DOI: 10.22620/agrisci.2025.45.004

Damage and weight losses of stored cereals caused by the lesser grain borer *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae)

Doncho Obretenchev[1]*, Firas Zidan[1], Daniela Atanasova[2]

[1] Plant Protection Institute, Kostinbrod, Bulgaria
[2] Agricultural University – Plovdiv, Bulgaria
***Corresponding author: d_obretenchev@yahoo.com**

Abstract

Observations on stored grain, products from its manufacture and materials from plant origin in the storage-silo bases in Bulgaria were conducted from 2000 till 2019 to establish the damage and weight losses from the lesser grain borer *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae). It was found that the grain beetle adults consumed 0.905 ± 0.00374 mg of food per day. With an average adult lifespan of 130 days, an adult consumes 117.678 mg of dry matter from the grain. In experiments aimed to determine the weight losses caused by the larvae of the grain beetle during their development, it was found that they amounted to 13.7861 ± 0.04632 mg per individual. Thus, losses for the development of individual amount to an average of 131.6647 mg. A test for the presence of mycotoxins (fumonisins - FB1 and FB2 total in ng/g) was done on maize attacked up to 5% and 25% with latent infection by the grain beetle. The results showed that at 5% latent infection the quality of mycotoxins was almost 5 times higher -lower than that at 25% corn infestation - 693.9 ± 69 ng/g and 3436.1 ± 34 ng/g, respectively. This shows that the development of the species in the grain stocks also leads to secondary processes of decay accompanied with an increase of mycotoxins consentrations.

Keywords: *Rhyzopertha dominica*, the lesser grain borer, damage, stored cereals

INTRODUCTION

The lesser grain borer *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) is one of the most destructive for stored grains insect pests worldwide (Aitken, 1975). A lot of world-renowned authors have worked on the problem associated with weight loss and damage caused by *R. dominica*. Gundu & Wilbur (1957) reported weight losses of about 9.5% of the wheat grain i when larvae of the species fed for 20 days and 19.4, 12.0, 9.5 and 6.5% of the wheat grain respectively in the 1st, 2nd, 3rd and 4th week after imagining the adults. According to Zheltova (1972) the weight loss caused by one beetle of *R. dominica* during its life is 45 mg, compared to those of the wheat weevil - 40 mg, which causes the largest losses among all economically important pests. Larvae of the grain beetle destroy 12 mg of dry matter, which is 40% of the grain weight, and is 9 times the weight of the adult insect. Compared to the losses caused by wheat weevil larvae (17 mg dry matter), grain beetle larvae are less damaging. The author estimates that the offspring of one pair of *R. dominica* can destroy 28 g of grain. Zakladnoi & Ratanova (1973) reported that if the harmfulness of the most widespread and highest-density storage pest, the rice weevil *Sitophilus oryzae* L., is taken as 1 (unit), then the coefficient of harmfulness of the grain beetle is 1.7. Kuzmanov et al. (1983) made a comparative assessment of the harmful activity of the grain beetle, rice and wheat weevils and found that in 6 months their population densities increased 70, 90 and 40 times respectively. The authors found that losses from the grain beetle were highest in wheat and lowest in rice arp.

In terms of the nature of the damage, Johnson (2000) reports that larval and adult

individuals of *R. dominica* are primary pests. They pierce roughly shaped holes in the entire non-damaged grains, and the larvae develop within the endosperm of the grain. According to the authors, the larvae and the adults develop, feeding inside and on the grain, and from it can remain unevenly cracked only the scales. Eating adults and larvae is accompanied by the release of a lot of dust and the presence of a sweet and unpleasant odor.

R. dominica causes economic losses to stored cereals. The damage occurs due to weight deterioration by producing frass from damaged cereals, bad odors and reduction of nutrient contents. These undesirable effects on cereals makes grains unsuitable for human consumption, reduce their essential amino acids and germination ability (Park et al., 2008; Ahmedani et al., 2009; Arthur et al., 2012). The larvae and adult stages pose a greater threat, causing more damage to stored cereal grains than other pests (Vardeman et al., 2007).

