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NUTRITIONAL PREFERENCES OF THE LESSER GRAIN BORER *RHIZOPERTHA DOMINICA* F. (*COLEOPTERA, BOSTRICHIDAE*) UNDER CONDITIONS OF FREE CHOICE OF FOOD

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Abstract: The subject of this study was *Rhizopertha dominica* F. population. The primary question referred to was the process of the lesser grain borer population spread depending on nutritional preferences of this species. The aim of performed laboratory experiments was to examine the adults' ability to choose preferred kinds of food i conditions of free migration among them and to analyze the dynamics of population size. Sex ratio and the migration rate were also analyzed. Four types of food were used during the experiments: wheat, oat flakes, pearl barley and semolina. The experiments were conducted at 28°C and 60 ±5% of relative humidity. Results of the study revealed that oat flakes were the most favourable nutriment for adult *R. dominica* whereas wheat grain was the most favourable for the population size since larvae were protected by grains and thus their increased number could survive. No population development in semolina was observed. It was the result of too small granulation of this food.

Key words: *Rhizopertha dominica*, feeding activity, population dynamics, mortality, sex ratio

INTRODUCTION

Food is one of the main environmental factors that influence a population size. For storage beetles cereal or its products are not only a trophic factor, but also a substrate and a habitat. The kind of food also influences the rate and nature of development as well as the population size or even the body size of individual organisms (Howe 1956; Joshi 1975). In case of *Sitophilus granarius* L. the size of adults is influenced not only by the amount of available nutrients but also by the grain size and volume (Nawrot 2002). Food shortage may be a reason for increased mobility and emigration of some individuals from the population. Studies on the migration of storage beetle populations indicate their enormous mobility (Surtees 1964; Ciesielska 1994; Ciesielska and Kłyś 2002).

The subject of this study was lesser grain borer *Rhizopertha dominica* (F.) – a dangerous pest of stored cereal and cereal products. In this paper based on laboratory studies the hypothesis was put forward that a nutrient granulation and its type significantly influence the nature and intensity of the *R. dominica* population development. Moreover, the aim of performed experiments was to examine the adults' ability to choose preferred kinds of food under conditions of free migration among them and to analyze the population size development in particular types of food.

MATERIALS AND METHODS

Laboratory lesser grain borer cultures were kept in glass vessels of the bottom area of 28 cm^2 closed with a perforated lid. The following products were used as food in separate vessels: 40 g (1.41 oz) of wheat, pearl barley, oat flakes and semolina. Forty individuals of the same age in 1:1 sex ratio were inserted in every vessel. The results of those experiments were treated as controls with reference to the data achieved under conditions of free migration of the individuals among different kinds of food.

The body structure of adults practically preventing them from moving on the smooth surface was taken into consideration (Kłyś 1991) when setting the methods for experimental studies on nutritional selectivity of the *R. dominica* population. Therefore the culture glass vessels of the bottom area of 28 cm^2 were divided into four identical compartments using a frame with a 1.5 mm holes diameter. Each quarter contained a different nutrient: 10 g of wheat, pearl barley, oat flakes and semolina. Ten individuals were put in each quarter thus enabling them possible migration among the food types and their choice within the vessel. Monitoring horizontal migration in case of this species is very important owing to the known possibilities of vertical migration within a pile of grains (Surtees 1964). When selecting the type of nutrients, their different hardness, granulation, kind and possession of a hard grain cover (wheat) as well as its lack taken into consideration were. The cultures were kept in a thermostat at the temperature of 28°C and 60 ±5% relative humidity (r.h.). Eight experiments were performed and each of them was repeated six times. The first assessment was carried out after forty days, i. e. after an approximate period of the *R. dominica* development from the egg to the imago in the above thermal and humidity conditions. The successive assessments were carried out every 70, 100, 130, 160, 190, 220 and 250 days. Every monthly inspection consisted of counting live and dead individuals found in each food compartment and determining the sex of adults. The sex was determined on the basis of removed reproductive organs. The insects used for the experiments came from general laboratory cultures kept under the same conditions as the experimental cultures. Prior to the experiments the insects lived for 15 days under laboratory conditions. The dynamics of the population size was analyzed against the nutritional selectivity, mortality rate, sex ratio and migratory background.

