d	0.28de	0.49a	0.46a	0.45a	0.42ef
$LSD_{0.05}$ – $NIR_{0,05}$		0.36	0.75	0.73	0.62	0.30	0.48	0.79	0.90	0.79	0.35	0.33	0.56	0.65	0.57	0.25

means followed by the same letter do not differ at 5% level of significance (Tukey's multiple range test) – średnie oznaczone tą samą literą nie różnią się na poziomie istotności 5% (test wielokrotnych porównań Tukeya)

Table 4. Mean number of caterpillars in stems above and below cob and in the cob in 2005-2008
Tabela 4. Średnia liczba gąsienic w łodydze powyżej i poniżej kolby oraz w kolbie w latach 2005-2008

Cultivar Odmiana	FAO	Mean number of caterpillars in the stem below the cob, pcs. – Średnia liczba gąsienic w łodydze poniżej kolby, szt.					Mean number of caterpillars in the stem above the cob, pcs. – Średnia liczba gąsienic w łodydze powyżej kolby, szt.					Mean number of caterpillars in the cob, pcs. Średnia liczba gąsienic w kolbie, szt.				
		2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia
KB1902	190	1.27a	1.88ab	1.21a	0.71abc	1.27a	1.61ab	1.30a-d	1.99a	1.53a	1.60abc	0.84abc	0.70a	1.01a	0.79a	0.83ab
Wilga	190	1.15ab	2.15a	1.11ab	0.98ab	1.35a	1.88a	1.80ab	2.01a	1.50a	1.80a	1.31a	0.93a	1.11a	0.70a	1.01a
Fido	210	1.13abc	1.76abc	0.71abc	1.09a	1.17a	1.65ab	1.89a	1.86a	1.48a	1.72a	0.96abc	0.74a	0.83ab	0.81a	0.83ab
Prosna	220	0.82bcd	0.95de	0.89abc	0.63abc	0.82bc	1.63ab	1.55abc	1.78a	1.55a	1.63abc	0.73bc	0.79a	0.80ab	0.60a	0.73bc
Glejt	230	0.75cd	1.13cde	0.74abc	0.56abc	0.79bcd	1.70ab	1.58abc	1.63ab	1.54a	1.61abc	1.13ab	0.70a	0.74ab	0.71a	0.82ab
San	240	0.70d	1.26bcd	0.73abc	0.78abc	0.87b	1.65ab	1.83ab	1.74ab	1.38a	1.65ab	0.96abc	0.74a	0.76ab	0.75a	0.80ab
Blask	240	0.62d	0.64de	0.60abc	0.61abc	0.62b-e	1.55ab	1.59abc	1.60ab	1.46a	1.55abc	0.67bc	0.68a	0.70ab	0.65a	0.67bc
Monumental	250	0.54de	0.80de	0.49bc	0.48bc	0.58c-f	0.95cd	1.11bcd	1.81a	1.33a	1.30c	0.80bc	0.64a	0.59ab	0.44a	0.62bc
Moncada	250	0.53de	0.51e	0.55abc	0.53abc	0.53def	1.32bc	1.01cd	1.65ab	1.30a	1.32bc	0.55c	0.46a	0.66ab	0.51a	0.55c
Gavott	270	0.18e	0.48e	0.29c	0.26c	0.30f	0.41e	0.91cd	1.18ab	1.04a	0.88d	0.79bc	0.49a	0.43b	0.40a	0.53c
Chambord	280	0.23e	0.50e	0.39c	0.34c	0.36ef	0.61de	0.69d	0.88b	1.09a	0.82d	0.70bc	0.48a	0.36b	0.50a	0.51c
$LSD_{0.05}$ – $NIR_{0,05}$		0.39	0.74	0.70	0.58	0.29	0.44	0.77	0.86	0.77	0.34	0.49	0.51	0.56	0.42	0.23

means followed by the same letter do not differ at 5% level of significance (Tukey's multiple range test) – średnie oznaczone tą samą literą nie różnią się na poziomie istotności 5% (test wielokrotnych porównań Tukeya)

Table 5. Mean number of feeding tunnels in plant, their length and grain yield in 2005-2008
Tabela 5. Średnia liczba tuneli żerowych w roślinie i ich średnia długość oraz plon ziarna w latach 2005-2008

