Pestic. Phytomed. (Belgrade), 36(2), 2021, 61–72
DOI: https://doi.org/10.2298/PIF2102061K

UDC 633.1:632.7+599.323.4:632.935
Original scientific paper

Protection of organic cereals from insect and rodent pests in a warehouse by combined use of traps and sticky tapes

Petar Kljajić*, Goran Andrić, Goran Jokić, Marijana Pražić Golić, Tanja Blažić and Ivana Jovičić

Institute of Pesticides and Environmental Protection, Banatska 31b, 11080 Belgrade-Zemun, Serbia
**Corresponding author: petar.kljajic@pesting.org.rs*

Received: 20 July 2021
Accepted: 17 September 2021

SUMMARY

Several options of protection of organic cereals (winter and spring wheat, rye and maize) from insect and rodent pests, using a combination of traps (with or without pheromone/attractant) and sticky tapes and no chemicals, were tested in a warehouse over the summer-spring season of 2019/2020. Temperature in the warehouse was 14-29°C and humidity around 50%. The average grain moisture of winter and spring wheat and rye was 10-11%, while it was 12-14% in maize grain, and the average grain temperature of all cereals was 13-27°C. Regarding stored-product insect pests, five coleopteran, two moth and one Psocoptera species were detected, and the coleopterans predominated (98.5%) along with secondary pest insects (94.0%). Regarding rodents, only specimens of *Mus musculus* were found throughout the test period, their maximum monthly frequency being 72 (in January 2020). A combination of traps (with or without pheromones) and sticky tape barriers was found to provide an effective tool for trapping insects. Also, snap traps and trapping boxes for killing rodents, when used simultaneously with sticky tape barriers, were found to provide good protection of cereals from house mice. The pest control effect was also confirmed by collecting samples of organic cereal grain, which showed no significant presence of stored-product insects or grain damage (0.94% and 0.96% in spring wheat and rye, respectively) at the end of the test period. The results showed a great potential of combined application of traps and sticky tapes for protecting organic cereals in horizontal bulk storages, but the use of chemicals approved for organic food production would be required under extended storage periods.

Keywords: cereals, insects, rodents, traps, sticky tapes, warehouse

INTRODUCTION

Plant products such as organic winter and spring wheat, rye and maize come under attack by various organisms during storage, namely insects, mites, microorganisms, rodents and birds (Hill, 1990; Meyer, 1994; Rees, 2004; Almaši, 2008; Stejskal et al., 2015). Some 15% of grain products are believed to be lost globally each year, 80% of which by insect and some 10% by rodent and bird infestation (Reichmuth et al., 2007).

Insects are able to damage stored products by feeding, and their destructive power may be total (Rees, 2004). Insect presence in food has a negative impact on human health, primarily through product contamination with body hair and feces, which may cause allergic reactions and other effects on humans, and change environment conditions in storage (temperature and humidity) so that fungi or some other harmful microorganisms may ultimately develop in plant products (Hubert et al., 2018; Stejskal et al, 2018). Stored-product insects may be primary pests that damage whole grain, such as the coleopterans *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae), *Sitophilus granarius* (L.), *Sitophilus oryzae* (L.) and *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae), the moth *Sitotroga cerealella* (Oliv.) (Lepidoptera: Gelechiidae), or pests that feed on damaged grain as secondary pests, including the coleopterans *Tribolium castaneum* (Herbst), *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae), *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Cucujidae) and *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae), and moths *Plodia interpunctella* (Hubner) and *Ephestia kuehniella* Zeller (Lepidoptera: Phycitidae) (Hill, 1990; Rees, 2004; Almaši, 2008, Nayak & Daglish, 2018).

Two types of rodents are the most frequent and equally destructive storage pests: the brown rat *Rattus norvegicus* (Berck.) and the house mouse, *Mus musculus* (L.). They are cosmopolitan species with exceptional adaptability to human environments, which is why they have been termed commensal rodents (Frantz & Davis, 1991). Storages provide them shelter and a choice of available food throughout the year, which is especially evident in storages of plant products over periods of unfavorable weather outside, e.g. when winter temperatures are low (Lund, 1994). Owing to their great reproductive potential, and favourable conditions existing inside warehouses, they produce copious offspring over the year, which causes great damage and control problems (Meyer, 1994). Estimation of damage that rodents are able to cause in storage facilities is very complex as they are able not only to spoil stored products and ruin installations in storages but they also pose a great threat to the health of humans and domestic animals because they are hosts and vectors of many infectious diseases (Battersby et al., 2008). A single rodent is known to require daily rations of food in the amount of 10% of its body weight, but contamination with its urine, feces and hair is an even greater concern (Meyer, 1994; Timm, 1994; Pimentel et all., 2001) as one house mouse is able to excrete up to 50 fecal pellets in a day, and a brown rat up to 40 (Meyer, 1994).

