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AN INFLUENCE OF HERBS ON THE SEX STRUCTURE IN POPULATIONS OF INSECT PESTS OF STORED PRODUCTS

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Abstract: The effects of powdered herbs (lavender *Lavandula officinalis* L., peppermint *Mentha piperita* L. and basil *Ocimium basilicum* L.) added to the food substances of three insect species: the rice weevil *Sitophilus oryzae* (L.), lesser grain borer *Rhyzopertha dominica* (F.), and the saw-toothed grain beetle *Oryzaephilus surinamensis* (L.) on the life span and development of the three insect species as well as habitat conditions, sex structure, and the survivability of males and females were considered.
The experiments were conducted in the laboratory at a temperature of 28°C and relative humidity (RH) 60 ±5%. In all the studied populations, high female mortality was found (♂/♀ < 1). The studied populations were: the rice weevil and the lesser grain borer cultured in wheat grain with herb additions, and the saw-toothed grain beetle cultured in semolina with herb additions. Among the herbs used, peppermint caused a significant effect in the form of increased mortality rates among females of *S. oryzae* and *O. surinamensis*. Lavender and basil had a similar impact among *R. dominica* females. The herbs applied in the experiments intensified the mortality of females and, consequently, led to the disappearance of entire populations.

Key words: *Oryzaephilus surinamensis*, powdered herbs, *Rhyzopertha dominica*, sex structure, *Sitophilus oryzae*

INTRODUCTION

During long-term storage of grain and food products, the insect pests infesting the products are a considerable problem. The economic damage caused by these pests worldwide is enormous, so controlling them is a necessity. The search for effective methods to control them is ongoing. There are a number of publications whose authors point out the effectiveness of essential oils (Tapondjou *et al*. 2005; Negahban *et al*. 2007; Rozman *et al*. 2007; Ahmed and Abd El-Salam 2010), plant powders (Tiwari 1994; Kłyś 2004; Akinkurolere 2007; Derbalah 2011), or alcoholic extracts from plants (Jbilou *et al*. 2006; Khoshnoud *et al*. 2008), in fighting pests of stored products. The main effects of the substances studied are those pertaining to the mortality and reproduction of these insect pests. The published references lack reports on the studied plants' effects on the sex structure in the pest insect populations and on the survivability of both males and females. This issue has been addressed in our study. The time needed for the formation of the sex structure in populations of three species of dangerous insect pests of stored products; namely: the rice weevil *Sitophilus oryzae* (L.), saw-toothed grain beetle *Oryzaephilus surinamensis* (L.), and the lesser grain borer *Rhyzopertha dominica* (F.), in which powdered herbs had been added to their optimum food, was studied. These herbs were: lavender *Lavandula officinalis* L., peppermint *Mentha piperita* L., and basil *Ocimium basilicum* L.

MATERIALS AND METHODS

The control cultures of rice weevils and lesser grain borers were maintained in the wheat grain substrate. This substrate was earlier recognised as the most suitable food and habitat for the development of these species (Kłyś 2006b). The cultures of the saw-toothed grain beetle were maintained in semolina – a suitable food and habitat for the development of this species (Loschiavo 1959; Ciesielska 1966). In experimental cultures, each of the powdered herbs studied *i.e.* lavender, peppermint, and basil, was mixed with wheat grain in a proportion of 0.2 g of herb per 40 g of wheat grain (concentration of 0.5%). In experimental cultures of saw-toothed grain beetles, the substrates were composed of semolina with the addition of lavender, peppermint, or basil in the same concentrations as in the cultures of rice weevils and lesser grain borers. In earlier studies, Kłyś (2004, 2006a) found that such a concentration of herbs was appropriate for studying the population processes in these species of beetles over longer periods. The herbs were purchased from a herb store and powdered in an electric grinder. The cultures were kept in a thermostat at a temperature of 28°C and relative humidity (RH) 60 ±5%, using glass vessels with a 28 cm^2 floor area capped with perforated lids allowing air access. All experimental colonies were made up of 40 same-aged adult individuals (20 males and 20 females). Live and dead individuals were removed every 30 days *i.e.* at the approximate time for the whole

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development from egg to adulthood, under the temperature and humidity conditions applied in the experiments. The sex of the insects was determined under a stereomicroscope by external features of sexual dimorphism. The adult individuals of the lesser grain-borer were washed in 10% KOH. Next, their reproductive organs were dissected under the stereomicroscope in order to positively determine their sex. The insects for the experiments were obtained from laboratory cultures, which were kept under the same temperature and humidity conditions as the experimental colonies. The insects were 15 days old prior to their use in the experiments. All the experimental regimes were run in six repetitions. The proportion of the number of females to the number of males was adopted as the sex ratio (♂/♀), determining the sex structure of the population (Andrzejewski and Falińska 1986). The results were statistically assessed. The Tukey's test was used for mean separation in the Statistica software package.