Cultivar Odmiana	FAO	Mean number of feeding tunnels in the plant, pcs. Średnia liczba tuneli żerowych w roślinie, szt.					Mean length of feeding tunnels in the plant, cm Średnia długość tuneli żerowych w roślinie, cm					Mean grain yield, $t \cdot ha^{-1}$ Średni plon ziarna, $t \cdot ha^{-1}$				
		2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia	2005	2006	2007	2008	mean średnia
KB1902	190	2.67ab	2.70ab	2.88a	2.44ab	2.67a	29.38a	31.90a	32.73a	23.51a	29.38ab	6.81de	5.09bc	6.14d	9.20de	6.81gh
Wilga	190	2.80a	3.11a	2.82ab	2.46a	2.80a	31.07a	37.55a	30.27a	23.87a	30.69ab	4.54f	2.12d	6.89cd	6.10f	4.91i
Fido	210	2.61ab	3.05a	2.46abc	2.53a	2.66a	27.52ab	34.93a	25.96ab	23.23a	27.91b	6.00ef	3.79cd	6.72cd	8.40e	6.23h
Prosna	220	2.23bcd	2.36bcd	2.20a-d	2.14abc	2.23b	21.15c	24.25b	20.62bc	18.57ab	21.15c	7.45de	4.40bc	7.09c	10.85a-d	7.44efg
Glejt	230	2.38abc	2.44bc	2.11b-e	2.09abc	2.25b	23.83bc	23.86bc	20.43bc	17.24bc	21.34c	7.21de	4.59bc	6.91cd	10.05cde	7.19fg
San	240	2.11cde	2.44bc	2.09cde	1.94a-d	2.14bc	20.76cd	21.50bc	19.74bcd	14.62bcd	19.16c	8.29bcd	4.50bc	7.33bc	10.63bcd	7.69efg
Blask	240	1.90def	2.04cde	1.88cde	1.78bcd	1.90cd	16.31de	18.29cd	18.45b-e	12.19cd	16.31d	8.13cd	6.53ab	7.45bc	10.40bcd	8.13de
Monumental	250	1.55f	1.85def	2.03cde	1.71cd	1.78d	14.32e	15.58de	18.76b-e	11.06d	14.93d	8.47a-d	7.46a	8.21ab	11.40abc	8.88cd
Moncada	250	1.75ef	1.64efg	1.91cde	1.71cd	1.75d	14.04e	13.48def	16.82cde	11.82cd	14.04d	9.24abc	8.40a	8.55a	10.78bcd	9.24bc
Gavott	270	0.74g	1.39fg	1.49de	1.39d	1.25e	6.69f	10.77ef	12.32de	9.23d	9.75e	10.02ab	8.69a	9.04a	12.75a	10.12a
Chambord	280	0.96g	1.28g	1.46e	1.58cd	1.32e	7.59f	9.77f	11.83e	10.30d	9.87e	10.12a	8.27a	8.95a	12.35ab	9.92ab
$LSD_{0.05} – NIR_{0,05}$		0.46	0.54	0.73	0.69	0.28	4.60	5.79	7.69	5.96	2.88	1.77	2.21	0.92	1.97	0.84

means followed by the same letter do not differ at 5% level of significance (Tukey's multiple range test) – średnie oznaczone tą samą literą nie różnią się na poziomie istotności 5% (test wielokrotnych porównań Tukeya)

Lisowicz [2003] reported the following major damage of maize plants affecting most negatively the grain yield: direct gnawing of kernels from the cobs, gnawing cobs at the base, and broken stalks below the cobs. Our studies confirmed the negative effect of these damage types on the grain yield.

The carried out analysis of coefficients of correlation and regression demonstrated that cultivar earliness had a significant effect on the number of caterpillars found on a plant (Y1), percentage of damaged plants (Y2), and grain yield, expressed in tonnes per hectare (Y3). Increased FAO index was associated with a decrease in the number of ECB caterpillars on the plant ($r = -0.87$; $p < 0.001$), reduced number of damaged plants ($r = -0.64$; $p < 0.001$) and with an increase grain yield ($r = 0.62$; $p < 0.001$).

The formulated regression equations (Y1, Y2, Y3) demonstrated that the increase in the FAO index by 100 units results in a decrease in the number of caterpillars in the plant, on average by 2.6 caterpillars, a decrease in the number of damaged plants, on average by 24.38% and an increase in the grain yield by 5.07 $t \cdot ha^{-1}$:

$Y1 = -0.0262 \times (FAO) + 9.06$ for $R^2 = 0.76$; $p < 0.001$; $N = 44$
$Y2 = -0.2438 \times (FAO) + 141.23$ for $R^2 = 0.41$; $p < 0.001$; $N = 44$
$Y3 = 0.0507 \times (FAO) - 3.98$ for $R^2 = 0.39$; $p < 0.001$; $N = 44$

The described correlations suggest that the earliness of maize cultivars determined the grain yield mainly through the reduction of the number of damaged plants and the number of caterpillars feeding on a plant.

Results from our studies differ from those obtained by Lisowicz [2004], who investigated six maize cultivars of different earliness (FAO from 190 to 280) and demonstrated a close correlation between the cultivar's earliness and the percentage of damaged plants and cobs, which was expressed by the coefficients of linear correlation of 0.72 and 0.58 respectively. However, Lisowicz did not find such a correlation for the percentage of stems broken below the cob and the percentage of cobs gnawed at the base. According to Lisowicz [2004] the earlier-maturing cultivar, the less susceptible it is to damage by *O. nubilalis* caterpillars. Also, the quoted author suggested that early maize cultivars were less frequently damaged by ECB caterpillars because fast maturing and tissue hardening made pest feeding more difficult, reducing in particular the pest feeding period.

