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PHENOLOGY OF *Helicoverpa* (=*Heliothis*) *armigera* (HÜBNER, 1808) (LEPIDOPTERA: NOCTUIDAE: HELIOTHINAE) IN THE CONDITIONS OF MOLDOVA

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Abstract. There are described the phenology and seasonal dynamics of cotton bollworm on tomatoes of "Fakel" variety with medium ripening term in the conditions characteristic to the central zone of Moldova. For forecasting terms of phenological events for cotton bollworm, a method of average daily temperatures, as well as pest development curves based on long-term observations have been used. A model of forecasting terms of oncoming phenological events for cotton bollworm on tomatoes of "Fakel" variety with medium ripening term is constructed.

Keywords: phenology, development dynamics, the sum of effective temperatures, development threshold.

Rezumat. Fenologia speciei *Helicoverpa* (=*Heliothis*) *armigera* (HÜBNER, 1805) (Lepidoptera: Noctuidae: Heliothinae) în condiţiile Moldovei. A fost descrisă fenologia şi dinamica sezonieră a speciei *H. armigera* la cultura de tomate "Fakel" semitimpuriu în condiţiile zonei centrale a Moldovei. Pentru prognozarea termenelor evenimentelor fenologice a speciei *H. armigera* a fost utilizată metoda temperaturilor medii diurne şi a curbelor de dezvoltare a dăunătorului, elaborată în baza observaţiilor multianuale. A fost elaborat modelul de prognozare a termenelor de apariţie a evenimentelor fenologice pentru *H. armigera* la cultura de tomate „Fakel" semitimpuriu.

Cuvinte cheie: fenologia, dinamica dezvoltării, suma temperaturilor efective, pragul de dezvoltare.

INTRODUCTION

Helicoverpa (=*Heliothis*) *armigera* (HÜBNER, 1808) is a widely-spread polyphage. It attacks over 120 species of agricultural plants important for Moldova – tobacco, tomatoes, peppers, corn, and chick pea. Among weeds, it attacks *Solanum*, *Artiplex*, *Datura*, *Hyoscyamus*, *Abutilon*, *Amaranthus*, etc. (LIU *et al.,* 2004, 2007; NASERI *et al*., 2009; VERDEREVSCHII & PRINT, 1951).

Damages cause a significant harm to cultivated plants, affecting appearance and degrading quality and quantity of products. Harvest losses make 10 to 12% and at high numerosity of pests it can reach 50 to 80% (TANSKII *et al*., 1975). In addition to direct destruction of flowers, ovary, fruits, and seeds, larvae of cotton bollworm facilitate the development of mold fungi and putrefactive microbes on damaged parts of the plants.

In recent years, due to the increase of the surface cultivated with sweet corn, tomatoes, chick pea, and soy the harmfulness of cotton bollworm has also significantly increased in Moldova. Due to the invisibility of larvae living inside fruits, pods or spadices, detection and registration of this pest is especially difficult. One of effective means of monitoring and reduction of cotton bollworm number is the usage of traps with sex pheromones. The determination of pest number dynamics allows optimizing terms of carrying out measures meant to lead to the decrease in the population of pests. Up to the present, there have not been carried out any phenology study on *H. armigera* on tomatoes in the conditions of Moldova.

The objective of our work consists in studying phenology and seasonal dynamics of *H. armigera* in the conditions of Moldova on direct-seeded tomatoes, as well as in developing a model for forecasting the terms of appearance, number and harmfulness of this pest for choosing appropriate destructive measures.

MATERIAL AND METHODS

Gathering phenological data has been carried on an experimental field (3.5 hectares) of the Institute of Plant Protection and Ecological Agriculture, Moldova Science Academy, on direct-seeded tomatoes of "Fakel" variety with medium ripening term.

When making repeated forecasts in spring and signalling the fly out of overwintered generation moths, observations of cotton bollworm development began 5 days prior to the predicted moment of the stable transition of the average daily air temperature over 15°C. Terms and dynamics of the fly out of overwintered generation moth have been determined by means of pheromone traps (Figs. 1; 2; 3). Standard traps developed by the All-Russian Research Institute of Biological Plant Protection have been used. A capsule with a pheromone (preparative form – rubber) was replaced each 30 days during the entire period of observations. Cartridges with glue were changed weekly or as needed. Records were made after 3-5 days.