RESULTS

In the experiments where powdered plants were added to the substrate, disturbances in sex structure were found in all populations studied. This was true both among living and dead individuals. In the control cultures of *S. oryzae*, *R. dominica*, and *O. surinamensis* reared without the addition of herbs, there were almost equal proportions of males and females in the populations. The sex ratio values fluctuated around 1 with minor deviations. Adding powdered plants to the optimum food for these species (*e.g.* wheat grain for the rice weevil and lesser grain borer, and semolina for the saw-toothed grain beetle) resulted in an increased proportion of living males in the studied populations.

As a consequence of the herbs applied: lavender, peppermint, or basil, there were major increases in the mortality of the insects (Tables 1, 2, 3). In general, in experiments carried out with the use of all these herbs in the populations of *S. oryzae*, *O. surinamensis*, and *R. dominica*, the numbers of dead female individuals were higher compared with the control cultures. The increased mortality of females was confirmed by the low values of the sex ratio presented in tables 4, 5, and 6. In the cultures of rice weevil, the highest female mortality rate was found in the wheat with peppermint, which displayed the lowest values of the sex ratio. The statistically significant effects of the peppermint addition on the suppression of sex ratio values in rice weevil compared with the control cultures (where food consisted of pure wheat grain), were found in all stages of the experiments. The significant effect of lavender on the lowering of the sex ratio values in the population of rice weevil, was found in the period spanning the beginning of the experiment until the 120th day of the experiment. It was only in wheat with basil that the sex ratio values were not significantly different from these found in the control culture (Table 4).

In the cultures of *O. surinamensis*, the effects of mint on female mortality rates were significant. In the culture of the saw-toothed grain beetles in semolina with peppermint added, the sex ratio values ranged from 0.3 to 0.6. After 30, 90, and 120 days following the beginning of the experiments, all of the herbs showed significant effects in lowering the sex ratio when compared with the control culture (where the food consisted of pure semolina) (Table 5).

Comparing the values of sex ratios in the populations of the lesser grain borer living on wheat grain, showed that the highest mortality rates for females were the result of adding lavender and basil. It is supported by the lowest values of this index in the experiment with the addition of lavender (0.2–0.5). After 30 days of the experiment, the impact of lavender and basil additions on the lowering of the sex ratio compared with the control group (where food consisted of pure wheat grain), was significant. The highest relative mortality (0.20) of females was observed in a culture on wheat with the addition of lavender. The ratio for this group was statistically significantly lower than the ratios for other herbs (Table 6).

Table 1. The effects of added herbs (0.5%) on the mortality of *R. dominica*

Foods	Number of dead individuals (the mean value)							
	days							
	30	60	90	120	150	180	210	240
Wheat (control)	8.66	14	9.5	16.83	18.66	40.66	66	78
Wheat with lavender	12	45.33	45.33	35.33	75	88	109.33	136.66
Wheat with peppermint	31.33	94.33	79.33	108.66	102	92.66	88	94.66
Wheat with basil	27.66	38.33	77	75.33	105.33	102.33	144	123.33

Table 2. The effects of added herbs (0.5%) on the mortality of *S. oryzae*

Foods	Number of dead individuals (the mean value)							
	days							
	30	60	90	120	150	180	210	240
Wheat (control)	12	12.16	13.83	34.66	49	60.5	74.16	52.33
Wheat with lavender	28	74	73.83	91	108	120.16	111	127
Wheat with peppermint	34.66	78.83	71	75.33	87	149	149.33	128.66
Wheat with basil	38.16	76.33	101.33	97.66	97.16	124.66	129.66	115.33

Table 3. The effects of added herbs (0.5%) on the mortality of *O. surinamensis*

Foods	Number of dead individuals (the mean value)							
	days							
	30	60	90	120	150	180	210	240
Semolina (control)	12.5	16.66	13	18	22	22.83	20.5	20.83
Semolina with lavender	16.33	21.33	38	67.33	35	85.33	43.66	40.66
Semolina with peppermint	34.66	74.66	100.33	78	68	41.33	26.66	34
Semolina with basil	17.83	49.33	66	48.66	24.83	36.66	42	71.33

Table 4. The effects of added herbs (0.5%) on the sex structure of the population of *S. oryzae*