Our studies did not confirm this correlation, and demonstrated a totally reversed effect. When early maize cultivars were grown next to medium-late cultivars, ECB caterpillars preferred the earliest cultivars. The later-maturing cultivar, the less it was damaged by the pest. Also, Sulewska and Ptaszyńska [2007] demonstrated in five-year studies that from among six analysed maize cultivars of different earliness (FAO from 200 to 270) the earliest cultivars were the most susceptible to damage. The quoted authors, however, did not provide statistical evidence for the correlation between the cultivars' earliness and their susceptibility to damage caused by *O. nubilalis*, which may have resulted from the relatively low harmfulness of caterpillars, which damaged from 5.2 to 13.3% of plants. Differences in the susceptibility of early- and late-maturing maize cultivars to damage caused by ECB caterpillars were also reported by Anglade *et al*. [1984], who found that early cultivars were less tolerant to damage caused by *O. nubilalis* than late ones.

On the other hand, Waligóra *et al*. [2008], in their study on sweet corn, did not find any correlation between the susceptibility of studied cultivars to damage caused by ECB and cultivar earliness.

In our studies *O. nubilalis* caterpillars damaged a higher number of plants from early and selected medium-late cultivars in comparison to medium-late ones, which may be associated with their growth dynamics. Early cultivars were characterised by faster development than medium-late cultivars, and thus they may have been more attractive to females depositing eggs. Barry [1989] reported that maize in early developmental stages (when plants are not taller than 38 cm) is less attractive to females depositing eggs, and does not ensure caterpillars' survival. This was also confirmed in studies by Beck [1987]. Moreover, juvenile maize plants have a short-term natural resistance to ECB, determined by the presence of 2-4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA) in their tissues [Barry and Darrah 1991].

Some studies also suggest that the date of grain sowing may be another factor differentiating the harmfulness of *O. nubilalis*. For example, Blandino *et al*. [2008] demonstrated that late sowing increases the damage rate caused by ECB caterpillars in plants. However, in our studies all maize cultivars were sown on the same date, and thus this was not a factor differentiating their susceptibility to damage.

On the other hand, Bača *et al*. [2008] reported that the extent of damage to plants caused by ECB depends not only on the sowing date, but also on the number of *O. nubilalis* generations produced within a year. In Poland the European corn borer produces one generation per year, and only in some years may second generation moths occur at the end of the vegetation season [Żołnierz and Hurej 2007]. Therefore, in our studies the effect of a higher number of ECB generations than one produced within a year on the extent of damage in individual maize cultivars was insignificant.

CONCLUSIONS

A significant effect of earliness of maize cultivars on the extent and type of plant damage caused by the caterpillars of ECB was found under conditions of high infestation with this pest. Early-maturing maize cultivars (FAO 190-220) grown on the field directly next to medium-late cultivars (FAO 270-280) were damaged to a greater extent. Therefore, it is recommended to grow later-maturing cultivars instead of early--maturing ones in regions where *O. nubilalis* causes significant economic losses in maize yields.

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WPŁYW WCZESNOŚCI ODMIAN KUKURYDZY (*Zea mays* L.) NA USZKODZENIA POWODOWANE PRZEZ *Ostrinia nubilalis* HBN. (LEP., CRAMBIDAE)

Streszczenie. Na podstawie wykonanych badań wykazano, że wczesne odmiany kukurydzy o liczbie FAO 190-220 były w większym stopniu uszkadzane przez gąsienice omacnicy prosowianki (*Ostrinia nubilalis* Hbn.) niż odmiany średnio późne o liczbie FAO 270-280. Przeprowadzona analiza współczynników korelacji i regresji wykazała, że wczesność odmian miała istotny wpływ na liczbę gąsienic w roślinie, procent uszkodzonych roślin oraz plon ziarna. Wraz ze wzrostem liczby FAO stwierdzono spadek liczby gąsienic omacnicy prosowianki w roślinie ($r = -0,87$; $p < 0,001$), redukcję liczby uszkodzonych roślin ($r = -0,64$; $p < 0,001$) oraz wzrost plonu ziarna ($r = 0,62$; $p < 0,001$). Z wyprowadzonych równań regresji wynika, że wzrost liczby FAO odmiany kukurydzy o 100 jednostek powoduje spadek liczby gąsienic w roślinie średnio o 2,6 sztuk, zmniejszenie liczby uszkodzonych roślin średnio o 24,38% oraz wzrost plonu ziarna o 5,07 $t \cdot ha^{-1}$.

Słowa kluczowe: FAO, *Ostrinia nubilalis*, podatność odmian, szkodliwość, wczesność odmian, *Zea mays* L.

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