When determining the dynamics of the numerosity of eggs and larvae of cotton bollworm on tomatoes, 10 samples with 10 plants per sample have been taken diagonally from each field plot with an area of 1 hectare. In each sample all plants have been examined and the number of invaded plants and eggs has been calculated. Further, the percentage of invaded plants and average number of pest eggs per invaded plant has been calculated and the number of pest eggs per 100 registered plants has been determined (Figs. 4; 5). The number of cotton bollworm larvae has been determined in the same way (Fig. 6).

Figure 1. Imagoes of *Helicoverpa armigera* in a trap with sex pheromone. / Figura 1. Adulți ai speciei *H. armigera* capturați în capcanele feromonale (original).

Figure 2. Experimental tomato field with pheromone traps. / Figura 2. Câmpul experimental de tomate cu capcane feromonale (original).

Figure 3. Imagoes of *Helicoverpa armigera.* / Figura 3. Adulți ai speciei *H. armigera* (original).

Figure 4. Larvae of *Helicoverpa armigera* on fruits. / Figura 4. Larva speciei *H. armigera* care afectează tomatele (original).

Figure 5. Eggs of *Helicoverpa armigera* on leaves. / Figura 5. Ouă ale speciei *H. armigera* pe frunze (original).

Figure 6. Eggs of *Helicoverpa armigera* on fruits. / Figura 6. Ouă ale speciei *H. armigera* pe tomate (original).

The density of pest population during the phase of the highest harm has been determined on basis of the data on catching males using pheromone traps, starting from seeding into ground till fruits reach a size of not less than 2.5 cm, taking into consideration the number of pest eggs and larvae per 100 plants. Harmfulness margin for cotton bollworm on tomatoes is 5 moths per trap, caught during 1 day, or 15-20 eggs per 100 plants for the first generation and 40-60 eggs – for the second generation, or 15 larvae per 100 plants (TANSKII V. P., *et al*., 1975).

Agroclimatic conditions on tomato field have been registered by means of the automatic station "Agroexpert" (AddVantage, Adcom Telemetry, 1996).

RESULTS AND DISCUSSIONS

Depending on the climatic conditions, the fly out of moths begins in the second half of May and continues till September and even later in rare cases (Fig. 6). In the conditions of Moldova, depending on the climatic features of each, cotton bollworm can give two or three generations. According to different sources, the fly out of the overwintered generation moths begins at an average daily temperature of + 15 to + 18°C and continues as a rule for a little more than a month (FITT, 1989).

As a result of the analysis of long-term observations of average daily air temperatures, it has been established that the predicted date of cotton bollworm awakening in 2005 (date when average daily air temperature steadily exceeds 15°C) was May, 20th (Fig. 7). That is why we placed pheromone traps preliminarily (5 days before the predicted date) on a tomato field for monitoring males of cotton bollworm.

