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LEDS AND SEMIOCHEMICALS VS. SEX PHEROMONES: TESTS OF THE EUROPEAN CORN BORER ATTRACTIVITY IN THE KRASNODAR TERRITORY

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In two geographical points of the Krasnodar Territory, viz. vil. Botanika, Gulkevichi District (eastern subzone of the Central natural-economic zone of the Krasnodar Territory) and st. Kurchanskaya, Temryuk District (Anapo-Taman natural-economic zone) on industrial plantations of maize, Delta sticky traps supplied with various baits were tested for attractiveness for adults of the European corn borer (ECB), *Ostrinia nubilalis* Hbn. In contrast to sex pheromones, traps with 'bisex lure' (semiochemicals phenylacetaldehyde and 4-methoxy-2-phenethyl alcohol) or LEDs captured a considerable number of females, whose prognostic value was significantly higher than that of males. On maize fields near Botanika traps with 'bisex lure' caught moths almost at 20- and traps with LEDs more than 70-fold higher rate as compared to sex pheromones. On maize plantations near Kurchanskaya, where both the saturation of crop rotations with maize fields and the pest population is significantly lower, semiochemicals caught ECB moths at the same rate as sex pheromones, in contrast to LEDs, which attracted insects by an order of magnitude more frequently. The results of the tests indicate that the use of LED traps for monitoring of ECB is promising under the modern economic situation of expanding the territories intended for the production of corn grain.

Keywords: attraction, *Ostrinia nubilalis*, sticky Delta trap, bisex lure, LED, sex pheromone

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Introduction

Phytosanitary monitoring is an essential component of integrated plant management systems and the All-Russian Institute of Plant Protection (VIZR) represents a long-standing center for development of technological solutions that ensure its implementation in relation to harmful entomological objects (Andreev et al., 1976; Burov, Sazonov, 1987). Although modern tools of catching insects are extremely diverse (Epsky et al., 2008; Golub et al., 2012) traps with synthetic analogs of sex pheromones are currently the most popular due to their undeniable advantages, i.e. cheapness, mobility, ease of installation and selectivity of the attracting action in relation to the target object of monitoring (Frolov, 2011). Thus, to account for the number of one of the most dangerous pests of maize, the European corn borer (ECB), *Ostrinia nubilalis* Hbn. (Lepidoptera: Crambidae) traps with synthetic sex pheromones have been used for many years (Laurent, Frérot, 2007). At the same time, the evidence increases showing that the attractiveness of *O. nubilalis* varies greatly depending on the area and season, sometimes reaching zero values in the number of captured males with significant damage to crop by larvae of the daughter generation (Grushevaya et al., 2015), which is an obvious consequence of the complexity of the insect's manner of migration behavior (Sappington, 2018). In addition, pheromone traps catch only males whose predictive value is significantly lower than that of females (Witzgall et al., 2010).

To date, many compounds of plant origin that are attractive to phytophagous insects, including ECB, have been identified (Reinecke, Hilker, 2018), phenylacetaldehyde being the most known among them (Cantelo, Jacobson, 1979; Maini, Burgio,

1990; Molnár et al., 2015). Recently, it has been found that the addition of 4-methoxy-2-phenethyl alcohol, also isolated from maize, to this compound increases the catchability of traps by a factor of 3–5 (Tóth et al., 2016). Tests conducted in five European countries of this semiochemical combination under the commercial name 'bisex lure' has confirmed this conclusion (Tóth et al., 2017). The results of our 2019 pilot tests of traps baited with 'bisex lure' also indicate that the combination of these semiochemicals is highly effective for monitoring ECB both in the Krasnodar Territory and Voronezh Region (Frolov et al., 2020).

Light traps have long been used as a tool of monitoring flying insects (Williams, 1940; Terskov, Kolomiets, 1966; Andreev et al., 1970). Like semiochemicals, light, unlike the sex pheromones of Lepidoptera, attracts individuals of both sexes (Gornostae, 1984; Nowinszky, Puskás, 2015). Until recently, the widespread use of light traps was hindered by their bulkiness and high energy consumption, but thanks to the advent of LED technology, these disadvantages were overcome (Chu et al., 2003; Holguin et al., 2010; Ismailov et al., 2016). Examples of the use of LED traps for ECB monitoring are still rare (Cizej et al., 2014), but their prospects for tracking fluctuations of the target species abundance have already been convincingly confirmed by the results of tests conducted in 2019 (Grushevaya et al., 2019).

