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EFFECT OF VARIOUS BRASSICA HYBRIDS ON PARAMETERS OF DEVELOPMENT OF CABBAGE MOTH *MAMESTRA BRASICAE* (L.) (LEPIDOPTERA: NOCTUIDAE) UNDER LABORATORY CONDITIONS

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The development, survival and reproduction of cabbage moth, Mamestra brassiae (L.), were studied in a laboratory (at room indoor temperature and 16 : 8 hours photoperiodism) on six host plants, including one hybrid of the broccoli F_1 Heraklion (Brassica oleracea L. var. italica) and 5 hybrids of the white cabbage F_1 Kolobok, F_1 Orion, F_1 CB-3, F_1 Kazachok and F_1 Agressor (Brassica oleracea L. var. capitata). The developmental time of immature stages ranged from 23.02 ± 0.61 days on broccoli F_1 Heraklion to 26.14 ± 0.96 days on white cabbage F_1 Orion. Cabbage moth larvae successfully survived on all host plants, although the highest and the lowest survival rates were registered on F_1 CB-3 and Orion, respectively. The sex ratio at pupal stage was the following: female – biased on the F_1 Heraklion, F_1 CB-3, F_1 Kazachok, and male – biased on F_1 Kolobok, F_1 Orion and F_1 Agressor. There was significant difference observed in fecundity of females depending on the tested food plants at reproductive stage. The highest and the lowest M. brassicae female fecundity rates were recorded on the F_1 Heraklion (1151.56 ± 301.42 eggs) and F_1 Agressor (513.67 ± 218.13 eggs), respectively. The 2 late–ripening cabbage hybrids F_1 Orion and F_1 Agressor showed themselves as the most resistant host plants to cabbage moth M. brassicae (L.).

Key words: cabbage moth Mamestra brassicae, developmental time, survival rate, fecundity rate, reproduction.

Cabbage moth *Mamestra brassicae* (L.) (Lepidoptera: Noctuidae) is the most widespread pest of brassica vegetables throughout Asia and Europe. This pest is polyphagous and affects over 70 host plant species that belong to 22 families, *Brassicaceae* and *Chenopodiaceae* being among the most preferred [5, 6]. Larvae development and feeding on the main host cabbage *Brassica oleracea* (L.) result in substantial economic losses when growing the crop.

Current strategies of cabbage moth management are based on the use of chemical insecticides, but this approach is undesirable as far as chemical control has several unwanted side effects, such as pesticide residues in consumer products, which in its turn cause adverse impact on human health, animals health and environment [4]. Moreover, most of the species such as cabbage moth *Mamestra brassicae* may show resistance to various groups of chemical insecticides. Considering this fact more environmental friendly methods should be used in plant protection, for instance, cultivation of resistant crop varieties and hybrids, the use of insecticides having microbial and viral nature, i.e. bacteria, viruses etc., in order to avoid undesirable effects of the chemical control.

The use of resistant crop varieties and hybrids is an important component of integrated plant protection. Host plants resistance is the relative amount of heritable qualities of a plant that reduce pest damage degree [2].

For polyphagous insects the availability of different host plant has an important role in triggering population outbreaks and studying the effects of food quality. Host plants with deleterious compounds are the key of reduced longevity, survival and reproductive rates of herbivorous arthropods or they may indirectly affect the natural enemies of pests as a result of prolonged development time [3].

The aim of this study was to investigate the influence of food plants on certain biological parameters of cabbage moth, *Mamestra brassicae* (L.), such as the duration of larval period, survival rate of larvae, reproductive rate of adults and sex ratio of pupae.

Materials and methods

Plant material. Six hybrids of cabbage plants were used in this experiment, including one hybrid of broccoli F_1 Heraklion (*Brassica oleracea* L. var. *italic*) and five hybrids of white cabbage (*Brassica oleracea* L. var. *capitata*): one hybrid of the early-ripening cabbage F_1 Kazachok, one of the mid-ripening cabbage F_1 CB-3, and three of the late-ripening cabbage F_1 Kolobok, F_1 Orion and F_1 Agressor. Seeds germinated in mid – May under the greenhouse conditions with no artificial lighting. When the seedling had 3 leaves, it occurred at the beginning of June and they were planted in the field. All plants were grown on the same experimental plot under equal agronomic conditions. The leaves of these hybrids were used in laboratory studies before cabbage head formation.

