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CORRELATION BETWEEN NUTRITIONAL SELECTIVITY AND MIGRATORY ACTIVITY OF *RHIZOPERTHA DOMINICA* F. (*COLEOPTERA, BOSTRICHIDAE*)

Małgorzata Kłyś

Pedagogical University of Cracow, Institute of Biology
Department of Ecology, Wildlife Research and Ecoturism
Podbrzezie 3, 31-054 Kraków, Poland
klysgosia@poczta.onet.pl

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Abstract: The subject of this study was the lesser grain borer *Rhizopertha dominica* F. The aim of the experiments was to verify the hypothesis suggesting that the course of simultaneous vertical migration and horizontal spread of the *R. dominica* population is determined by nutritional and habitat selectivity. The following products were used as nutrients in the experiments: wheat, oat flakes, pearl barley and semolina. It was found that the course of a migration process is connected with nutritional preferences determined mainly by a nutrient type and its granulation. At the initial stage of the study the highest emigration was noted in the oat flakes. After a time the highest migration was directed to as follows: wheat, oat flakes, pearl barley and semolina. Females showed a higher migratory activity.

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

INTRODUCTION

Insects – granary pests are adapted to life in closed storehouses and granaries under conditions of moderate climate. Only the bean weevil (*Acanthoscelides obtecus* Say) can develop both in crop fields and storehouses (Nawrot 2002). In closed rooms these insects find the environment with stabilized ecological conditions. They are provided with a substrate, nutrients surplus and they are practically protected against predators (Krebs 1996). Transcontinental trade contributes to storage pests dispersion. This dispersion however, does not occur solely through spreading because these species populations are characterized by a high migratory activity (Sinha 1995; Ciesielska and Kłyś 2002).

The subject of these studies was lesser grain borer *Rhizopertha dominica* F., which has been observed in Poland since 1952 when it was found in imported wheat (Śliwiński 1960). It is a well known fact that nibbling grain *R. dominica*, as a primary

pest, facilitates penetration and attacks of many other insect species. Moreover, this species is apparently torpid. Its specific morphological structure basically hinders this insect from moving across an even surface. This pest however, efficiently moves within grain piles in granaries. Moreover, this pest very rarely comes out on the outer grain layer (Kłyś 1991).

Nutritional selectivity of this species found out in earlier studies (Kłyś, unpublished) was a starting point for further investigations. Their aim was to verify the hypothesis suggesting that the course of simultaneous vertical migrations and horizontal spread of the *R. dominica* population is also determined by nutritional and habitat selectivity. Such a set up of the experiment is a version most similar to natural conditions prevailing in granaries.

MATERIALS AND METHODS

During the studies on migratory activity of the *R. dominica* population in connection with nutritional selectivity, two versions of laboratory experiments were performed in order to examine:

1) Migration connected with a possibility of horizontal spread of individuals and free nutrient choice.
   A two-vessel set was used. The external glass vessel of the botton area of 50 cm^2 was equipped with a metal frame with the 1.5 mm holes diameter. The frame divided the vessel into four identical compartments. Each of them contained a different nutrient type – 10 g of wheat, pearl barley, oat flakes and semolina. The plastic internal vessel, its bottom and sides had 32 holes of 1.5 mm diameter, contained 40 g of wheat. It had the bottom area of 28 cm^2 and was filled with nutrients to the height of 2.5 cm. Forty adults of the same age were inserted in the internal vessel. They were obtained according to the methods worked out by Ciesielska (1966, 1971). They had a chance to emigrate from the internal vessel and to choose a preferred nutrient (Fig. 1a).
2) Migration without a chance of horizontal spread of individuals among different kinds of food.
   Modification of the experiment depended on preventing the individuals from migrating among nutrients after infesting. To achieve that a metal frame without holes was used in the external vessel dividing it into four identical compartments (Fig. 1b).