The aim of this work is to conduct a comparative assessment of the attractiveness of LEDs and plant-derived semiochemicals for ECB adults in comparison with synthetic sex pheromones when using Delta sticky traps of similar design.

Material and Methods

The research was carried out on commercial maize plantations in 2020 in two localities of the Krasnodar Territory: (1) in the vicinity of village Botanika, Gulkevichi District (45°12'51"N 40°47'41"E) on the territory of the Kuban Experimental Station VIR (KOS VIR, branch of the All-Russian Institute of Plant Genetic Resources named after N. I. Vavilov) and (2) in the vicinity of stanitsa Kurchanskaya, Temryuk District (45°12'56"N 37°33'48"E) in the fields of the Kurtakov enterprise. In each of the test points, two fields occupied by maize plantings were selected: one near vil. Botanika, plots of 13 and 10 ha (both of hybrid Komandos KWS), and another near st. Kurchanskaya, plots of 27 and 16 ha (both of hybrid Ladozhsky 292 AMR). Two types of Delta sticky traps were used for testing: standard cardboard products manufactured by JSC "Shchelkovo Agrokhim" (Moscow) and plastic ones manufactured in VIZR (St. Petersburg, Pushkin). One of the following baits was placed in each cardboard trap: 1) a rubber dispenser with a synthetic sex pheromone (100 mcg/dispenser) attracting males of ECB race Z (pheromone composition 3:97 E/Z 11-14:OAc), E (99:1 E/Z 11-14:OAc) or ZE (65:35 E/Z 11-14:OAc) (all produced by JSC "Shchelkovo Agrokhim" and designated as test variants Z, E and ZE correspondingly); 2) a rubber dispenser with a synthetic sex pheromone (100 mcg/dispenser) attracting males of ECB Z race (produced by Company "Pheromone Ltd", Moscow, designated as the Z1 variant); 3) 'bisex lure' (a combination

of phenylacetaldehyde and 4-methoxy-2-phenethyl alcohol, 100 mg each) in a plastic dispenser, produced by the Institute of Plant Protection, Budapest, Hungary (test variant SC). Plastic traps (Miltyn et al., 2020) were equipped with a removable cassette with two LEDs with a peak power of 3 W each, emitting light with a wavelength of 365–370 nm in opposite directions along the trap body. The power source was 6 1.2 V batteries, 2200 mA/h, and the controlling device was Attiny 13A microcontroller, which allowed automatically reprogramming the threshold for triggering the trap in terms of illumination (test variant LT). Thus, a total of 6 types of baits were used in the tests designated as Z, E, ZE, Z1, SC, and LT respectively. Traps equipped with the above mentioned types of bait were placed in three randomized blocks on each of the studied maize fields in early July. The distance between the traps inside the block was 8–10 m, and between the blocks — at least 30 m. Inspection of traps and counting of captured moths was carried out every 3–4 days, starting from the moment when the first ECB adult was trapped (before this time point the traps were examined daily). Insects caught in traps were removed, and the sticky sheet could be replaced with a fresh one in case of severe contamination. Statistical data processing was performed using ANOVA with logarithmic or Fisher's ϕ data transformation; Duncan's multiple range test at $p_a \leq 0.05$ was used to compare the significance of differences found.

Results and Discussion

Flight of ECB moths was recorded in traps set on maize plantations near vil. Botanika from July 11 till August 27, and near st. Kurchanskaya — from July 09 till August 23. Average

estimates of the densities of captured insects per 1 trap per 7 days of flight depending on the type of bait are shown in table 1.

