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# Feeding preferences and progeny production of *Rhyzopertha dominica* (Fabricius 1792) (Coleoptera: Bostrichidae) in small grains

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***Abstract*:**

**Perišić, V., Perišić, V., Vukajlović, F., Pešić, S., Predojević, D., Đekić, V., Luković, K.: *Feeding preferences and progeny production of Rhyzopertha dominica (Fabricius 1792) (Coleoptera: Bostrichidae) in small grains. Biologica Nyssana, 9 (1). September, 2018: 55-61.***

The lesser grain borer, *Rhyzopertha dominica* (Fabricius, 1792) (Coleoptera: Bostrichidae) is a primary pest of stored wheat. Many authors studied its development on this cereal. The wheat is commonly stored together with other grain, especially barley, rye, oats and triticale. The objectives of this study are to assess the feeding preferences for the small grains (wheat, barley, rye, oat and triticale) and to evaluate their susceptibility/resistance to progeny production of *R. dominica.* The mean survival rate of *R. dominica* adults, progeny emergence and amounts of insect-damaged grains and dockage in various small grain species were determined. Also, influence of *R. dominica* feeding on chemical properties (moisture protein and ash contents in grains) was found out. The influence of the grain species on the development of *R. dominica* was significant. The highest mortality of parents and the lowest progeny counts in oats, while triticale is very suitable for development of *R. dominica*, much more then wheat, as a primary host. The biggest amount of damage kernals and dust were found in triticale. The contents of moisture, protein and ash in the grain has been changed due to feeding of *R. dominica*.

**Key words**: *Rhyzopertha dominica* F., small grains, progeny, damaged kernels, dust

***Apstrakt*:**

**Perišić, V., Perišić, V., Vukajlović, F., Pešić, S., Predojević, D., Đekić, V., Luković, K.: *Preferencija u ishrani i pojava potomstva Rhyzopertha dominica (Fabricius 1792) (Coleoptera: Bostrichidae) u strnim žitima. Biologica Nyssana, 9 (1). Septembar, 2018: 55-61.***

Žitni kukuljičar (rizoperta) - *Rhyzopertha dominica* (Fabricius, 1792) (Coleoptera: Bostrichidae) je primarna štetočina uskladištene pšenice. Njen razvoj na ovoj vrsti strnih žita proučavali su brojni autori. Pšenica se obično skladišti sa drugim strnim žitima, posebno ječmom, raži, ovsom i tritikaleom. Ovo istraživanje je sprovedeno u cilju ispitivanja preferencija u ishrani *R. dominica* u strnim žitima (pšenica, ječam, raž, ovas i tritikale) i ocene osetljvosti/otpornosti ovih žita na pojavu potomstva *R. dominica*. Utvrđen je prosečan broj preživelih jedinki *R. dominica*, pojava potomstva i broj zrna oštećenih insektima, kao i količina prašine u različitim vrstama strnih žita. Takođe, utvrđen je uticaj *R. dominica* na hemijske osobine strnih žita (sadržaj vlage, proteina i pepela u zrnu). Uticaj vrste žitarica na razvoj *R. dominica* bio je značajan. Najveća smrtnost roditelja i najmanja pojava potomstva utvrđena je kod ovsa, dok je tritikale veoma povoljan za razvoj *R. dominica*, mnogo više nego pšenica, kao primarni domaćin. Najveća količina oštećenih zrna i prašine nađeni su u tritikaleu. Ishrana *R. dominica* je dovela do promene sadržaja vlage, proteina i pepela u zrnu.