The insects used for the experiment came from general laboratory cultures. General and experimental cultures were kept in a thermostat at the temperatures of 28°C, 60 ± 5% relative humidity. Before they were used for the experiments, insects lived for 15 days under laboratory conditions. Seven experiments were carried out (each of them was repcated six times) and their state was inspected after 40, 70, 100, 130, 160, 190 and 220 days. The inspection consisted of selecting and counting live and dead individuals found in each nutrient and determining the sex of adults. The sex was determined on the basis of removed reproductive organs. Evaluation of nutritional and migratory activity was based on analysing the population size and on the following indicators: migration rate, mortality rate and sex ratio. The results were worked out by means of the analysis of variance (ANOVA).

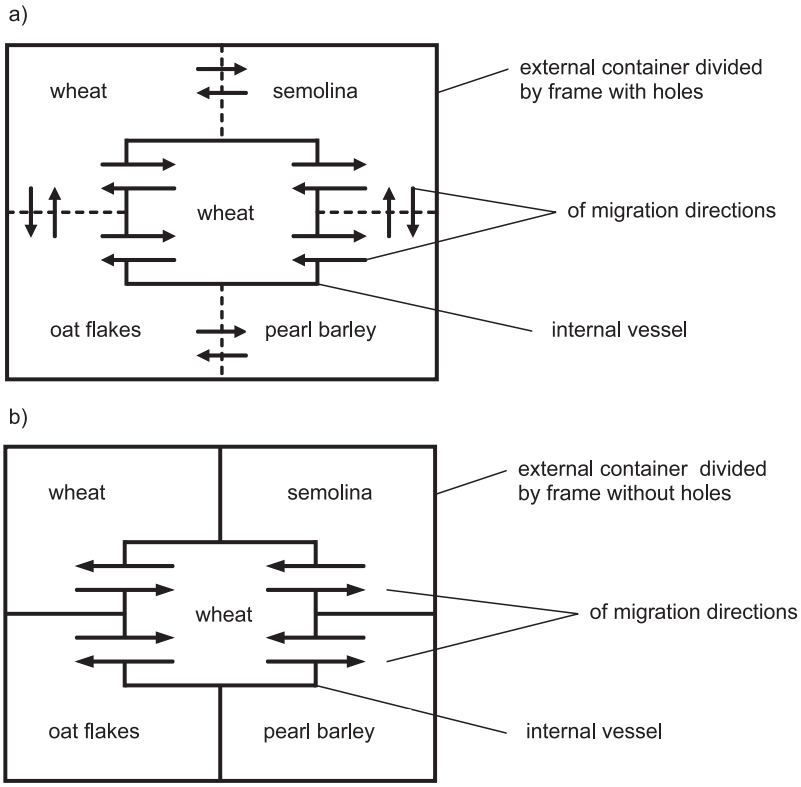

Fig. 1. Diagram of the experimental vessels: a) migration connected with a chance of horizontal spread of individuals and free nutrient choice; b) migration without a chance of horizontal spread of individuals across different foods

RESULTS

Under combined conditions of vertical migration with a chance of horizontal population spread and free choice of a nutrient it was revealed that the migratory activity of *R. dominica* is extremely high. Even at the initial stage of a substrate infestation after 40 days, almost 100% of the individuals emigrated from the parental population to particular nutrients. The highest migration rate was recorded in oat flakes and subsequently in wheat, pearl barley and semolina. After a time, i.e. between the 100th and 220th day, the highest migration was observed towards wheat and then towards oat flakes and pearl barley. Migration towards semolina was the least (Fig. 2).

Despite the fact of a high emigration rate in the parental habitat a dynamic increase of population size was observed between the100th and 190th day. The population reached its maximum size of 718 individuals and then fell down. Within migrating groups after 40 days the highest population size was recorded in oat flakes. Starting from the 130 day however, the growth of population size was insignificant. The highest growth of population size was characteristic for wheat and then subsequently for oat flakes and pearl barley. In semolina an insignificant growth of the population size was observed during the final period of the study (Table 1). The variance analysis

of presented data showed that differences of the population size in particular types of food in different time periods were statistically significant. Only after 40 days, between wheat and semolina (p = 0.789198), after 130 days between wheat and oat flakes (p = 0.71978) and after 220 days between pearl barley and oat flakes (p = 0.286629) the results were statistically insignificant.