Only a very small number of control products based either on synthetic chemicals or natural preparations are allowed to be used for protection of organic plant products in storages, and they have different modes of action and levels of effectiveness. Some EU countries (Kljajić et al., 2019), as well as Canada (OMRI, 2020) and the US (Grieshop et al., 2012; USDA NOP, 2020) allow organic plant products to be protected in storages either by physical means (ventilation, hot or cool airing) or by applying boric acid, azadirachtin, pyrethrin or diatomaceous earth (without synthetic substances), while spinosad-based products are allowed to be used but they have not yet been registered for protection of stored products. The situation in Serbia is similar as its Organic Production Act (2010), and the related Code on Control and Certification in Organic Production and Methods of Organic Production (2011), which includes a list of plant protection products registered for use in organic production, do not yet specify any registered chemical as adequate for protecting plants and plant products from harmful insects and rodents in storage facilities.

The modern concept of protection of stored products from insect and rodent pests relies predominantly on two approaches: integrated and biorational, and mandatory sanitary measures are implicit as a primary form of protection, followed then by other means and methods of optimized monitoring and control that involve low risks to human health and the environment. Traps with or without pheromones/food baits make an important tool, as well as insect sampling during product upload and storage (Kljajić et al., 2016; Hagstrum & Phillips, 2017; Morrison et al., 2020). Snap traps and sticky tapes are also often used for monitoring and controlling rodents (Buckle & Smith, 1994; Hubert et al., 2018).

The objective of this study was to examine the effects of combined use of traps (with or without pheromones/attractants) and sticky tapes for the protection of organic cereals (winter and spring wheat, rye and maize) from stored-product insects and rodents in a horizontal bulk shed (warehouse) during an extended period of storage.

MATERIALS AND METHODS

Storage facility and organic commodities

Testing was performed in Kikinda, Serbia (N45°49’217”, E20°28’469”) from the summer 2019 to spring 2020. The trial was performed in a warehouse that was 60 m long, 30 m wide and 6 m high, and having concrete floor and sides, and roof constructed of metal panels.

Organic cereals, consisting of 2019 harvests of wheat (winter and spring), rye and maize, were stored as bulk grain along one side of the warehouse over an area 40 m long and 10 m wide and separated within metal boxes constructed of 1.2 m high panels fixed to metal pillars which were set at 2 m distance. Maximum height of cereal bulk did not exceed 1 m. The initial amounts of organic cereals were: 33.000 kg winter wheat, 18.000 kg spring wheat, 5.000 kg rye, and 60.000 kg maize grain.

Storage conditions for the organic cereals we measured by mini meteorological stations Kestrel 3000 and 4000 (Environmental Meter, USA). Air temperature mostly did not exceed 29°C, while relative humidity was predominantly up to 50%, except in late December 2019 when temperature was lower (14.3°C) and humidity higher (52%). Moisture content and temperature of all organic cereals were measured during sampling by a Dickey-John Mini GAC (Dickey–John Co., USA). Parameters were determined as the sum for collective samples (two) based on minor samples which were collected at different locations/depths of grain per type of commodity at the beginning (summer 2019), in the middle (winter 2019/20) and at the end of storage period (spring 2020). The average grain moisture content of all organic cereals over the entire storage period was 10-11% for winter and spring wheat and rye, and 12-14% for maize grain. The average grain temperature of organic cereal samples varied significantly, depending on the season, i.e. indoor and outdoor air temperature, but it never dropped below 13°C or exceeded 27°C.

Measures applied

In order to increase the efficacy and reliability of monitoring, and to achieve the "pest control effect" by reducing their populations, based on principles specified by Toews and Nansen (2012) and guidelines provided by producers of traps and tapes, a great number of traps was laid throughout the warehouse, more than it is practiced conventionally (20 per warehouse) and at smaller distance than the usual 10 m approximately. Moth traps were set at 2-4 m distance, traps for coleopterans at 5 m and pitfall cone traps at < 2 m distance. Coleopteran traps were laid just around the boxes, while pitfall cone traps were thrust into the bulk grain. Pheromone traps for moths were set up on pillars around the grain boxes. Sticky tape barriers were laid around the boxes and along the entire length of walls and inside the bulk grain.