**Ključne reči**: *Rhyzopertha dominica,* strna žita, potomstvo, oštećena zrna, prašina

## Introduction

The lesser grain borer, *Rhyzopertha dominica* (Fabricius, 1792) (Coleoptera: Bostrichidae) is a primary pest of stored grain, with the great economic importance in the Republic of Serbia and many regions of the world (Kljajić, 2008). It feeds mostly on grains from families Poeaceae (e.g. rice, wheat, sorghum, oats, pearl, millet, malt, barley) and Fabaceae (e.g. chickpeas, peanuts, beans) (Edde, 2012). A lot of research was conducted which dealt with the influence of the species and variety of the plant on the development of *R. dominica* and occurrence of the progeny (Arthur et al., 2012, 2013; Astuti et al., 2013; Metwaly et al., 2015; Pires, 2016). Although it is one of the most important stored-grain insect pests in the world, most of research was conducted on wheat and rice (Chanbang et al., 2008; Mebarkia et.al, 2009; Nawrot et al., 2010). Wheat is commonly stored together with other grain, especially barley, rye, oats and triticale. However, there are no studies in which adults of *R. dominica* have been directly exposed to small grains and assessed the influence of these species on progeny production and feeding preferences.

The larvae and adults of *R. dominica* spend most of their life inside the kernel, feeding on both the germ and endosperm, directly causing damages and changes in grain physicochemical properties (Rees, 2004; Edde, 2012). Insect-damaged kernels are characterized by the presence of irregularly shaped holes (about 1 mm in diameter) of increasing depth that extends from the point of larval entry, around the edge of the kernel to the pupation chamber (Rees, 2004). Adult feeding activities produce large amount of dust, which often leads to the reduction of grain kernel to the pericarp. Jood & Kappor (1993), Mebarkia et al. (2009) and Nawrot et al. (2010) investigated the amount of grain consumed by *R. dominica* under experimental conditions, but the losses of nutrient value varied among the authors.

Small grains contain different quantities of main nutrition groups, which are very important for development and progeny production of *R. dominica*. The most commonly grown grain species in Serbia are wheat, barley, rye, oats and triticale. According to Serna-Saldivar (2010a), this species differed in amount of proteins, starch and other nutrients. Furthermore, above-mentioned species express differences in morphological properties, for example, presence/absence of a hull. Nitrogen and phosphorus are particularly mismatched when herbivorous insects are compared with their host plants (Huberty & Dennno, 2006).

The objectives of this study are to assess feeding preferences of *R. dominica* for small grains (wheat, barley, rye, oats and triticale) through determination of some grain properties, i.e. mass of infested-damaged kernels (IDK) and dust, contents of moisture, proteins and ashes in grains infested with *R. dominica* and to evaluate their susceptibility/ resistance to progeny production of *R. dominica.*

## Material and methods

Examination of the influence of different small grain species (wheat, barley, oats, rye and triticale) on the emergence of the progeny of *R. dominica*, on stored small grains, as well as effect of their presence on chemical properties of small grains were conducted in laboratories of Center for Small Grains Kragujevac, Serbia during 2016.

### Tested insects

Adults of *R. dominica* of both sexes and 2-4-weeks old were used during the experiment, reared in the Center for Small Grains on the whole wheat kernels, in laboratory conditions with temperature (T) 26±1°C and relative humidity (RH) 60±5%.

### *Tested cereal species*

*R. dominica* was reared on five commercially available small grain varieties (wheat variety Vizija, barley variety Rekord, oat variety Vranac, rye variety Raša and triticale variety Favorit), originating from the Center for Small Grains Kragujevac, Serbia. Different cereal species with the grain moisture 11-12% were used during the testing. This value was chosen because it has been proposed level of the moisture for stored small grains (The Official Gazette of RS, 2016). The moisture content was determined with Motomco moisture meter (Motomco Inc, 919, Canada) according to AACC method 44-11 (AACC, 1995).