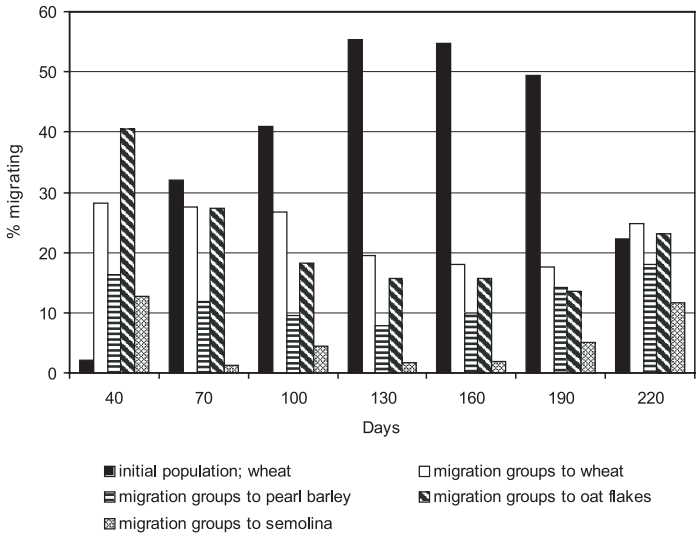

Fig. 2. Migration activity of *Rhizopertha. dominica* connected with food selection

Table 1. Number of *Rhizopertha dominica* in conditions of migration connected with food selection

Days	Number of individuals									
	initial population		migration groups							
	wheat		wheat		pearl barley		oat flakes		semolina	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
40	1	0	2	0	6	1.6	17	3	3	0
70	92	5.4	72	5	29	3	77	3.3	1	0
100	119	5.8	67	3.2	26	0.9	49	5.1	6	1.1
130	444	36.2	141	14.2	57	10.7	119	6.4	8	1.5
160	521	11.9	151	13.3	88	2.9	134	8.6	14	1.5
190	719	22.1	226	17.1	188	6	151	25	54	4.3
220	176	11.7	184	16	137	12.3	124	9.7	46	5.3

SD – standard deviation

Mortality in the initial population was smaller than in the migrant groups and ranged from 0 to 9%. Only during the final period, as the population was growing older, mortality was high and amounted to over 50%, similarly to the other nutrients. Within the group of individuals migrating towards wheat, the highest mortality was found at the initial and final period of the study. Between high initial (85%) and final (55%) mortality, the rate remained at a relatively low level. In oat flakes and pearl

barley, the values of mortality rate ranged from 5% to 58%. Constant high mortality was observed in semolina with a simultaneous small population size – the values of this rate ranged between 24% and 76% (Fig. 3).

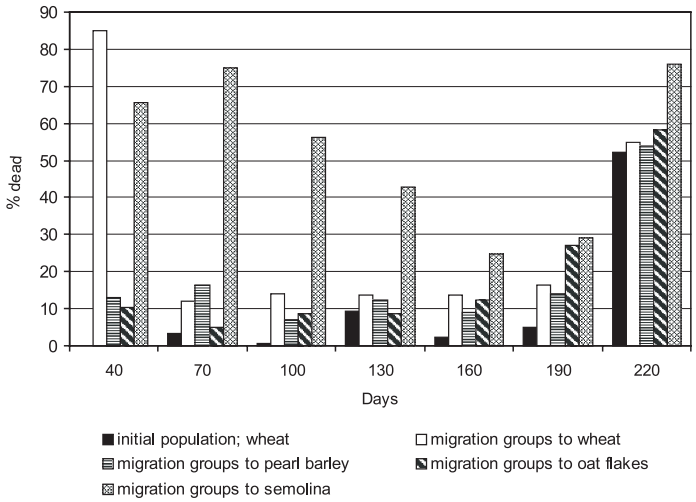

Fig. 3. Per cent of dead individuals of *Rhizopertha dominica* in conditions of migration connected with food selection

The changes of the sex structure in the population indicate that males prevailed (♂/♀ > 1) within the starting population during the initial and final periods of development. However, during the periods preceding a rapid growth of the population size, i.e. after 100, 130 and 160 days, a rapid decrease of the sex proportion below 1 followed indicating a female share majority in the population. In the groups of migrating individuals, values of the sex ratio were smaller than one and they ranged between 0.5 and 0.9. (Table 2).