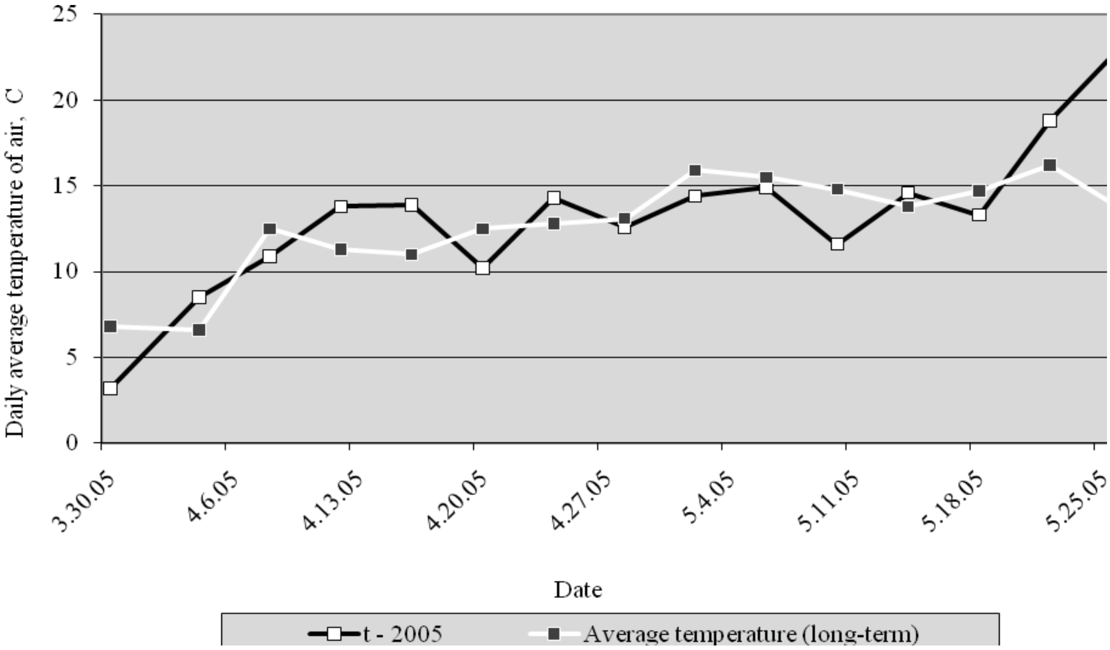

Figure 7. Daily average air temperature.
Figura 7. Temperatura medie diurnă a aerului.

The data of field records show an advancing in comparison with the forecast by 1 day. This is due to the fact that the sum of effective temperatures necessary for imagoes to finish wintering was reached 1 day earlier than it follows from the diagram made on the basis of average long-term observations in 2005. Thus, in 2005 the beginning of catching males of *H. armigera* into pheromone traps in the conditions of central zone of Moldova on a field with tomatoes of "Fakel" variety with medium ripening term was registered on May, 19th, corresponding to the sum of effective temperatures of 77°C at lower development threshold of 11°C, and upper threshold – 33°C (Fig. 8, Table 1). The peak of catching males of *H. armigera* of the overwintered generation occurred in the period between June, 27th and July, 6th. In this connection, we observed that the first shoots of tomatoes appeared on May, 18th and the first true leaf - on May, 24-25th. It was established that till the second decade of June the population density of *H. armigera* of the overwintered generation remained relatively low; average daily catch of males was 1 to 10 individuals per trap. However, during summer, the daily number of caught males reached 32-44 individuals per trap (Fig. 8).

Forecasted period between spring awakening and the beginning of egg laying has been calculated by means of temperature-and-phenological nomogram (PODOLISKII, 1974) and our biological curves for cotton bollworm, based on long-term observations. Thus, in 2005, the predicted term of the beginning of egg laying by overwintered generation was June, 13th. The data of field records show an advancing in terms in comparison with the forecast by 7 days: the beginning of egg laying by the first generation was registered on June, 6th (when the sum of effective temperatures reached 228°C). Since temperatures of the spring 2005 in the central zone of Moldova were close to norms, they could dictate the date of the first oviposition, equal to long-term date. Therefore, such an early oviposition could be explained by a sudden increase of air temperature after imagoes finished wintering. The peak of egg laying by *H. armigera* of the overwintered generation came to the period between June, 27th and July, 8th (Fig. 8, Table 2).