Snap traps for small rodents, hidden in bait boxes, and sticky tapes were laid along the internal of facility walls. Trapping boxes containing rodenticide baits were laid around the external side of the facility. Sticky tape barriers were laid around the grain boxes, and in places where introduction of insects or rodents was possible during grain handling, and around the main and secondary entrances/exits.

All sets of equipment (traps and sticky tapes) were emptied or replaced with new ones in keeping with manufacturer guidelines and depending on the state they are in and findings made during warehouse inspection.

We used a total of: 35 pheromone traps for moths (Tip: AF DEMI DIAMOND), 10 coleopteran traps containing pheromone/attractant (Type: Xlure MST), 35 pitfall cone traps for setting inside cereal grain to monitor coleopterans, 20 rodent trapping boxes (12 AF-RAT bait boxes installed around the facility and 8 AF SNAPPA boxes containing AF NO ZONE tape inside the facility), 32 rodent boxes containing snap traps (SNAP-E-MOUSE inside AF SNAPPA boxes), and 300 m of 30 cm wide sticky barrier tapes for insects and rodents (AF NO ZONE). All types of traps and the sticky tape were provided by the company Sanus-M d.o.o. of Novi Sad, Serbia.

Monitoring in storage facility

Insect frequency in traps (pheromone traps for moths, for coleopterans and pitfall cone traps) was determined as recommended by trap manufacturers or more often depending on the findings during each inspection of the warehouse. After counting, insects in traps were destroyed, while specimens that could not be determined immediately were taken to the laboratory to be more closely inspected and determined. Lethal trap boxes and sticky barrier tapes allowed direct monitoring of rodent species presence and animal frequency, as well as their seasonal dynamic in the facility. Rodent specimens caught on sticky tapes were removed during shed inspection, and the tape was replaced at such points with new tape. Storage insects were also noted on the tapes but their frequency was not determined.

The presence and frequency of stored-product insects in organic cereals during storage was determined based on instructions given in a manual for public grain storage operation (Mastilović et al., 2011). Samples were collected with a probe at different points and depths of bulk grain and two samples of 6 kg were formed for each type of organic cereal grain.

After determining moisture content and temperature, samples were sieved through 1, 2 and 3 mm sieves (Haver & Boecker, Germany) in order to check insect presence and frequency. A 6 × magnifying glass with lighting was used for the procedure. Besides determining the presence of insects, samples were also checked for rodent feces and hair.

After inspection, the samples collected in the warehouse were packed in plastic bags and transferred to the laboratory for further analyses.

Laboratory examination of effects

Grain samples were collected and tested in the Laboratory of Applied Entomology of the Institute of Pesticides and Environmental Protection, Belgrade, Serbia. After arriving in the laboratory, the samples were first subsampled into two working samples, each of 1 kg, then poured into glass jars (2.5 l) and covered with cotton cloth and fixed with rubber band. The samples rested in the laboratory at the temperature of 25±1°C and relative humidity of 60±5% for 60 days of incubation. After incubation the samples were sieved through 1, 2 and 3 mm sieves (Haver & Boecker, Germany), depending on the type of grain. Detected insects were determined under a stereo microscopes MSZ 5400 (Kruss, Germany) and SZX 122 (Olympus, Germany). Grain that remained after sieving and removal of insects was poured back into jars, lidded and hand mixed for 1 min to achieve regular dispersion of dust and tiny particles of grain. After mixing, portions of 25 g of wheat or rye, and 50 g of maize grain from each jar were poured with a plastic cup into plastic containers (50 cm x 20 cm), providing three replicates (3 × 2 per cereal type). Winter and spring wheat and rye samples were then sieved through 0.8, 1 and 2 mm sieves, and maize grain through 0.8, 1 and 3 mm sieves. Several categories of grain were separated in each subsample: undamaged grain, broken grain, infested grain and dust with impurities. The grain of each category was weighed to determine its proportion in each subsample. Undamaged and infested grains were also determined in order to calculate weight loss (FAO, 1992).

The samples were examined for the presence of insects, as well as rodent feces and hair in the process of sieving.

Data analysis

All data were processed in StatSoft version 7.1 (StatSoft Inc., 2005, Tulsa, OK, US). Frequency count and proportion data are presented as exact values or means. In tests resulting in means, data were subjected to one-way ANOVA and the means were separated by the Tukey-Kramer (HSD) test at P=0.05 (Sokal & Rohlf, 1995).