Moth rearing. The laboratory experiments were started from egg clutches collected from white cabbage on an experimental field of the Department of Plant Protection in Russian Timiryazev State Agrarian University, Russia. To avoid the systematic error by the time factor affecting the food plant quality, the egg clutches were all collected within one week. These egg clutches were placed in Petri dishes (8 cm diameter and 2 cm height) and these dishes were placed in an thermostat at 28°C. The eggs were checked daily and the number of daily emerged larvae was recorded.

Larvae hatched from egg clutches were taken from Petri dishes using a small brush and reared on cut leaves of the host plant, placed in Petri dishes on moist filter paper discs. Each host plant underwent to five treatments, every treatment with at least 10 larvae, i.e. in all dishes there were no less than 50 larvae. The larvae were transferred to transparent plastic cages (15 cm × 8 cm × 5 cm) after they reached the fourth larval instar. The fresh foliages were provided daily as necessary until the pupal stage.

Development and survival. Experiments were carried out in a chamber at the Department of Plant Protection in Russian Timiryazev State Agrarian University, Russia, set at room indoor temperature and a photoperiodism of 24 hours. Experiments began when *M. brassicae* larvae reached II instar stage, each food plant being infested. The larvae were daily checked and were fed by fresh cabbage leaves. Before pupation, the plastic cages were filled with sawdust to allow the larvae to pupate. Their developmental time, survival rate were recorded on each tested host plant.

Reproduction and population growth parameters. After adult emergence, 10 pairs of the male and female (each pair as one replicate) reared on each host plant were taken for the reproduction experiment. Each pair was placed in a transparent plastic cage for subsequent mating and egg laying. The top of the cage replaced by a covering of fine mesh gauze.The inside of cages was glued by filter paper for oviposition of the females. The newly laid eggs on filter paper were checked daily, removed from cages and counted for quantitative and qualitative analysis. The male and female adults of *M. brassicae* daily fed on cotton soaked into 1% honey solution.

Daily monitoring continued until death of adults. To obtain the sex ratio on each host plant, 50 hatched larvae were placed on the each corresponding host plant foliage and maintained until pupae emergence. Such different parameters as oviposition period, adult longevity and age-specific fecundity were also determined.

Statistical analysis. The data were analysed using Statistica 5.5. Differences in developmental duration, survival, longevity and fecundity of cabbage moth population were tested by one – way ANOVA/ MANOVA.

Results

Developmental time. The development of cabbage moth larvae, *Mamestra brassicae* (L.) was affected by the host plant (Table 1). The longest total developmental duration was on white cabbage F_1 Orion (26.1 ± 0.96 d) and the shortest – on broccoli F_1 Heraklion (23.0 ± 0.61 d) ($F = 5.08$; $p < 0.05$).These results showed no significant differences of the developmental time larvae in instars II ($F = 1.64$; $p > 0.05$), instars III ($F = 1.70$ $p > 0.05$) stages and prepupa stage ($F = 1.88$; $p > 0.05$).

Survival rate. The different host plants affected the survival of the cabbage moth *M. brassicae* (L.) larvae ($F = 2.74$; $p < 0.05$) (Table 2). The lowest survival rate of larvae was on F_1 Orion (38.0 ± 10.51%), and the highest on F_1 CB-3 (80.0 ± 13.97%) ($F = 2.74$ $p < 0.05$). The survival rate on Orion was significantly lower than on other food plants. This was due to a lower survival rate at second instars larva stage as well as at fourth instars. There was no significant difference observed between survival rates of larvae on six hybrids in each stage.

Sex ratio of pupa. The sex- ratio of pupae from larvae fed on broccoli F_1 Heraklion and cabbage F_1 CB-3, F_1 Kazachok were female – biased, whereas pupae from larvae fed on cabbage F_1 Kolobok, F_1 Orion and F_1 Agressor were male – biased (Table 4).