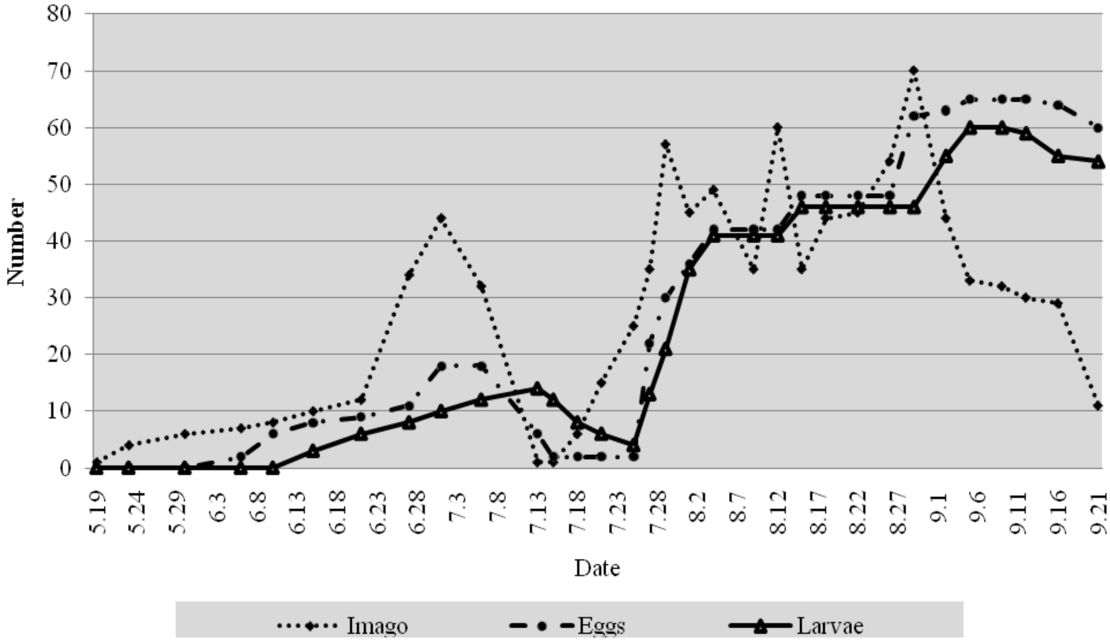

Figure 8. Dynamics of imagoes, eggs and larvae of *Helicoverpa armigera* on direct-seeded "Fakel" tomatoes, 2005.
Figura 8. Dinamica adultului, ouălor şi larvelor *H. armigera* la cultura de tomate din seminţe „Fakel", 2005.

Hatching of *H. armigera* larvae of the first generation (273°C) was registered on June, 13th, that coincided in terms with budding of tomatoes (Fig. 8, Table 2). It was established that the development of the first generation took 49 days, equalling to 600°C of summarized effective temperatures (11/33).

The beginning of the summer period for *H. armigera* males of the first (summer) generation occurred on July, 25th (677°C), egg laying was registered on July, 27th (699°C), and hatching of larvae – on July, 29th (729°C). The population density of the summer generations of *H. armigera* was higher than the overwintered generation. Daily catching of males reached 60-70 individuals per trap and averaged 48-50 individuals per trap during mass fly out. Our observations confirmed the fact early established by other authors, that the terms of the fly out for moths of cotton bollworm of the first and second generations can intercross (MORAL GARCIA, 2006; POSPELOV, 1989).

As a result of made phenological observations, it has been established that the summer generation (generation I) starts laying eggs earlier (on the next day), whereas overwintered generation - significantly later – after 6 days. The same tendency towards reducing terms of oncoming phenophases is traced for hatching of larvae of the second generation: hatching begins the next day, while hatching of the first generation has been observed only after 6 day. At the same time, the third generation of *H. armigera* shows an increase in duration of development for each phase (eggs, larvae and pupae) by 2-3 days in comparison with the second generation (Table 2).

It has been established that the fly out of imagoes of the overwintered generation is associated with the apparition of tomato shoots, and hatching of larvae – with the beginning of budding. The fly out of imagoes of the summer generation (generation I) is associated with the formation of fruits on tomato plants with a size of 2.0-2.5 cm. Thus, larvae of cotton bollworm are provided with food in form of generative organs of plants – the first generation eats buds and flowers and the second one – flowers and fruits. Larvae of the third generation basically eat ripening or ripened fruits that apparently improve accumulation of body fat necessary for chrysalides to winter.

On basis of phenological observations and studying dynamics of imagoes, eggs and larvae of cotton bollworm, we have concluded a phenogram describing terms of oncoming basic phenological events for *H. armigera* population, associated with phenology of direct-seeded tomatoes with medium ripening term in conditions of central zone of Moldova (Table 1).

As seen from Table 1, it has been established that the periods of mass oviposition by moths of each generation and hatching of larvae coincide with phases of flowering, fructification and ripening of tomatoes. Depending on the agroclimatic year conditions, variety and seeding terms of cultivated plants, geographical zone and other factors, terms of oncoming phenological events can be displaced towards one or another side. Earlier a number of authors have proved that there is a direct dependence of the terms of appearance and development of insects on ambient temperature (DOBROVOLISKII, 1969; MIRONIDIS *et al.,* 2008). Therefore the most reliable parameter describing pest population condition is the sum of effective temperatures calculated for various thresholds of insect development. On the basis of obtained data, we propose a model for forecasting the development of *H. armigera*, describing the dependence of oncoming pest phases on the sum of effective temperatures (Table 2).