The present study aimed to establish the weight losses caused by the lesser grain borer *R dominica* and to clarify the influence of its hidden infection on the quantitative and qualitative indicators of stored cereals.

MATERIALS AND METHODS

The study was carried out by routine inspections of warehouses, silos, mills, factories and workplaces in the Republic of Bulgaria. Samples of stored grain from cereals, products of its processing and materials used to determine the type of attacked food were collected. For this purpose, stage and cone probes, thermal rods were used. Average samples of 2 kg were formed by the diagonal method or by the checkerboard pattern. In the laboratory, the samples were screened through a set of sieves with a bottom and a lid, the insects were separated by species and their population density was taken into account, equating to 1 kg of sample and the type of food on which they were found.

Methodology for determining weight losses

Grains of wheat variety Pobeda (6 kg) is brought to humidity of 15%. 10 g of the prepared grain are measured on an analytical balance and placed in glass vessels with a capacity of 100 ml. In each vessel were placed 200 beetles of *R. dominica* aged 20 – 30 days from imagination. After 15 days, the seeded beetles were removed from the grain and it was reweighed, the moisture content of the grain was also measured at the end of the trial and the weight was corrected for moisture (Henderson & Pixton, 1982). For more accurate measurement of the weight losses, the grain in the control and that in the experimental variant at the end of the experiment was brought to an absolutely dry substance by heating in a special dryer and their exact weight was measured. The difference was considered as the resulting weight loss caused by 200 beetles for 15 days. The weight of food eaten by an adult per day was also calculated. Then, based on the average life expectancy of adults, the loss that one adult incurs in their lifetime was calculated.

To calculate the weight losses caused by the larvae during their development, 100 g of the prepared grain are weighed, of which 10 g are coarsely ground and placed in glass containers with a capacity of 200 ml. 200 adults of the species of the above egg-laying age are released into the grain, which were removed by sieving after 24 h. The vessels with the grain were placed under optimal conditions for species development (t – 32 ºC and relative humidity of the air 75 ± 5 %) until the adults of the new generation imagined. Newly imagined beetles were removed daily and enumerated until imagination ceased. The difference between the weight of the wheat at the beginning and at the end of the experiment was consider as the total weight loss. The amount of grain eaten by 200 beetles per day was subtracted from it and the remaining value was divided by the number of imaginary adults in the F1 generation and the weight loss from the development of one larva obtained. Trials were run in 10 replicates.

The changes in qualitative and quantitative indicators of the wheat grain infected to varying degrees and the resulting flour were carried out in the SOFIA-MEL mill laboratory. The following indicators were analyzed: absolute mass of 1000 grains in g; hectoliter weight g/l; wet gluten yield in weight units; amount of gluten - looseness in mm; ash content of the grain - % dry in/in; acid number of fats - mg (KOH)/g oil; yield of flour during one-time grinding in %., ash content - % dry content of 70% flour; whiteness - R of 70% flour.

For mycotoxin content were tested 250 g of maize grain either with 5 or 25 % latent infestation of the grain beetle *R. dominica*. The research was carried out twice according to the VVLM 504-08 method, and Fumonisins FB1 and FB2 were determined, in total ng/g.

RESULTS AND DISCUSSION

Current observations confirm the nature of damage noted by Tsvetkov (1976), in particularly, the irregular shape of the gnawed openings on the kernel shell, the large amount of separated dust and its specific sweet smell. The damage caused by the beetle is both direct that affects the weight loss of the grain and also indirect. Damage affects the germination of the grain and the baking qualities of the flour. The damaged grain, caused by adult and larval beetles, along with the accumulated flour dust, creates favorable conditions for the multiplication of secondary storage pests that cannot independently damage whole grains. The current experiments which aimed to determine the weight losses and the influence of the grain beetle on the quality of the grain and the resulting flour revealed that the grain beetle adults consumed 0.905 ± 0.00374 mg of food per day (Table 1). With an average lifespan of 130 days, an adult can consume 117.678 mg of grain dry matter throughout its lifetime.