Reproductive parameters. In our unpublished data, flight of the females and males moth from pupae on hybrid F_1 Orion was low, so we could not assess the fertility of females on this host plant. We conclude that one of the reasons for such result is reduced viability of larvae growing on the lower quality host plant for cabbage moth.

The fecundity results showed that at the high average temperature (27.5°C) there were differences in fecundity of female's cabbage moth depending on various food sources (Table 4). The highest and lowest fecundity of females *M. brassicae* was recorded on the F_1 Heraklion (1151.6 ± 301.42) and F_1 Agressor (513.7 ± 218.13), respectively. The number of laid eggs per female per day showed the similar trend with its low value on F_1 Agressor and high value on F_1 Heraklion. There was no significant difference observed among oviposition periods of females on all the five food plants ($F = 1.20$; $p > 0.05$). The longest and shortest of the oviposition periods of the female *M. brassicae* were recorded on the F_1 CB-3

Table 1

Mean developmental time (day ± SE) **of immature stage of *M. brassicae* on various brassicaeous host plants at 24.1°C**

Host plant	Stages							
	L_1	L_2	L_3	L_4	L_5	L_6	Prepupa-pupa	L_1 – pupa
F_1 Kolobok	3.0 ± 0.04 a	3.2 ± 0.21ab	3.0 ± 0.19 ab	3.0 ± 0.22ab	3.4 ± 0.26 a	5.5 ± 0.43ab	3.9 ± 0.23	25.2 ± 0.63bc
F_1 Orion	3.4 ± 0.11 b	3.1 ± 0.09ab	3.1 ± 0.07 b	3.4 ± 0.17 c	3.4 ± 0.23 a	6.1 ± 0.62 b	3.6 ± 0.38	26.1 ± 0.96 c
F_1 Heraklion	3.0 ± 0.07 a	2.9 ± 0.12 a	2.9 ± 0.12 a	2.8 ± 0.12 a	3.1 ± 0.07ab	4.8 ± 0.35 a	3.4 ± 0.27	23.0 ± 0.61a
F_1 CB – 3	3.1 ± 0.04 a	3.1 ± 0.09ab	3.1 ± 0.08 ab	3.1 ± 0.08 b	3.1 ± 0.09ab	5.1 ± 0.24 a	3.8 ± 0.19	24.3 ± 0.26 ab
F_1 Kazachok	3.3 ± 0.11 b	3.2 ± 0.04 b	2.9 ± 0.12 ab	2.9 ± 0.14ab	3.1 ± 0.33ab	4.7 ± 0.76 a	4.0 ± 0.46	24.2 ± 1.41 ab
F_1 Agressor	3.3 ± 0.11 b	3.1 ± 0.04 ab	3.1 ± 0.07 ab	3.0 ± 0.10ab	2.9 ± 0.18 b	5.0 ± 0.32 a	3.4 ± 0.39	23.8 ± 0.89 ab
	$F_f > F_t$	$F_f < F_t$	$F_f < F_t$	$F_f > F_t$	$F_f > F_t$	$F_f > F_t$	$F_f < F_t$	$F_f > F_t$

Mean marked with the same small letter within the same row are not significantly different (Duncan's multiple range test, α = 0.05).

Table 2

Survival rate (%) **at various stages and instars of cabbage moth on six brassica host plants**

Host plant	Stages							
	L_1	L_2	L_3	L_4	L_5	L_6	Prepupa-pupa	L_1 - pupa
F_1 Kolobok	94.0 ± 4.42ab	91.8 ± 10.56ab	94.9 ± 5.68 a	100.0 ± 0.00 a	97.5 ± 4.51	94.3 ± 10.30	90.8 ± 8.30	68.0 ± 13.25 b
F_1 Orion	94.0 ± 10.82ab	82.3 ± 14.24 a	89.5 ± 8.11 a	81.9 ± 21.10 b	88.3 ± 13.10	92.5 ± 13.52	88.5 ± 13.64	38.0 ± 10.51a
F_1 Heraklion	90.0 ± 8.06 ab	96.0 ± 4.42 ab	97.5 ± 4.51 a	97.8 ± 4.01 a	100.0 ± 0.00	97.8 ± 4.01	82.1 ± 20.84	66.0 ± 18.57 b
F_1 CB – 3	98.0 ± 3.61b	100.0 ± 0.00 b	96.0 ± 4.42 a	100.0 ± 0.00 a	100.0 ± 0.00	100.0 ± 0.00	84.9 ± 13.72	80.0 ± 13.97 b
F_1 Kazachok	76.0 ± 23.23 a	95.0 ± 9.02ab	93.8 ± 7.32 a	98.0 ± 3.61 a	100.0 ± 0.00	100.0 ± 0.00	93.8 ± 7.32	60.0 ± 18.91ab
F_1 Agressor	96.0 ± 4.42 ab	80.9 ± 9.70 a	94.2 ± 6.55 a	97.1 ± 5.15 a	100.0 ± 0.00	91.8 ± 10.16	98.0 ± 3.61	64.0 ± 13.49 b
	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	$F_f > F_t$