Table 1. Phenology of *Helicoverpa armigera* on direct – seeded tomatoes of "Fakel" variety with medium ripening term (IPPAE, 2005).
Tabel 1. Fenologia speciei *Helicoverpa armigera* la cultura de tomate „Fakel" din seminţe, semitimpurii (IPPAE, 2005).

Development phases	**Phenological phases for *Helicoverpa armigera* and tomatoes depending on terms (month, decade)**														
	May			**June**			**July**			**August**			**September**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Bollworm	⊇	⊇ ≈	≈	≈ 1•	≈ • 1Θ	≈ • Θ	≈ Θ	≈ 1⊇	1∈ 2• 2Θ	≈ • Θ	≈ • Θ	≈ 2⊇ 2∈ 3•	3 Θ ≈	≈ • Θ	≈ Θ 3⊇
Tomatoes		٧	Ұ		φ	ψ	ψ	ψ Ω	ψ Ω	ψ Ω	ψ Ω	ψ Ω	ψ Ω	ψ Ω	Ω

٧-emergence of shoots; Ұ-apparition of first true leaf; φ - budding; ψ - flowering; Ω - fructification; ⊇ - pupae; 1, 2, 3 - generations; ∈ - beginning of flying of a generation; ≈ - fly out of overwintered imago; • - egg laying; Θ - hatching of larvae of age I

Table 2. Model of forecasting development of *Helicoverpa armigera* on tomatoes.
Tabel 2. Modelul de prognozare a dezvoltării speciei *Helicoverpa armigera* la tomate.

Phenophases of *H.armigera*			**Phases of cotton bollworm development and direct – seeded tomatoes of "Fakel" variety and accumulated sum of effective temperatures**								
			Beginning of overwintered imagoes flying	**Generation I**			**Generation II**			**Generation III**	
				Beginning of oviposition	**Hatching of larvae of age I**	**Beginning of imagoes flying**	**Beginning of oviposition**	**Hatching of larvae of age I**	**Beginning of imagoes flying**	**Beginning of oviposition**	**Hatching of larvae of age I**
Date ↑			19.05	06.06	13.06	25.07	27.07.	29.07	25.08	29.08	02.09
Development thresholds for *H. armigera*, °C	11/ 33	$\sum_1$	77	228	273	677	699	729	1038	1080	1120
		$\sum_2$		151	45	190	22	30	124	42	40
		$\sum_3$			196	600	622	652	961	1003	1043
Date ↓			18.05	25.05	15.06	21.06	27.06	29.06	22.07	01.08	11.08
Phenological events for tomatoes			**Shoots**	**First true leaf**	**Budding**	**Beginning of lowering**	**Mass flowering**	**Formation of the first fruits**	**Fruits with a size of ≈ 2 cm**	**Beginning of fruit ripening**	**Mass fruit ripening**

Legend: $\sum_1$– sum of effective temperatures with accumulation
$\sum_2$– sum of effective temperatures only for a certain development phase
$\sum_3$ – sum of effective temperatures from the moment when imagoes finished wintering

Note: Sums of effective temperatures were calculated by means of computer program elaborated by Doctor habilitate of Biology Todirash V. (http://i.1asphost.com/probio).

Thus, proceeding from the offered model based on values of average long-term temperatures, it is possible to calculate the date of oncoming phenological phase for *H. armigera* in various geographical zones for the current period of time.

CONCLUSIONS

The determination of the seasonal dynamics of *H. armigera* flying on direct-seeded tomatoes of "Fakel" variety with medium ripening term in the central zone of Moldova has revealed the presence of two full generations and one incomplete generation of the pest. It has been experimentally confirmed that the occurrence of the phenological events for *H.armigera* is timed to the phenology of tomatoes. Hatching of larvae of the first generation coincides with the terms of the the phases of mass blossoming – beginning of budding, but hatching and development of larvae of the second and third generations occurs in the period of fruiting and fruit ripening stage.

The model elaborated by us may be used for forecasting the terms of optimizing the choice of necessary protective measures and terms of their implementation.

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