Table 1. Mean densities of ECB adults captured by Delta sticky traps with different baits (calculated per 1 trap per 1 week) (Krasnodar Territory, 2020)

The point of testing	JSC "Shchelkovo Agrokhim"			"Pheromone Ltd", (Z1)	Bisex lure, (SC)	LEDs, (LT)
	Z*)	E	ZE			
Vil. Botanika	0.28 ± 0.14 a**)	0.23 ± 0.08 a	0.09 ± 0.05 a	0.23 ± 0.06 a	5.69 ± 0.51 b	19.74 ± 1.21 c
St. Kurchanskaya	0 a	0 a	0 a	0.03 ± 0.03 a	0.03 ± 0.03 a	1.37 ± 0.32 b

Notes: *) decoding baits: Z and Z1 — synthetic sex pheromones that attract males of ECB race Z, produced by JSC "Shchelkovo Agrokhim" and "Pheromone Ltd", respectively; E and ZE — synthetic sex pheromones that attract males of ECB races E and ZE, produced by JSC "Shchelkovo Agrokhim"; SC — 'bisex lure' produced by the Institute of Plant Protection, Budapest, Hungary; LT — LED device manufactured in VIZR (for details, see the section Materials and Methods); **) $\bar{X} \pm SE$; different alphabetic characters are provided with the average values in the lines that differ significantly according to the Duncan's multiple range test at $p_a \leq 0.05$.

Data from moths catches show a significantly lower level of ECB population observed near st. Kurchanskaya, Temryuk District compared to that near vil. Botanika, Gulkevichi District. This conclusion is consistent with the results of tests conducted in 2019, when Delta sticky traps equipped with dispensers with synthetic sex pheromones and LEDs were used (Grushevaya et al., 2019).

The differences in the estimates of ECB densities in the field trials find their logical explanation in the historical background of the structure of crops cultivated in the territories where we conduct testing of baits. It is known that despite the potential polyphagous nature, the main habitat of ECB in the Krasnodar Territory is corn crops for grain (Frolov, Grushevaya, 2019). Land use area of the vil. Botanika, Gulkevichi District located in the Eastern subzone of the Central natural-economic zone

in Krasnodar Territory (Korobka et al., 2015), specialized in grain production, where the level of saturation of crop rotations with corn for grain is at least 11% during the season (Agricultural Portal ..., 2020; Frolov, Grushevaya, 2019). According to the long-term data obtained near vil. Botanika (Frolov, Grushevaya, 2020) the average density of ECB estimates 4.2 full-grown larvae per 1 sq. m. of maize sowing during the 1st generation and 17.6 — during the 2nd generation. Temryuk District of Krasnodar Territory belongs to the Anapa-Taman natural-economic zone with specialization in the grape production (Korobka et al., 2015). Until recently, production of corn for grain was practically extremely rarely, and the plant infestation with ECB larvae did not differ significantly from zero (Kononchuk, 2013). Only in recent years, growers of Temryuk District began to sow corn quite actively. According

to the personal message of O. A. Voblova, the head of the group of technical experts of “Syngenta Ltd”, in 2020 in the farms of this district, corn for grain was grown on an area of 2582 ha, i.e. about 4% of the area under farmland in the Temryuk District, comprising 61578 hectares, according to information provided by Agricultural Portal ... (2020).

Variation of ECB adult densities captured in 2020 in both test points (table 1) evaluated by ANOVA revealed a highly significant effect of the bait factor ($p_a \leq 0.001$), which constitutes 53.8% of the total dispersion in tests performed in the vicinity of vil. Botanika, and 97.0% — near st. Kurchanskaya. In the conditions of vil. Botanika baits were divided into 3 statistically significant groups according to their attractiveness: the smallest numbers of ECB adults were caught by traps with sex pheromones (average estimates ranged from 0.09 to 0.28 moths per 1 trap per 1 week). Traps with semiochemicals caught insects almost 20 times more frequently (5.69 adults on average per 1 trap per 1 week), and

traps with LEDs caught insects > 70 times more frequently (on average 19.74 moths per 1 trap per 1 week) as compared the traps with sex pheromones. It is important to note that in conditions of low pest population (st. Kurchanskaya), the catch of ECB adults by semiochemicals was as low in quantity as by sex pheromones, while LEDs attracted moths in quantities that were significantly larger (table 1).