Foods	Sex ratios							
	days							
	30	60	90	120	150	180	210	240
Wheat (control)	1.00 a	0.90 a	1.10 a	1.08 a	1.10 a	1.00 a	0.90 a	1.00 a
Wheat with lavender	0.50 b	0.55 b	0.60 b	0.50 b	0.80 ab	0.92 a	0.80 a	0.90 a
Wheat with peppermint	0.50 b	0.45 b	0.50 b	0.50 b	0.50 bc	0.47 b	0.67 ab	0.40 b
Wheat with basil	0.90 a	0.90 a	0.90 a	0.92 a	0.80 ab	0.80 a	0.90 a	0.90 a

Means followed by different letter(s) vertically are significantly different at $p < 0.05$ according to Tukey's test

Table 5. The effects of added herbs (0.5%) on the sex structure of the population of *O. surinamensis*

Foods	Sex ratios							
	days							
	30	60	90	120	150	180	210	240
Wheat (control)	1.10 a	0.90 a	1.20 a	1.20 a	1.10 a	1.02 a	1.28 a	1.20 a
Wheat with lavender	0.40 b	0.48 b	0.70 b	0.60 b	0.90 a	1.00 a	1.10 ac	1.00 a
Wheat with peppermint	0.40 b	0.43 b	0.30 c	0.35 b	0.40 b	0.50 b	0.60 b	0.60 bc
Wheat with basil	0,53 b	0.60 ab	0.70 b	0.58 b	1.00 a	0.90 a	0.80 bc	0.92 a

Means followed by different letter(s) vertically are significantly different at $p < 0.05$ according to Tukey's test

Table 6. The effects of added herbs (0.5%) on the sex structure of the population of *R. dominica*

Foods	Sex ratios							
	days							
	30	60	90	120	150	180	210	240
Wheat (control)	0.98 a	1.10 a	1.03 a	1.10 a	0.90 a	1.00 a	0.90 a	1.10 a
Wheat with lavender	0.20 b	0.50 b	0.40 b	0.42 b	0.40 b	0.50 bd	0.38 b	0.40 b
Wheat with peppermint	0.70 ac	0.60 b	0.70 c	0.50 b	0.90 a	0.90 ac	1.00 a	1.00 a
Wheat with basil	0.60 c	0.70 b	0.40 b	0.50 b	0.50 b	0.70 bc	0.50 b	0.40 b

Means followed by different letter(s) vertically are significantly different at $p < 0.05$ according to Tukey's test

DISCUSSION

The results of many studies indicate that all populations are experiencing relentless pressure from the environment. Under this stress, not only do the population numbers change but also other parameters such as *e.g.* age structure, sex structure of a population, as well as body size and condition of the average individual. All this, in turn, results in population numbers settling at levels consistent with the current capacity of the environment (Collier *et al*. 1978). The storage pests live in an environment with stabilised ecological conditions. These are often associated with limited storage space and granaries always filled with cereal grain. The pests are provided with a substrate to live in and an oversupply of food. Among the factors directly affecting the development, numbers and activity of these populations, the temperatures, relative air and grain humidity, as well as available food were recognised as the most essential (Chang and Loschiavo 1971; Cuff and Hardman 1980; Kłyś 2009). Adding powdered plants to the food not only increased the mortality among insects but affected the sex structure of their populations (Kłyś 2004). The sex structure is the simplest form of the demographic structure of populations since males and females are the only two elements.

The sex structure is not a constant value although its initial structure is usually balanced. In the scientific literature, there are no studies describing the sex structure in populations of storage insects, in experimental cultures where additional substances suppressing the numbers and increasing mortality are applied.

In the experiments carried out in this study, some interesting results were obtained. The results showed significant changes in the sex structure of the studied populations of insects because of the application of herbs. These changes were monitored over a long 240-day period. Adding powdered herbs to the optimum food of insect pests of stored products resulted in an increase in the proportion of living males in populations of *S. oryzae*, *R. dominica*, and *O. surinamensis*. This increase in the numbers of living males results from enhanced mortality among females in these populations. A general increase in female mortality was noted in the populations of *S. oryzae*, *R. dominica*, and *O. surinamensis* in all the experimental cultures which had additions of powdered herbs. The addition of peppermint resulted in increased mortality rates among rice weevil and saw-toothed grain beetle females, that were statistically significant. Under the effect of lavender and basil, the proportion of dead lesser grain borer females increased.

The herbs applied intensified the mortality of females, and as a consequence, led to a reduction in numbers and the disappearance of the entire population. The results from the application of herbs is an interesting aspect of the studies and may prove useful in the search for alternative methods to control insect feeding on stored products.

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