Examination of the influence of different small grain species (wheat, barley, oats, rye and triticale) on the emergence of the progeny of *R. dominica*, on stored small grains was based on the modified method according to Arthur et al. (2013). After the harvest, grains were put in the refrigerator at 4 °C. Before the incorporation of adults of *R. dominica*, grains were sieved on the 2 mm sieve and cleaned by hand. Then, plastic vessels of 200 ml were filled with 50 g of grains and put in the incubator with controlled T 26±1 °C and RH 60±5% (Incubator XO 1450 special, Iskra, Loka, Slovenia). Twenty-five adults of *R. dominica* were released into each vessel. Vessels were then closed with cotton cloths fixed with a rubber band. For each small grain species, eight replications were conducted.

Hatching period is about seven days or less (Crombie, 1940; *cit.loc*. Edde, 2012), while we decided to determine the influence of commodity on feeding preferences and survival of *R. dominica* for a period of three weeks. Parental adults were removed from the vessels after three weeks and classified as alive or dead. Afterwards, damaged grains and dust (the feeding damage) were separated and their mass was measured on analytical balance (Mettler 609-B6, Zürich, Switzerland) for each sample (50 g) of grain types, and then the contents were put back into the vessels.

Since egg-to-adult development of *R. dominica* could be shorter than five-six weeks on wheat (Edde, 2012), the period of seven weeks was chosen for incubation, as duration of development was expected to be longer in non-preferred commodities.

After seven weeks at the constant temperature and humidity, vessels with grains were opened and the progeny emergence was determined by counting insects separated from grains. Damaged grains and dust were weighed again, after progeny counting. The whole procedure was repeated twice.

***Determination of the influence of R. dominica feeding on chemical properties of small grains***. Infested and damaged kernel, as well as dust, were returned to the vessel after weighing. For this research, uninfested samples from the same year of production were used as a standard (control). All samples were milled and prepared for chemical analysis of moisture, total protein and ash contents. The moisture content was determined based on the loss of samples weight after drying on T 130-133 °C (ICC Standard No. 110/1: 1976). The total protein content of grains (N x 5.7 for wheat, rye and triticale, and N x 6.25 for oats and barley) was determined according to modified Kjeldahl’s method (ICC Standard No. 105/2:194). Ash content was estimated by burning a sample at 900 °C and measuring the residue (ICC standard method No.104/1: 1990). Results were expressed as percent (%) from the sample weight and represented as a dry matter.

***Statistical analysis.*** Results of examination were expressed in percent of mortality (%) with computed standard error (SE). Before analysis, results for the progeny number was transformed with formula *log(x+1)*, while formula sqrt(x) was used for the amount of damaged grain and dust.

Recorded data were analyzed by one-way or two-way analysis of variance (ANOVA) depending on the trial design. The significance of mean differences was determined according to Duncan test (for $p$=0.05).

Pearson's coefficient at $p$=0.005 was used to determine linear correlation between the survival parents or the number of progeny and the number of damaged kernels, and correlation between mass of damaged kernels and the parameters of chemical analysis (moisture, proteins and ash contents).

All data were processed on StatSoft version 7.1 (StatSoft Inc., Tulsa, Oklahoma).

## Results

Survival of *R. dominica* parents on different small grain species three weeks after the infestation ranged from 91.25% on oat to 99.25% on rye (**Tab. 1**) and was significantly smaller in oat than in other examined cereals. The significantly smaller amount of insect-damaged grains and dust after two weeks was found in oats. The highest mass of damaged grains and dust was found in the triticale (3.87 g/1.96 g).

Mean *R. dominica* parent survival and feeding damage were compared using a linear correlation analysis with Pearson’s coefficient and significant positive correlations were not detected for $p$<0.005, N=16 (wheat r=-0.123, $p$=0.650; barley r=0.287, $p$=0.281; rye r=-0.257, $p$=0.925; oats r=-0.564, $p$=0.836 and triticale r=0.232, $P$=0.386).

Based on the data given in **Tab. 2**, our analyses show that the production of *R. dominica* progeny and feeding damage varied considerably in dependence of cereal type. The influence of the grain species on the development of *R. dominica* was significant. The highest progeny was recorded in triticale (430.35 in average), followed by rye (221.42 in average), wheat (150.2 in average), barley (91.1 in average) and the smallest in oats (35.15 in average).