Table 2. Sex ratio in *Rhizopertha dominica* in conditions of migration connected with food selection

Days	Initial population	Migration groups			
	wheat	wheat	pearl barley	oat flakes	semolina
40	2	0.5	0.8	0.6	0.8
70	1	0.9	0.9	0.7	0.5
100	0.8	0.8	0.8	0.6	0.9
130	0.9	0.9	0.9	0.9	0.8
160	0.6	0.7	0.8	0.9	0.9
190	1	0.9	0.8	0.8	0.7
220	1.2	0.8	0.9	0.9	0.9

In the conditions preventing dispersion of individuals among nutrients, as soon as after 40 days of studies, a high 96% emigration of pests from the initial substrate towards all nutrients occured. After a time the values of migration rate were lower,

although they were still very high. At the initial period, up to the 40th day, the migrating individuals prefered oat flakes. But still after 70 days however, in wheat, pearl barley and oat flakes migration rates equalization was observed. Starting from the 100th up to the 220th day the highest orientation of migratory activity was directed towards wheat and then to oat flakes, pearl barley and semolina. The migration rate in semolina was the lowest (Fig. 4).

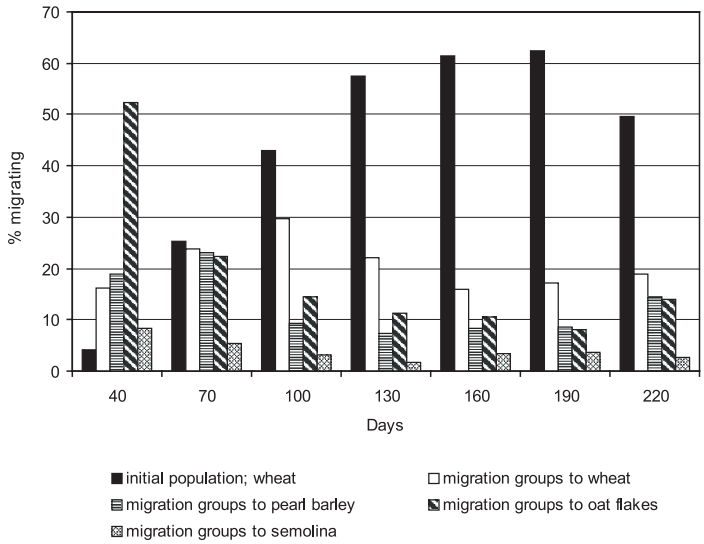

Fig. 4. Migration activity of *Rhizopertha dominica* delimited by food selection

A dynamic growth of the population size in the initial substrate was observed after 70 days, i.e. during the period when the migratory activity of the population declined. The maximum size was on the 190th day of the population development and then a gradual decline was observed. The maximum number of individuals in this population during its most intensive development was as high as 974 individuals. Although at the initial period the number of migrating individuals towards oat flakes was the highest yet from the 70th day an equalization of the population size in the groups of migrants infesting all nutrients except semolina was observed. At that time the differences of the population size between wheat and pearl barley ($p = 0.910646$), wheat and oat flakes ($p = 0.280759$) and pearl barley and oat flakes ($p = 0.640642$) were statistically insignificant. From the 100th up to the 220th day an increase of the population size was recorded in wheat. In pearl barley this increase started from the 130th day and similarly to the other nutrients reached the highest value on the 220th day. In semolina the population development was almost invisible and its insignificant size, similarly to previous experiments, was caused by emigration of individuals from the initial population (Table 3).

Mortality in the initial population was very small and did not exceed 7%. The highest mortality was observed in the individuals migrating to semolina. The highest mortality rate was recorded there in the first three months followed by mortality reaching even 30%. In the remaining nutrients the highest mortality was recorded at

the initial emigration stage after 40 days. Later, it remained on a relatively low level ranging from 3.5 to 18%. The lowest values of mortality rate were observed in the groups of insects infesting oat flakes (Fig. 5).