Unlike sex pheromones, both semiochemicals and LEDs have attracted a lot of females in addition to males. Male quote has turned out to be significantly higher in traps with semiochemicals as compared to those with LEDs both in Botanika and in Kurchanskaya (table 2). However, the absolute numbers of captured females per 1 trap by LEDs has outnumbered those caught with semiochemicals. Although the LED trap catch a larger number of ECB adults, trap with semiochemicals are easier to maintain and cheaper. However, the latter obstacle is partially compensated by the fact that the design of LED traps provides for their long-term use.

Table 2. Means of ECB female catches in Delta sticky traps (calculated per 1 trap per 1 week) (Krasnodar Territory, 2020)

Bait	The point of testing	Females in traps	
		numbers	% of adults caught
SC*)	vil. Botanika	2.60 ± 0.23 **)	48.72 ± 4.81
	st. Kurchanskaya	0.01 ± 0.01	41.67 ± 8.33
LT	vil. Botanika	5.94 ± 0.36	28.78 ± 1.58
	st. Kurchanskaya	0.37 ± 0.09	27.36 ± 10.90

See the notes to table 1.

The long-term strategy for the development of grain complex of the Russian Federation until 2035 (Russian Federation Government, 2019) largely relies on a significant expansion of acreage for corn grain production, even beyond the borders of traditional cultivation of this crop (Bykov,

Semkin, 2020). This implies an increased demand in pest monitoring and control tools. The results presented in the paper indicate the possibility of using new means of monitoring ECB, especially LED traps, under the modern conditions of expansion of corn grain production territories.

Conclusion

The test results presented above clearly indicate the prospects of using traps equipped with both LEDs and plant-based semiochemicals for monitoring ECB. Both are obviously advantageous as, unlike sex pheromones, they attract a lot of females, whose predictive value is significantly higher than that of males.

The LEDs show the maximum gain in catch of ECB adults as compared to all other tested baits in sticky traps, including semiochemicals, especially in areas with low pest population.

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Краткое сообщение

СВЕТОДИОДЫ, СЕМИОХЕМИКИ ИЛИ ПОЛОВЫЕ ФЕРОМОНЫ: ИСПЫТАНИЯ НА АТТРАКТИВНОСТЬ ДЛЯ КУКУРУЗНОГО МОТЫЛЬКА В КРАСНОДАРСКОМ КРАЕ

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В двух географических пунктах Краснодарского края — пос. Ботаника Гулькевичского р-на (восточная подзона Центральной природно-экономической зоны Краснодарского края) и ст. Курчанская Темрюкского р-на (Анапо-Таманская природно-экономическая зона) на производственных посевах кукурузы проводили испытания снабженных различными приманками клеевых ловушек Дельта на аттрактивность для имаго кукурузного мотылька *Ostrinia nubilalis* Hbn. В отличие от половых феромонов ловушки с бисексуальной приманкой (семиохемики фенилацетальдегид и 4-метокси-2-фенэтиловый спирт) и светодиодами отлавливали немалое количество самок, прогностическая ценность которых существенно выше таковой самцов. На посевах кукурузы близ пос. Ботаника ловушки с бисексуальной приманкой отлавливали бабочек вредителя почти в 20 раз интенсивнее половых феромонов, а со светодиодами — более чем в 70 раз. На кукурузных полях в окр. ст. Курчанская, где насыщенность севооборотов посевами кукурузы, так и численность вредителя были существенно ниже, семиохемики отлавливали бабочек кукурузного мотылька столь же слабо, как и половые феромоны, в отличие от светодиодов, привлекавших насекомых на порядок активнее. Результаты испытаний свидетельствуют о перспективности использования светодиодных ловушек для мониторинга кукурузного мотылька в современных экономических условиях, способствующих расширению территорий, предназначенных для производства зерна кукурузы.

Ключевые слова: аттрактивность, *Ostrinia nubilalis*, клеевая ловушка Дельта, бисексуальная приманка, светодиод, половой феромон

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