RESULTS AND DISCUSSION

Effects of measures applied to stored-product insects

Temperature and relative humidity data show that conditions in the warehouse storing organic cereals were good over the trial period from the summer of 2019 to the spring of 2020 but they were also good for storage insects (coleopterans and moths), as well as rodents. Insects are known to be organisms whose body temperature shows the highest dependence on external temperature, and optimal temperatures of stored-product insects range from 25-33°C, and suboptimal from 13-25°C and 33-35°C when their activity decreases and metabolism and development slow down (Fields et al., 2012). The temperature of 14.3°C recorded in December 2019 evidently had a negative impact on the activity and development of insects in the warehouse.

Eight species of harmful arthropods were collected and determined in the trial: two stored-product insect species in the order Lepidoptera, five species of storage beetles (order Coleoptera) and one booklouse species (order Psocoptera). Table 1 shows the captured species of stored product insects classified based on specific methods of their collection, i.e. by trapping or by sieving. The results show that the storage beetles *R. dominica*, *O. surinamensis*, *C. ferrugineus* and *T. confusum* were most successfully detected by pitfall cone traps, the moths *S. cerealella* and *P. interpunctella* by pheromone traps, and the booklouse *Liposcelis bostrychophila* Bad. by sieving.

Samples of organic cereals examined after 60 days of incubation in the laboratory were found to contain secondary stored-product insects (*T. confusum, C. ferrugineus, O. surinamensis, P. interpunctella*) as the most frequent (94.0%) of all detected insects, while primary storage pests (*S. zeamais, R. dominica, S. cerealella*) were far less frequent (6.0%) (Figure 1a). Besides, 98.5% of all insects were beetles, and storage moths made 1.5% (Figure 1b). Beetles were the secondary storage insects that caused no significant damage of organic cereals at any time during the period of storage in the warehouse.

Table 1. Types of stored-product insects collected by different types of traps and species identified after sampling organic cereals and sieving

Insect species	Sampling method			
	Pheromone traps for moths	Pheromone traps for wingless insects	Cone traps	Sampling/ Sieving
Order Lepidoptera - moths				
Sitotroga cerealella (Oliv.)	+	–	–	–
Plodia interpunctella (Hbn.)	+	–	–	–
Order Coleoptera – beetles				
Sitophilus zeamais Motsch.	–	+	+	+
Rhyzopertha dominica (F.)	–	–	+	–
Oryzaephilus surinamensis (L.)	–	+	+	+
Cryptolestes ferrugineus (Steph.)	–	–	+	–
Tribolium confusum DuVal	–	+	+	+
Order Psocoptera – booklouse				
Liposcelis bostrychophila Bad.	–	–	–	+

+ presence confirmed; - presence not confirmed

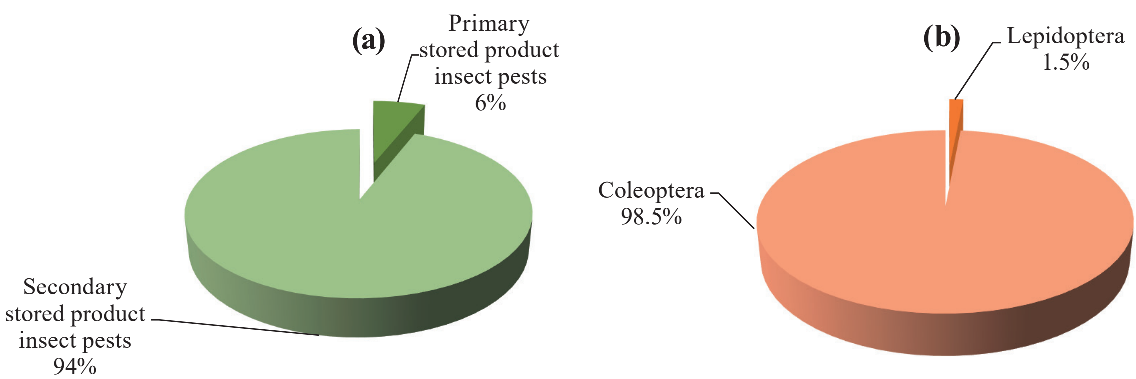

Figure 1. Primary and secondary stored-product insect pests (a), and Coleoptera and Lepidoptera insect pests (b) detected in organic cereals