Table 3. Number of *Rhizopertha dominica* in conditions of migration delimited by food selection

Days	Number of individuals									
	initial population		migration groups							
	wheat		wheat		pearl berley		oat flakes		semolina	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
40	2	0	3	0.5	7	0	22	1.7	0	0
70	30	1.4	26	2.3	26	3.1	27	0.7	1	0.8
100	112	2.6	73	3.1	21	0.7	37	3.2	3	0.6
130	401	35.4	140	16.6	46	2.5	75	5.3	10	1.8
160	129	19.9	160	7.5	82	7.8	108	5.8	28	3.1
190	974	14.9	240	23.9	121	4.1	116	11.4	47	2.2
220	923	16	307	17.5	254	28	256	32.3	39	3.9

SD – standard deviation

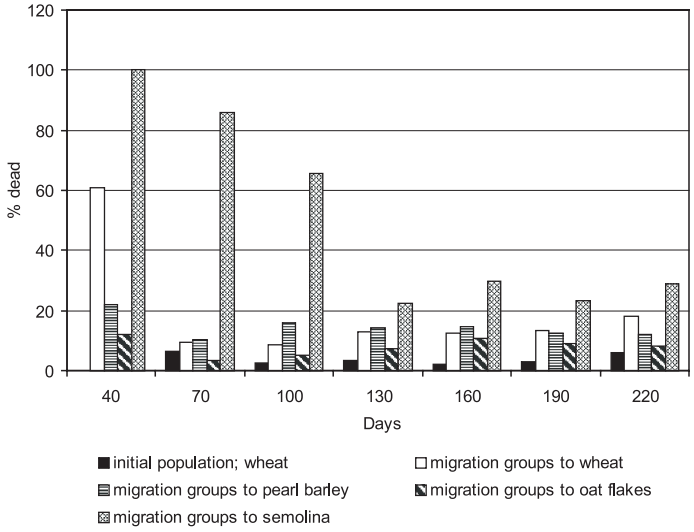

Fig. 5. Per cent of dead individuals of *Rhizopertha dominica* in conditions of migration delimited by food selection

The males' proportion in the initial population was approximately equal to the number of females. Only within the time interval between the 70th and the 160th day the number of females increased, which was correlated with the growth of population size. In the groups of emigrants infesting wheat and pearl barley during the initial period males prevailed, but starting from the 100th day the females' proportion increased. A decrease in the sex ratio was followed by the growth of population size

in the groups of emigrants. During the initial period of infesting oat flakes from the 40th to the 130th day the highest migratory activity was found in the females. The values of sex ratio amounted to 0.5 to 0.9 during this period. Later the number of the males increased. After 70 days a higher proportion of females was recorded in the population infesting semolina (Table 4). It was not a consequence of the population development in this nutrient, but it resulted from their higher tendency to emigrate from the initial population.

Table 4. Sex ratio in *Rhizopertha dominica* in conditions of migration delimited by food selection

Days	Initial population	Migration groups			
	wheat	wheat	pearl barley	oat flakes	semolina
40	1	1.1	1.1	0.5	0
70	0.9	1.1	1.3	0.5	0.5
100	0.8	0.9	0.9	0.7	1.3
130	0.8	0.8	0.8	0.9	1.1
160	0.7	0.7	0.8	1.1	1
190	1.1	0.8	0.7	1	1.2
220	1	0.9	1	1.2	1.1

DISCUSSION

A tendency to dispersion by migration, which is observed in storage beetle populations, is the primary reason for their constant attack of stored cereal and food products. It is a serious worldwide problem mainly because of heavy economic loss which is a result of destroying stored food by those insects, and also due to exclusion of universally accepted pesticides in their habitats. Natural methods of fighting against this group of insects consist, first of all, of preventing their occurrence. The problem of conditions determining their population migratory activity is of both theoretical and practical importance. The migratory activity depending on the species characteristics may lead to creating clusters by the population or to its even dispersion.