RESULTS

Although it is wheat groats, no lesser grain borer population development was observed in semolina. Granulation of this nutrient hinders the insects from moving and actually makes them overturn back down. This prevents them from taking food and subsequently leads to gradual death of all insects.

At the initial stage of the population development, the number of insects remained at the baseline level in three other nutrients. After 70 days of breeding however, the highest number of insects was reported in oat flakes. From that time a dynamic increase of the population size was observed in wheat continuing up to the 190th day of the study. Then the *R. dominica* population reached the maximum size consisting of 884 insects. In pearl barley and oat flakes however, the population size reached a much smaller level. The maximum population size in these nutrients amounted to about 300 insects (Table 1).

Table 1. Number of *Rhizopertha dominica* in different habitat and diet conditions

Days	Number of individuals					
	wheat		pearl barley		oat flakes	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
40	31	7.9	51	7.5	35	2.9
70	120	6.5	109	6.8	173	22.9
100	236	21.2	159	13.1	120	0.9
130	280	35.9	251	12.4	139	5
160	541	23.2	287	9.4	307	37.9
190	884	64.2	308	22.7	263	29.5
220	708	38.5	231	29.5	151	3.4
250	460	40.8	53	3.8	135	5

SD – standard deviation

The highest mortality during the entire study was recorded in oat flakes. In wheat however, mortality was highest during the initial and final population development stages. During the substrate infestation mortality was 21% whereas at the final stage of this experiment, i.e. in the population aging period, mortality reached 30%. General mortality in pearl barley was low, but the highest value reaching 46% was recorded 250 days from the baseline (Fig. 1).

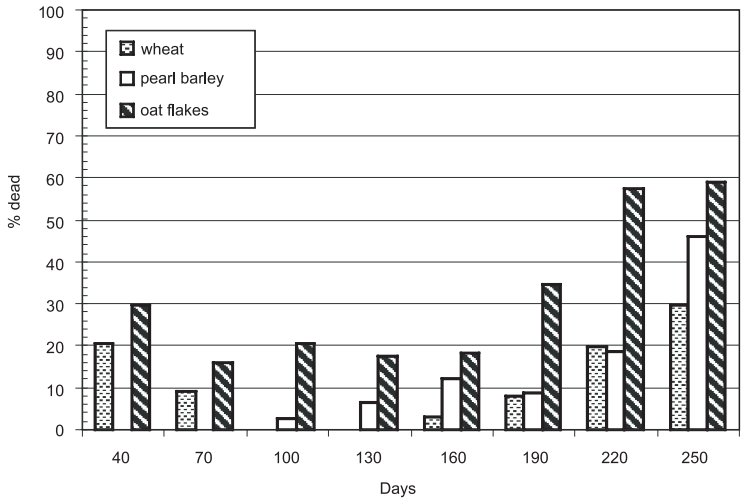

Fig. 1. Per cent of dead individuals in populations of *Rhizopertha dominica* in different habitat and diet conditions

At the initial and final stages of the population development in wheat, the proportion of males was higher (♂/♀ > 1), whereas a higher number of females was observed in the period between the 100th and 160th day of the experiment. This higher proportion of females in the population preceded the period of an intensive increase in the population size. In the population kept in pearl barley female proportion was higher (♂/♀ < 1) during the period between the 70th and 160th day of the experiment. This situation preceded the increase of population size (Table 1). After 190 days, the values of this sex ratio ranged from 1.2 to 1.3 and was correlated with the population size decrease. In oat flakes the values of this sex ratio varied about 1 with a trend towards a higher male proportion (Fig. 2).

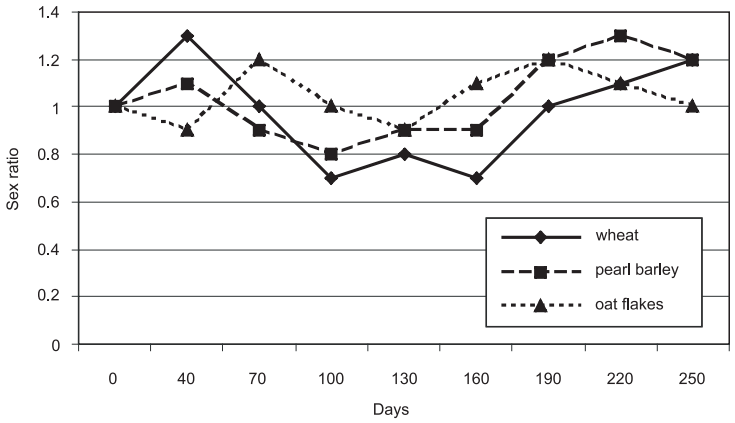

Fig. 2. Sex ratio in *Rhizopertha dominica* in different habitat and diet conditions