Mean marked with the same small letter within the same row are not significantly different (Duncan's multiple range test, α = 0.05).

and F_1 Kazachok, respectively. The oviposition periods of the females cabbage moths on broccoli F_1 Heraklion and early-ripening cabbage F_1 Kazachok were shorter than on other food plants and this was due to the fact that their longevity is lower than on F_1 Heraklion and F_1 Kazachok ($F = 0.93$; $p > 0.05$). Male adult longevity showed the similar trend, its value being lower on F_1 Heraklion and F_1 Kazatrok ($F = 2.36$; $p > 0.05$).

The age-specific reproductive parameters of cabbage moth were obtained by female-based method (Table 5). According to this table, the *M. brassicae* cohort reared on hybrid F_1 Agressor had the lowest intrinsic rate of increase (r_m) – 0.38, whereas the cohort on F_1 Heraklion had higher value – 0.56. The net reproductive rate (R_0) and the finite rate of population change (λ) showed the similar results, its value being the lowest on F_1 Agressor (71.82) and the highest on F_1 CB-3 (389.56) and F_1 Heraklion (312.07).

Table 3

Sex ratio of pupal cabbage moth *M. brassicae* (L.) on six host plants

Hybrid	Pupal sex ratio
F_1 Kolobok	1 : 1.4
F_1 Orion	1 : 1.19
F_1 Heraklion	1.15 : 1
F_1 CB-3	1.26 : 1
F_1 Kazachok	1.52 : 1
F_1 Agressor	1 : 1.32

Table 4

Oviposition period, adult longevity (days ± SE) **and fecundity** (eggs per female) **of cabbage moth, *M. brassicae* (L.) on five brassicaceous host plant**

Host plant	Stage							
	Pre - oviposition period	Oviposition period	Post-oviposition period	Female longevity	Male longevity	Fecundity	Fertile eggs	Laid egg/ day
F_1 Kolobok	2.4 ± 0.36a	6.6 ± 1.62a	2.0 ± 0.93a	11.0 ± 2.25a	10.0 ± 1.09ab	919.9 ± 181.26ab	460.4 ± 187.80a	160.5 ± 34.27ab
F_1 Heraklion	2.4 ± 0.51a	5.9 ± 1.38a	2.1 ± 0.84a	10.3 ± 1.87a	8.6 ± 1.25a	1151.6 ± 301.42b	583.4 ± 395.04a	196.6 ± 49.71b
F_1 CB-3	2.0 ± 0.25a	8.1 ± 1.29a	0.8 ± 0.25a	10.9 ± 1.33a	10.1 ± 1.10ab	1120.0 ± 312.17ab	698.0 ± 406.62a	139.1 ± 34.68ab
F_1 Kazachok	3.2 ± 1.05a	5.1 ± 1.67a	1.9 ± 0.69a	10.2 ± 0.96a	8.3 ± 1.66a	762.0 ± 422.58ab	297.2 ± 275.06a	124.8 ± 48.14ab
F_1 Agressor	2.8 ± 0.42a	5.8 ± 1.80a	1.9 ± 0.59a	11.3 ± 1.79 a	10.8 ± 1.00b	513.7 ± 218.13a	170.0 ± 151.52a	86.4 ± 22.84a
	$F = 1.34$ $p = 0.273$	$F = 1.19$ $p = 0.326$	$F = 1.27$ $p = 0.297$	$F = 0.93$ $p = 0.984$	$F = 2.36$ $p = 0.069$	$F = 1.76$ $p = 0.156$	$F = 1.07$ $p = 0.382$	$F = 2.45$ $p = 0.061$

Mean marked with the same small letter within the same row are not significantly different (Duncan's multiple range test, α = 0.05).