The amounts of insect-damaged grains and dust after the removal of the progeny on various grains is presented in **Tab. 3**. The dust weight after progeny count was significantly lower in oats (0.45 g). The highest damage and dust were detected in the triticale, compared to the wheat, as primary host of *R. dominica* (9.60 g vs. 4.52 g).

Pearson's correlation coefficient revealed a significant positive correlation between progeny production and damaged grain in wheat (r=0.948, $p<0.005$ ), barley (r=0.677, $p<0.005$ ), rye (r=0.807, $p<0.005$) and triticale (r=0.880, $p<0.005$), while no correlation was found between the two data in oats (r=-0.194, $p=0.470$).

The infested samples, with an exception of oats, had significantly higher moisture content, compared to un-infested sample. Moisture content and the weight of damaged grain (**Tab. 2**) were compared using a linear correlation analysis with Pearson's coefficient and significant positive correlations were detected for wheat (r=0.564, $p<0.005$), triticale (r=0.847, $p<0.005$) and rye (r=0.867, $p<0.005$), the lowest for barley (r=0.135, $p<0.005$), while no correlation was found between the two data for oats (r=0.319, $p=0.229$).

Total content of proteins was significantly lower in infested sample in all types of grain, except in oats, where no difference was found (**Tab. 3**). Pearson's correlation coefficient revealed a significant negative correlation between protein content and damaged grain in wheat (r=-0.738, $p<0.005$), barley (r=-0.786, $p<0.005$) rye (r=-0.909, $p<0.005$) and triticale (r=-0.483, $p<0.005$ ), while no correlation was found between the two data in oats (r=-0.189, $p=0.317$).

Significant differences in ash content between the tested variants were recorded only for rye and triticale where ash contents were significantly increased. Pearson's linear correlation coefficient between ash content and damaged grain revealed significant positive correlations in rye (r=0.647, $p<0.005$) and triticale (r=0.847, $p<0.005$), while no correlation was recorded for wheat (r=0.198, $p=0.038$), barley (r=0.119, $P=0.201$) and oats (r=0.194, $p=0.104$).

**Table 1.** Mean survival (% ± SE) of *Rhyzopertha dominica* adults and amounts of insect-damaged grains and dockage (g ± SE) after three weeks of infestation of various cereal grains species.

| Grain type | Adult survival (% ± SE) | Damaged kernels (g ± SE) | Dust (g ± SE) |
|---|---|---|---|
| Wheat | 98.25±0.11 b* | 1.84±0.03d | 0.43±0.05c |
| Barley | 96.75±1.28 b | 0.97±0.12b | 0.18±0.06b |
| Rye | 99.25±0.08 b | 1.58±0.18c | 0.89±0.09d |
| Oat | 91.25±0.15 a | 0.09±0.09a | 0.02±0.01a |
| Triticale | 98.25±0.89 b | 3.87±0.23e | 1.96±0.11e |
| F | 11.163 | 59.56 | 74.22 |
| *p* | < 0.05 | < 0.05 | < 0.05 |

* Within each column, means followed by the same letter are not significantly different, in all cases df=4.75; Duncan test at $p>0.05$.

**Table 2.** Progeny emergence ( $\bar{x}$ ± SE) and amounts of insect-damaged grains and dockage (g ± SE) after the removal of the progeny from various cereal grains species

| Grain type | Number of progeny ( $\bar{x}$ ± SE) | Damaged kernels (g ± SE) | Dust (g ± SE) |
|---|---|---|---|
| Wheat | 150.2±0.67c* | 5.42±0.05c | 1.69±0.06c |
| Barley | 91.1±0.40b | 2.61±0.09b | 0.95±0.04b |
| Rye | 221.42±0.79d | 5.17±0.10c | 3.33±0.09d |
| Oats | 35.15±0.19a | 0.45±0.03a | 0.21±0.02a |
| Triticale | 430.35±0.42g | 9.60±0.11d | 4.52±0.08e |
| F | 72.08 | 43.42 | 50.12 |
| *p* | < 0.05 | < 0.05 | < 0.05 |

* Within each column, means followed by the same letter are not significantly different, in all cases df=4.75; Duncan test at $p>0.05$.