Data in Figure 2a show that pheromone traps for Coleoptera, positioned around the boxes containing organic cereals, as well as pitfall cone traps pressed into grain, were highly effective in capturing beetles. The largest number of beetles was caught at the beginning of December 2019, i.e. 25-30 specimens/trap, and from the end of January to June 2020, when their frequency was 15 specimens/trap. Data presented in Figure 2b show that pheromone traps for Lepidoptera set around the boxes with organic cereals were highly effective in catching storage moths. The highest number of them were captured in May 2020, 10 moths/trap on the average, while their average number was 6-7 and 4.0 moths/trap in December and September of 2019, respectively. Pheromone and other traps for storage moths significantly impacted their mating, which resulted in a significant reduction in their numbers. When the starting number of moths in a storage is low, such approach to moth control is a very effective and cost-effective tool (Trematerra & Gentile, 2010; Trematerra et al., 2011; Toews & Nansen 2012; Trematerra & Colacci, 2020).

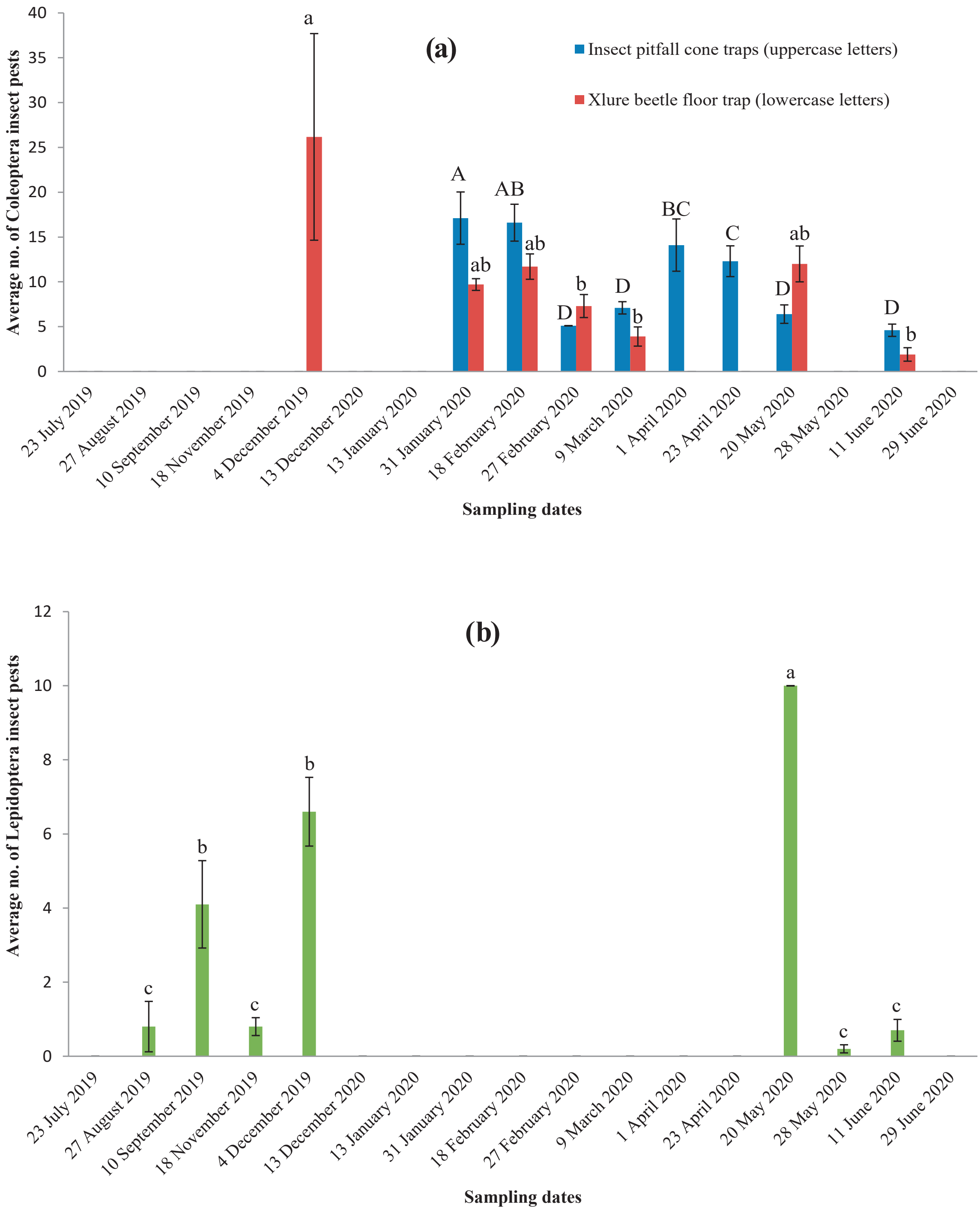

Figure 2. Average number of captured Coleoptera (a) and Lepidoptera (b) insect pests