In experiments aimed to determine the weight losses caused by the larvae of the grain beetle during their development, revealed that they amounted to 13.7861 ± 0.04632 mg per individual. Thus, losses for the development of individual amount to an average of 131.6647 mg. Regarding losses from larvae, the data from the study correspond to those of Zheltova (1972), but regarding losses from adult individuals the current study indicated significantly higher losses.

Table 1. Weight losses caused by the adults and larvae of the grain beetle *Rhyzopertha dominica* F. under optimal conditions for development 32 ˚C, resp. air humidity 75 ± 5 % and grain humidity of 15 %

Larvae	Food consumed for the period of larval development		
	from	to	average x ± m в mg
	13.5180	14.3998	13.9861 ± 0.04632
Adults	Food consumed for 1 day by an adult		
	from	to	average x ± m
	0.8411	0.9458	0.90522 ± 0.003721
	The average lifespan of an adult under optimal conditions is 130 days x 0.90522 mg = 117.6786 mg		
Total	Weight losses		
	Larvae	Adults	Total
	13.9861	117.6786	131.6647 mg

The evaluation of the influence of the percentage of grain infection with the hidden infection of the grain beetle on the quality of the grain and the resulting flour, revealed that up to 5% hidden infection in the grain did not affect most of the quality indicators (Table 2). The absolute mass of 1000 grains was in the range of 49.03 to 47.98 g and the reliability of the differences was not proven statistically. Differences in the hectoliter weight were also not proven statistically (from 782.6 to 769.3 g/l). The yield of wet gluten was from 31 to 32 weight units. At 5% the latent infection had no effect on gluten relaxation (from 9.8 to 10.3 mm), flour yield 65.6-64.8%, flour ash content 0.48-0.49% (dry w/v on 70% flour) and whiteness (R on 70% flour) which varied only from 53.9 to 52.7 units. Above this value, with an increase in the percentage of hidden infection, all quality indicators of grain and flour deteriorate, and at 25% they were significantly low.

Comparing quality indicators with those estimated at 5% infection revealed that the absolute mass per 1000 pcs. grains decreased from 48.03 g to 41.32 g, and the hectoliter weight - from 769.3 g/l drops to 738.3 g/l. The wet gluten yield of the grain also decreased sharply - from 31 weight units to 19 weight units. The gluten relaxation worsened and from 10.3 it reached 14.8 mm. The ash content of the grain (% of the dry matter) increased - from 1.53 to 1.74 %, and such increase in the indicator is considered as very large. With infestation above 5%, it strongly decreases and the yield of flour (yield) decreased from 64.8% to 60.1%. The whiteness - R factor of the flour was also significantly affected, from 52.7 to 46.3 units.

Table 2. Average values of the results of the trials to establish the influence of the latent infection of the grain beetle *Rhyzopertha dominica* F. on the qualitative and quantitative indicators of wheat variety Pobeda

Percentage of grain infested	Absolute mass per 1000 grains in g	Hectoliter weight g/l	Production of wet gluten weight units	Quantity of gluten-desolation in mm	Ash content of the grain % dry substance	Acidic number of the fats mg (KOH)/g oil	Production of flour at one time grinding in %	Ash content % dry substance at 70% flour	Whiteness – R at 70% flour
Control	48.59	782.6	31	9.8	1.53	12.60	65.6	0.48	53.9
1	48.58	781.8	32	10.2	1.54	12.56	65.2	0.49	53.7
2	49.03	782.1	32	9.8	1.54	12.70	65.2	0.48	53.7
3	48.12	778.3	31	9.8	1.58	13.68	65.1	0.49	53.3
4	47.98	771.1	31	10.1	1.56	14.40	64.8	0.49	53.1
5	48.03	769.3	31	10.3	1.58	15.32	64.8	0.49	52.7
6	46.48	763.6	28	11.2	1.60	16.71	64.1	0.50	51.9
7	46.10	761.3	26	11.8	1.62	17.13	63.2	0.50	50.3
10	45.13	758.3	29	12.3	1.65	18.80	63.0	0.51	48.8
15	43.26	746.4	22	13.4	1.69	19.30	62.0	0.53	47.6
20	42.73	740.3	20	13.9	1.71	28.60	60.7	0.54	46.9
25	41.32	738.3	19	14.8	1.74	36.70	60.1	0.56	46.3