Enabling the *R. dominica* individuals a choice of the nutrients under conditions of free migration among them caused that at the initial stage of the population development the number of insects infesting a particular food type remained at the baseline level similarly to the cultures kept in separate nutrients. A clustering trend was observed only in oat flakes (Table 2). Starting from the 70th day of the experiment a population size increase was observed in all the nutrients excluding semolina where an insignificant population size increase was observed only after 100 days of the experiment. The maximum size of individuals in all the nutrients was observed after 220 days. Only in pearl barley the population size peak fell in the previous period, i.e. between the 160th and 190th day of culture, but then a decrease in the population size was recorded (Table 2). The analysis of variance showed that the differences of the population sizes in particular nutrients in every period of time were statistically significant.

The highest mortality was found among the insects which infested semolina, their number being small and their development was not observed while the smallest mortality occured in oat flakes. 100% survival was reported during the first 70 days of the study (Fig. 3).

Sex composition of the groups infesting particular nutrients was diverse. In the wheat infested group sex ratio was close to 1. Only in periods preceding the population size increase, i.e. after 100, 130, and 190 days of culture female proportion was

Table 2. Number of *Rhizopertha dominica* in given free choice of food

Days	Number of individuals							
	wheat		pearl barley		oat flakes		semolina	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
40	7	0.5	5	0	19	1.3	1	0
70	27	1.3	9	0	20	1.2	0	0
100	42	1.7	17	1.2	34	1.8	1	0
130	86	1.7	36	2.1	62	0.5	6	0.8
160	134	3.4	84	2.9	98	2.1	14	0.9
190	129	6.6	84	2.5	111	2.6	26	2.1
220	194	8.4	70	2.2	121	3.6	34	2.2
250	185	8.2	60	2.5	118	2.6	30	0.9

SD – standard deviation

higher (♂/♀ < 1). In pearl barley male proportion was higher during the whole time of the experiment. Only after 100 and 130 days the sex ratio was close to 1. In the oat flakes infested group the sex ratio values were smaller than 1, reflecting a high female proportion. In semolina the males to females proportion was variable and varied at 1 while the number of insects was very small and did not qualify the data to sex composition assessment. As time went by, the number of insects infesting semolina increased with a trend towards the higher female proportion (Fig. 4).

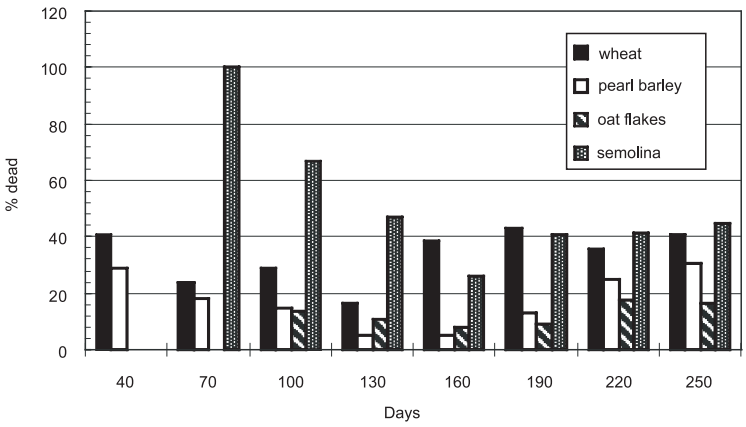

Fig. 3. Per cent of dead individuals in given free choice of food

Free, horizontal migration of insects among different nutrients led to unequal dispersion. After 40 days the highest migration rate close to 50% was reported in oat flakes, and subsequently starting from the 70th day of culture, it decreased to 34%, whereas the migration rate increased to 49% in wheat where it remained at an almost unchanged level until the end of the study. In pearl barley the migration rate did not exceed 20% and in semolina the migration rate was the smallest (Fig. 5).