**Table 3.** Moisture, protein and ash content (% ± SE) in various cereal grains species after Rhyzopertha dominica progeny count.

| Sample | Moisture, protein and ash contents (% ± SE) in various grain types | | | | |
|---|---|---|---|---|---|
| | Wheat | Barley | Rye | Oats | Triticale |
| | | | Moisture content | | |
| Infested sample | 14.4±±0.05[b]* | 12.3±0.05[b] | 13.4±0.05[b] | 11.3[a] | 14.2±0.05[b] |
| Un-infested sample (control) | 12.1 ±0.05[a] | 11.7±0.05[a] | 11.7±0.05[a] | 10.8±0.05[a] | 11.8±0.05[a] |
| *F* | 56.49 | 68.04 | 15.23 | 1.8 | 72.91 |
| *P* | < 0.05 | < 0.05 | < 0.05 | 0.204 | < 0.05 |
| | | | Protein content | | |
| Infested sample | 12.5±0.05 [b] | 11.73±0.05b | 15.37±0.05[b] | 13.26±0.05a | 10.90±0.05[b] |
| Un-infested sample (control) | 13.21±0.05[a] | 12.04±0.05[a] | 15.78±0.05[a] | 13.30±0.05a | 12.34±0.05[a] |
| *F* | 95.3 | 42.6 | 33.36 | 2 | 195.94 |
| *P* | < 0.05 | < 0.05 | < 0.05 | 0.149 | < 0.05 |
| | | | Ash content | | |
| Infested sample | 1.83[a] | 2.45[b] | 2.08[b] | 3.41[a] | 2.81[b] |
| Un-infested sample (control) | 1.71[a] | 2.36[a] | 1.91[a] | 3.38[a] | 2.25[a] |
| *F* | 1.21 | 3.745 | 22.05 | 0.42 | 98.91 |
| *P* | 0.280 | 0.07 | < 0.05 | 0.52 | < 0.05 |

* For each parameter separately, means within columns followed by the same letter are not significantly different, in all cases df=1.30; Duncan test at $p>0.05$. Un-infested sample (control) - dockage and insect free sample

## Discussion

Mechanisms of tolerance of cereal grains are complex and depend on many factors, such as the physicochemical and biochemical grain properties as well as the insects' capacity for biochemical and physical adaptation to post-harvest conditions (Nawrot et al., 2006). It should be noted that physical and chemical properties of cereal grain have a fundamental influence on the developmental rate of *R. dominica*.

The physical properties significantly affect the percentage of grain infestation of *R. dominica* (Kavallieratos et al., 2010). Keskin & Ozkaya (2013) stated that grain hardiness represents one of the main reasons for stronger or weaker infestation of *R. dominica*. In our study, the highest progeny was found in triticale, which grain is classified as the softest (Perišić et al., 2009a) and rye, which is significantly softer than wheat, while significantly smaller number of progeny was found in the barley, whose grain is harder than wheat (Serna-Saldivar, 2010b). Also, triticale has the biggest 1000-kernel mass (AM ≈ 45 g), compared to the oats and rye (AM ≈ 29.35 and 36 g, respectively) (Perišić et al., 2009b). According to Kavallieratos et al. (2010), smaller size and kernel shape of grain could discourage the lesser grain borer from laying eggs in clusters on the kernels. Edde (2012) claims that the texture of larval food can have significant influence on the rate of brood development. Our data confirmed results reported by Nawrot et al. (2010), who established high resistance of some varieties of wheat to *Sitophilus granarius* (Linnaeus, 1758) infestation. This resistance was associated with vitreosity-grain hardness and lower 1000-kernel mass and kernel diameter.