Table 3. Effect of infection of maize grain with latent infection of the grain beetle *Rhyzopertha dominica* F. on its mycotoxin content

Hidden infection in grain in %	Characteristic name (unit of magnitude)	Test results (value and uncertainty) ng/g
0 %	Fumonisins FB1 and FB2, total, ng/g	2.3±0.37
5%		693.9±69
25%		3436.1±34

Among all grain parameters, the acid value of the fat (measured in mg KOH/g oil) was the most significantly affected. The acid number was affected when the grain was infected by a latent infection of *R. dominica* above 3%, as in the control and at 2% infection it was 12.60 and 12.70 mg KOH/g oil. At 3% infection of the grain it reached 13.68, and at 5% - 15.32 mg KOH/g oil. At 25% contamination, this indicator has value of 36.70 mg KOH/g oil. Since the acid number is one of the most important indicators due to the vital activity of the grain beetle, it can be assumed that the threshold of harmfulness of the species is 2% infected and damaged by hidden infection grain.

For the presence of mycotoxins (fumonisins - FB1 and FB2 total in ng/g) was done a test on maize attacked by the grain beetle at 5% and 25% latent infection. The results showed that at 5% latent infection the quantity of mycotoxins was almost 5 times higher -lower than that at 25% corn infestation - 693.9 ± 69 ng/g and 3436.1 ± 34 ng/g respectively (Table 3). This indicated that the development of the species in grain stocks also resulted in secondary processes of decay associated with an increase in the mycotoxins quantity. The increase of mycotoxins levels in the grain stocks intended for feed often leads to serious intoxications in animals and even death, and it is necessary to use additional antitoxins and protectors that make feed more expensive. Additionally, mycotoxins have teratogenic and carcinogenic effects on animals and humans.

In our practice, we have often observed that after a high degree of infection in grain stocks by *R. dominica*, leads to a massive infestation in them by secondary storage insects such as *Tribolium castaneum* Herbst., *Latheticus oryzae* Waterh., *Palorus depresus* F., *Oryzaephilus surinamensis*. L. and *Cryptolestes ferrugineus* Steph., which leads to additional losses of grain mass.

CONCLUSIONS

With an average adult lifespan of 130 days, an adult consumes 117.678 mg of dry matter from the grain during its lifetime. Weight losses caused by the grain beetle larvae during their development amounted to 13.7861 ± 0.04632 mg per individual. In general, the grain losses for the overall development of one individual averaged 131.6647 mg. Up to 5% hidden infection of the grain beetle in the wheat grain did not affect the values of several studied quantitative indicators such as: absolute mass of 1000 grains, hectoliter weight, wet gluten yield, gluten relaxation, grain ash content, flour yield, ash flour content and flour whiteness. However, with a hidden infection above 5%, these indicators deteriorate significantly. Among all grain parameters, the acid value of the fat (measured in mg KOH/g oil) was the most significantly affected. The acid number was affected when the grain was infected by *R. dominica* latent infection above 3%. In the control and at 2% contamination, it was respectively 12.60 and 12.70 mg KOH/g oil, at 3% contamination of the grain it was 13.68, and at 5% - 15.32 mg KOH/g oil. The acceptable damage threshold for grain beetle infestation in wheat food stocks was 2% latent infestation. Infestation of grain stocks with grain beetle also could affect the content of mycotoxins in them.

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