Table 5

Female – age based – specific reproductive parameters of *Mamestra brassicae* (L.) on five brassica hybrids

Hybrid	Net reproductive rate per generation, R_0	Intrinsic rate of increase, r_m	Finite rate of population change, л	Mean length of a generation, T
F1 Kolobok	191.53	0.48	1.61	11.00
F1 Heraklion	312.07	0.56	1.74	10.33
F1 CB-3	389.56	0.55	1.73	10.89
F1 Kazatrok	179.28	0.51	1.66	10.22
F1 Agressor	71.82	0.38	1.46	11.33

The highest and lowest of the finite rate of population change (λ) were recorded on F_1 Heraklion (1.74) and F_1 Agressor (1.46), respectively. Moreover, the mean generation time (T) ranged from 10.22 days (F_1 Kazachok) to 11.33 days (F_1 Agressor).

Discussions

Biological parameters of cabbage moth, *Mamestra brassicae* (L.), vary considerably with cultivars and hybrids of host plants [8]. Certain plant characteristics including biochemical or morphological factors, or combination of both may promote resistance to this insects [7]. Not many studies have examined the effects of host plants on the developmental parameters of cabbage moth population such as survival larvae, longevity and fecundity of the adults.

This study indicated that the development time of larvae varied considerably with the food plant. In the present study the longest developmental time of individuals from neonate to the end of the pupal stage was recorded on cabbage F_1 Orion (26.1 ± 0.96 days) and the shortest – on broccoli F_1 Heraklion (23.0 ± 0.61 days). This result allows assuming that difference in food sources probably affect the duration of developmental time of the larval stage. In the studies, conducted by T.A. Popova on the resistance effect of cabbage cultivars on cabbage moth *M. brassicae* at 25°C temperature and 65–75% RH, the development time of larvae fluctuated from 19.9 d (on Kohlrabi) to 22.6 d (on cabbage Zymovka) [5]. Divergence of results of the studies could be attributed to distinctions among nutritional content of host plants cultivars and differences within tested moth population.

The survival rate of insect on Orion (38.0 ± 10.51%) was the lowest as compared with that one on the other food plant. The highest survival rate was recorded on mid-ripening cabbage F_1 CB-3 (80.0 ± 13.97%).The high survival rate was also observed on the broccoli F_1 Heraklion (66.0 ± 18.57%).This difference could result from the presence of such nutrient compounds as glucosinolates which affect as toxin for various pests as well as for Lepidopterans [7]. Our studies indicated that broccoli F_1 Heraklion and early – ripening cabbage F_1 Kazachok were recognized as the most suitable host plants for development of cabbage moth larvae, *Mamestra brassicae* (L.), and late-ripening cabbage F_1 Orion may increase the developmental time of the larvae and reduce their survival.

Fecundity is defined as the number of offspring produced by an individual insect, whereas fertility is the number of viable offspring produced. Awmack and Leather [1] suggested that if larvae of an insect were fed on poor-quality host plant, their females emerging from pupae of these larvae may modify its oviposition behaviour either by reducing the number of laid eggs on each host plant or, in some cases, adjusting the size or nutritional content of eggs. And changes in host plants may also lead to changes in the sex ratio of insect and affect the male insect's contribution to the production of fertile eggs [1]. In our studies the sex ratio of the pupae from larvae fed on broccoli F_1 Heraklion and cabbage F_1 CB-3, F_1 Kazachok was female – biased, whereas pupae from larvae fed on cabbage F_1 Kolobok, F_1 Orion and F_1 Agressor was male – biased. In this case, fecundity and the number of fertile eggs were the lowest on the new cabbage hybrid F_1 Agressor, but on hybrid F_1 Kolobok they were the highest. High fecundity and number of the fertile eggs were recorded on the F_1 Heraklion and F_1 CB-3, while he minimal values were typical of F_1 Kazatrok, although sex ratio of theses host plants was female- biased.