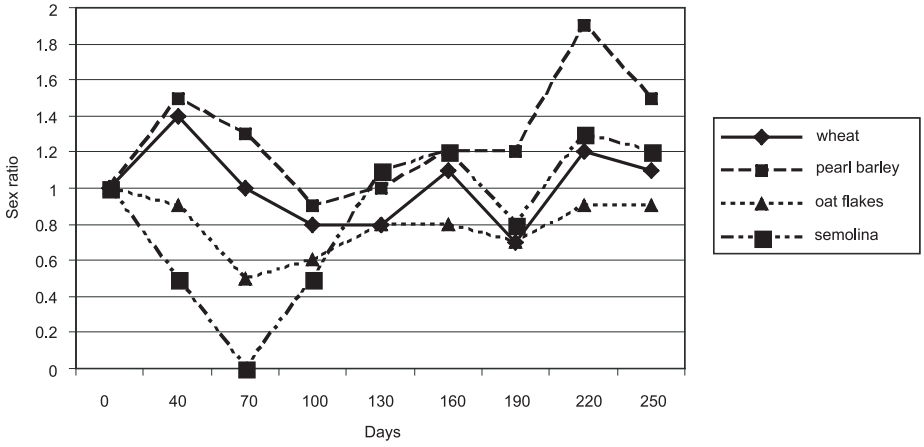

Fig. 4. Sex ratio in *Rhizopertha dominica* in given free choice of food

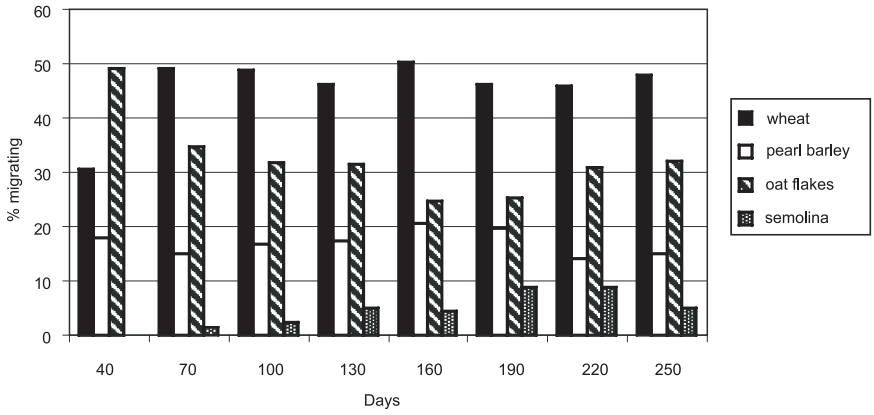

Fig. 5. Migrational activity of *Rhizopertha dominica* in given free choice of food

DISCUSSION

Temperature, relative air humidity as well as grain moisture and a nutrient content (Howe 1956; Surtees 1965; Chang and Loschiavo 1971) were considered to be the most important factors directly influencing the development and activity of storage pest populations. Arbogast and Carthon (1970) and Pajni and Mohinder (1974) showed that temperature, humidity, type and a number of nutrients and light intensity influence the population size. Swain (1975) studied the tolerance of *R. dominica* individuals for a temperature decline, and food deprivation. He showed that population mortality increased proportionally to the amplitude of those factors. It seems, however, that a substrate is the most important factor influencing the rate and nature of a population development as it plays the role of both trophic and habitat factors.

Gołębiowska et al. (1976) showed that lesser grain borer beetles feed more intensively on damaged wheat kernels, consuming more grain and producing more dust. But they produce more progeny in whole grains. The poorest feeding was observed in barley and oat grains. The authors found preferences for wheat as a better nutrient for this pest population development. My studies supported this opinion as the lesser grain borer population kept in wheat reached a higher number compared to the population which fed on oat flakes or pearl barley. Flakes of oats, however, appeared to be the best nutrient for *R. dominica* owing to easy availability – as they lack a hard grain pericarp. But at the same time it is an inconvenient habitat to exist and develop. Therefore only at the initial stage of the population development, the number of insects was highest, whereas in wheat semolina no development of the *R. dominica* population was observed. This indicates that not only a nutrient type but also a granulation degree determines this species population development.