It must be emphasized that kernel of barley and oats have a hull as an outer layer, namely hull stayed intact on the grain of this species after the harvest. Hull of barley is completely concrescence with pericarp of kernel, while oats' hull could be mechanically removed from the grain. Mebarkia et al. (2009) noted that barley grain covered with its cellulose envelopes is unfavorable for *S. granarius*, but it is not disadvantage for *R. dominica*. The development of progeny in our study on barley can therefore be explained only by the greater hardness and with some chemical properties (content of proteins).

In our study, the highest mortality of parents and the low progeny count was determined in oats. Among all studied species, only oats have a hull which is not grown up with grain and which is covered with hair. The hull is unpalatable, dry, and brittle outer layer which accounts for approximately 25–36% of the total dry weight of the oat (Welch, 1995). According to Nawrot et al. (2010), the hull in oats is composed mainly of silica, which protects the kernel against insects and can slow down the infestation by these pests. These authors also claim that an additional factor which can be taken into consideration is the compact structure of the lemma and palea.

Reproduction insect ecology postulate is that the oviposition preference of a female should be correlated with the host's suitability for the development of its offspring. Hull on oats covers its grain as well as the clusters on the grain where *R. dominica* lays eggs which significantly reduces this phase of development.

The amounts of damaged kernel and dust were in correlation with the emergence of progeny. Since the highest number of progeny was determined in triticale, it was quite expected that aforementioned parameters were greatest in this species. Mebarkia et al. (2009) examined the influence of grain species (soft and hard wheat, barley, rice, maize) on the development and the way of feeding of *R. dominica*. Their results were similar to our study, with established differences between examined species for progeny number, length of development and the loss of dry matter generated after feeding of this pest. Furthermore, loss of a dry matter as a consequence of the development of *R. dominica* progeny was different in examined species of small grains (wheat, barley, rice, and maize).

All samples showed a significant change in moisture content, except in oats. As more damage was found in those grains, the increase in moisture was expected. Pearson's correlation coefficient also confirmed the association of these two parameters.

As *R. dominica* mostly feed on seed endosperm and germ, it is able to reduce the grain merely to its pericarp (Edde, 2012) and increased infestation and higher grain damage are expected to reduce total protein contents in untreated grains. Jood & Kapor (1993) also reported reduced protein contents in wheat seeds but only under intensive *R. dominica* infestation of 75%, while Ozkaya et al. (2009) determined significant increase of protein, moisture and ash contents. The explanation for these opposites between different researches is based on the presence of impurities and uric acid, while the real content of protein was decreased as a consequence of *R. dominica* feeding.

A significant difference in ash content was detected in triticale and rye. Changes in ash content were caused by *R. dominica* presence and feeding, which was confirmed by Pearson's correlation coefficient. Our data are in agreement with those reported by Jood et al. (1992), who found that *R. dominica* influence the content of mineral matter in grain by increasing it under strong infestation. Keskin & Ozkaya (2013) confirmed the same effect of *S. granarius* as this insect also feeds mostly on seed endosperm and germ. These experiments were conducted only on wheat, with no results on the other small grain.

Small grains - wheat, barley, rye and triticale can be considered as "nutritionally suitable" for *R. dominica* development. Triticale is the most susceptible to attacks and suitable for development of *R. dominica.* It is clearly demonstrated that oats is less infested and is not a suitable host for the strain of *R. dominica* used in the present study. The presence of the hull in oats proved to be important morphological characteristic of a kernel which has an effect on development and feeding of the examined pest. The role of the hull can be objective of future research, i.e. is it represents a physical barrier only or possesses some chemical substances which act as a repellent against *R. dominica*.

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