The fecundity of cabbage moth females in our study ranged from 513.7 to 1151.6 eggs on cabbage hybrid F_1Agressor and broccoli hybrid F_1 Heraklion, respectively. Broccoli F_1 Heraklion appeared to be more appropriate for oviposition than the other cabbage hybrids. There was difference in fecundity and laying fertile eggs between the moth females on all tested host plants. But in some replicates of the present studies (our unpublished data) females laid only sterile eggs, particularly on cabbage F_1 Agressor and F_1 Kazachok. This can be explained by the fact that various food source may affect fecundity of the females. In addition, the study was carried out when the average temperature in the laboratory rose to 27.5°C. Therefore, we supposed that not only various food sources, but high temperature as well can influence the behaviour, longevity and fecundity of the female moth. Thereby, the lowest amount of the laid fertile eggs and the laid eggs per female per day was recorded on late-ripening cabbage F_1 Agressor. The highest values of these biological indicators of cabbage moth females were recorded on broccoli F_1 Heraklion.

The intrinsic rate of increase (r_m) is an important indicator of population dynamics that represents many biological characteristics such as fecundity, survivorship and developmental time of an insect in relation to its qualities. Its value determines whether a population increases exponentially ($r_m > 0$), remain constant in size ($r_m = 0$), or declines to extinction ($r_m < 0$). The higher value of r_m indicates the susceptibility of a food plant to herbivorous insect, while the lower value indicates that the host plant is resistant to the insect [3].

In this study, the highest r_m value was recorded on F_1 Heraklion (0.56), which is the repercussion of lower mortality and shorter developmental time of the cabbage moth *M. brassicae*. According to this, lower r_m value (0.38) indicates that moth larvae had long developmental time, high mortality and low fecundity on hybrid F_1 Agressor.

Our results showed that broccoli F_1 Heraklion was recognized as the most suitable host plant for development of cabbage moth larvae, *Mamestra brassicae* (L.), and late-ripening cabbage F_1 Orion showed itself as the most resistant to this pest. In addition, the new cabbage hybrid F_1 Agressor was significantly affected by the offspring of cabbage moth.

The results of these studies could lead to understanding of the host plant influence on the biological parameters of the cabbage moth and help to minimise the damage and economic losses caused by cabbage moth *Mamestra brassicae*.

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ВЛИЯНИЕ КАПУСТНЫХ ГИБРИДОВ НА ПАРАМЕТРЫ РАЗВИТИЯ КАПУСТНОЙ СОВКИ *MAMESTRA BRASSICAE* (L.) (LEPIDOPTERA: NOCTUIDAE) В ЛАБОРАТОРНЫХ УСЛОВИЯХ

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Исследования по изучению биологических параметров капустной совки Mamestra brassicae (L.) были проведены в лаборатории на 6 различных кормовых источниках, включающих в себя 1 гибрид брокколи F_1 Гераклион и 5 гибридов F_1 белокочанной капусты Колобок, Орион, СБ-3, Казачок и Агрессор. Продолжительность развития капустной совки при 24,1°С колебалась от 23,02 ± 0,61 сут. на гибриде Гераклион до 26,14 ± 0,96 сут. на гибриде Орион. Выживаемость гусениц находилась в пределах от 38% до 80%. При этом максимальная гибель была зафиксирована в варианте Орион, минимальная – в варианте СБ-3. Питание в репродуктивный период оказывало влияние и на соотношение полов в потомстве: в вариантах Колобок, Орион и Агрессор – увеличение доли самцов; напротив, в вариантах Гераклион, СБ-3 и Казачок – выше доля самок. Плодовитость самок варьировала от 513,7 ± 218,13 (Агрессор) до 1151,6 ± 301,42 яиц (Гераклион). Таким образом, по биологическим параметрам капуст-

ной совки можно судить о степени устойчивости (восприимчивости) кормового источника для вредителя. По нашим данным, гибриды F_1 Орион и Агрессор относительно устойчивы к капустной совке.

Ключевые слова: капустная совка Mamestra brassicae (L.), продолжительность развития, выживаемость, плодовитость, репродукция.

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