Barrer et al. (1993) found that the increase in the *R. dominica* population density causes the increase of migration process by intensification of the flying activity. In Polish climate however, this insect does not demonstrate active flying. It lives in closed granaries and storerooms (Ciesielska and Kłyś 1995).

As migration is a populational process, the causes for migration of larval stages are not known except for searching food. The studies on causes of the Khapra beetle larvae *Trogoderma granarium* Everts. migration carried out by Stanić and Shulov (1972) showed that the direction and intensity of migration may depend on the relation between smell of feces and smell of fresh wheat.

The studies on the influence of population density, temperature and humidity on creating clusters and dispersion of different beetle species were conducted by Surtees (1964, 1965). One of the species examined by him was also lesser grain borer. The author demonstrated that at the air temperature of 15° C the beetles of lesser grain borer gather in central layers of a pile where the temperature is usually higher. In higher ambience temperatures, the dispersion is more even with a tendency to seizing dry portions of the grain.

Gołębiowska et al. (1976) reported a tendency of the lesser grain borer population to migrate down the pile simultaneously claiming that females of this species lay the largest amount of eggs in deep grain layers. The mentioned authors analyzed active nutritional selectivity of several storage beetle species concerning mainly wheat, rye and maize. Granary weevil *Sitophilus granarius* L. and the rice weevil *Sitophilus oryzae* L. left initial food first. The adults of *R. dominica*, however, stayed in it, no matter what kind of grain was there. It resulted primarily from the lack of chance for migrating out of the initial habitat of *R. dominica* because the results obtained in the course of my own studies concerning the conection between the migration process and nutritional selectivity are different. It was noted that *R. dominica* shows a strong tendency to migration connected with an active nutritional selectivity. There is an interrelation between "attractiveness" of a nutrient and the migration process. At the initial stage of active colonization of a new nutritional habitat, it leads to creating clusters in the preferred food – oat flakes. The next stage of migration is oriented at wheat that provides the most favourable development conditions. However after a time, the migration aims at wheat and then oat flakes, pearl barley and semolina. The final size of the populations developing in particular nutrients (in conditions where migration among them is impossible) is higher in the nutrients where horizontal spread takes place. It may be connected with constant migration of adults under conditions of free choice of food and thus horizontal spread with significant energy loss.

Similarly to the populations of other storage beetle species (Ciesielska 1992), females of *R. dominica* are characterized by a high migratory activity. The sex ratio in migrating groups is usually < 1. Prevalence of the female proportion among migrants is particularly important when attacking new habitats as it causes a danger of this pest new populations development. Moreover, even under conditions of food surplus *R. dominica* actively disperse and attack new grains at a relatively low actual consumption (Kłyś 2004 b). There is a large characteristic "wastefulness" in using nutritional reserves. It is an extremely dangerous phenomenon in relation to granaries where, as a result of such a population strategy, the pest quickly spreads and still attacks new stocks of stored grains.

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POLISH SUMMARY

WSPÓŁZALEŻNOŚĆ WYBIÓRCZOŚCI POKARMOWEJ I AKTYWNOŚCI MIGRACYJNEJ POPULACJI *RHIZOPERTHA DOMINICA* F. (*COLEOPTERA, BOSTRICHIDAE*)

Obiektem laboratoryjnych badań był kapturnik zbożowiec *Rhizopertha dominica* F. Celem przeprowadzonych eksperymentów była weryfikacja hipotezy, czy przebieg zachodzącej równocześnie pionowej migracji i poziomego rozprzestrzeniania się populacji kapturnika zbożowca jest uwarunkowany wybiórczością pokarmowo-siedliskową.

W eksperymentach jako pokarm zastosowano: pszenicę, płatki owsiane, kaszę jęczmienną i kaszę mannę. Stwierdzono, że przebieg procesu migracji jest związany z preferencją pokarmową, uwarunkowaną głównie rodzajem pokarmu, jego granulacją i stopniem rozdrobnienia. W początkowym okresie badań najwyższa emigracja następuje do płatków owsianych. W miarę upływu czasu najwyższa migracja zachodzi kolejno do: pszenicy, płatków owsianych, kaszy jęczmiennej i kaszy manny. Samice wykazują wyższą aktywność migracyjną.