Similarly Breese (1960) showed that if the pericarp of a brown rice grain is hard and undamaged the *R. dominica* adults are usually unable to feed. Sinha (1969) believes that *R. dominica* do not reproduce themselves at all in undamaged oat grains which are not separated from the chaff. Similarly for the *S. granarius* L. development, the grains mechanically damaged and devoid of the pericarp are much better than whole grains (Gołębiowska and Nawrot 1978).

It is the morphological structure as well as biological and ecological adaptation that make wheat the best nutrient for the lesser grain borer. Based on the examined adaptations in the morphological structure Kłyś (1991) found that this pest easily migrates in a nutrient consisting of large granules. It means that grains are not only important as a nutrient and the ontogenetic development environment but also as a substrate that becomes an environmental factor which determines the behaviour of this species.

Sex composition of the population is not a constant quantity, although its primary structure is usually initially balanced. Studies carried out by Ciesielska (1985) on the example of *S. granarius*, *S. oryzae* and *O. surinamensis* showed that the population size control takes place through changes in relation to the sex composition within a population.

As a result of the studies, it has been found out that the nutritional deterioration and overcrowding led to a decrease of the lesser grain borer population size. The value of decrease reflects the increase of mortality and changes in the sex composition. The increase of a population size generally follows the females' proportion growth, whereas the decrease in the population size is a result of their greater mortality. Mortality increases in overcrowding, but it is also high at the initial stage of infesting a substrate provided with a sufficient amount of food and small population density. Perhaps it results from the population adaptation to changing conditions. At that time females undergo a higher reduction as they are more active than males.

Ciesielska and Kłyś (2002) examining initially the migration processes of *R. dominica* pointed out a high migration activity of this species. The studies also show that the *R. dominica* population demonstrated a tendency to rapid dispersion and equal control of the substrate. With the environmental diversity however, the course of dispersion and special structure of the population are conditioned by nutritional selectivity. Oat flakes are the best nutrient for the lesser grain borer. The size of groups that emigrate to oat flakes is the greatest during the initial period of the population disper-

sion. The highest migration rate during the whole study period was found in wheat, which is a result of optimal developmental conditions in grains. Slightly smaller values of the migration rate were observed subsequently in oat flakes and pearl barley. Semolina is only an accidental habitat for *R. dominica*. Migration of adults to semolina was observed during the final period of experiments from overcrowded to more convenient population development habitats. Choice of a nutrient under conditions of free migration is consistent with the results achieved in separate cultures. During the initial period of infesting, the migration of *R. dominica* population is connected with nutritional preferences and thus it is conditioned by a food type and its granulation facilitating the migration and consumption. In a later period the choice of a nutrient and its infesting is conditioned by an appropriate place for the larvae development and metamorphose.

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POLISH SUMMARY

PREFERENCJE POKARMOWE KAPTURNIKA ZBOŻOWCA *RHIZOPERTHA DOMINICA* F. (*COLEOPTERA, BOSTRICHIDAE*) W WARUNKACH SWOBODNEGO WYBORU POKARMU

Obiekt badań stanowiła populacja *Rhizopertha dominica* (F.). Główny problem badawczy dotyczył przebiegu procesu rozprzestrzeniania się populacji kapturnika zbożowca w zależności od preferencji pokarmowych tego gatunku. Celem podjętych eksperymentów laboratoryjnych było sprawdzenie zdolności wyboru przez osobniki dorosłe preferowanych rodzajów pokarmów w warunkach swobodnego przemieszczania się między nimi oraz prześledzenie dynamiki liczebności populacji. Przeanalizowano również strukturę płciową oraz wskaźnik migracji. W eksperymentach zastosowano cztery rodzaje pokarmu: pszenicę, płatki owsiane, kaszę jęczmienną i kaszę mannę. Hodowle prowadzone były w termostacie w temperaturze 28°C i wilgotności względnej 60 ± 5%.

W efekcie przeprowadzonych badań stwierdzono, że płatki owsiane są najkorzystniejszym pokarmem dla *R. dominica*. Natomiast dla rozwoju populacji najkorzystniejsze jest ziarno pszenicy, z uwagi na to, że wewnątrz ziarna larwy posiadają osłonę i większa ich liczba ma szanse przeżycia. W kaszy mannie nie zaobserwowano rozwoju populacji. Powodem jest zbyt mała granulacja tego pokarmu.