Table 2 shows the average frequency of stored-product insects per 1 kg of organic cereal grain as determined immediately after sampling in the warehouse and after the incubation period of 60 days in the laboratory. Few insects were detected in the organic cereals at the moment of sampling, and the most abundant and frequent was the beetle *O. surinamensis* in winter wheat captured on May 19, 2020, namely 20 specimens/kg on

Table 2. The average number of insects/kg organic cereal grain, counted immediately after sampling in the warehouse and after 60 days of incubation in the laboratory

Cereals	Sampling date	Stored-product insects	Average no. of insects/kg cereal grain ($\bar{x}$±SE)	
			At sampling	After incubation
Winter wheat	23. 7. 2019.	*O. surinamensis*	0.5±0.5	218.0±1.9
	18. 12. 2019.	*S. zeamais*	1.0±1.0	31.0±9.0
		O. surinamensis	0.0±0.0	27.5±25.6
		C. ferrugineus	0.0±0.0	0.5±0.5
	19. 5. 2020.	*O. surinamensis*	20.5±1.5	764.0±77.2
		S. zeamais	0.0±0.0	35.5±7.5
		C. ferrugineus	0.0±0.0	154.5±59.7
Spring wheat	23. 7. 2019.	*O. surinamensis*	0.0±0.0	11.5±3.5
	18. 12. 2019.	*O. surinamensis*	0.0±0.0	61.0±31.1
		S. zeamais	1.0±1.0	7.0±4.0
		A. calandrae [a]	0.0±0.0	8.0±2.0
	19. 5. 2020.	/ [b]	/	/
Rye	23. 7. 2019.	*O. surinamensis*	0.0±0.0	0.5±0.5
	18. 12. 2019.	*S. zeamais*	0.5±0.5	57.5±25.6
		O. surinamensis	0.5±0.5	0.5±0.5
		S. cerealella	0.0±0.0	29.0±3.0
	19. 5. 2020.	*O. surinamensis*	8.5±0.5	436.0±156.4
		C. ferrugineus	0.0±0.0	515.5±85.2
		Ephestia sp.	0.0±0.0	13.5±2.5
Maize	23. 7. 2019.	/ [c]	/	/
	18. 12. 2019.	*O. surinamensis*	0.0±0.0	0.5±0.5
		S. cerealella	0.0± 0.0	3.5±0.5
	19. 5. 2020.	*O. surinamensis*	4.0±2.0	651.5±301.3
		S. zeamais	0.0± 0.0	13.5±5.5

[a] Parasitoid; [b] Wheat (spring) issued from storage; [c] Maize not yet loeaded in storage

average, then in rye with the average of 8.5 specimens/kg, and in maize with the average of 4.0 specimens/kg. Considering primary pests, the most frequent was the beetle *S. zeamais*, detected at the rate of 1.0 specimen/kg in winter and spring wheat at sampling on December 18, 2019, and then in rye, 0.5 specimens/kg on average.

After 60 days of incubation, insects were abundant in all organic cereals, and *O. surinamensis* was again the most frequent regarding specimen counts and its proportion in the samples collected on May 19, 2020 from winter wheat, was 764 specimens/kg on the average, and the average of 651 specimens/kg was found in maize samples. In this variant, the beetle *S. zeamais* was again the most frequent primary pest detected during sampling on December 18, 2019 in rye with the average of 57 specimens/kg, while in winter wheat the average was 31 specimens/kg.

Table 3 presents the results of sample analyses regarding the average proportion of undamaged grain, broken grain, impurities and dust, infested grain and weight loss of organic cereal grain as determined after 60 days of incubation in the laboratory at 25°C and 60% relative humidity. The results show that the proportion of undamaged and broken organic cereal grain, as well as impurities and dust, would change very little, especially for winter wheat and rye, if grain were stored under conditions that exist in the laboratory, i.e. under stable optimal temperature and relative humidity, while changes would be significant regarding infested grain and weight loss of grain. As different types of traps were laid in the warehouse throughout the experimental period and conditions for survival and development of harmful insects were unfavorable during winter and early spring, their development was slowed down and their numbers increased barely.

Generally, the results indicate a hidden infestation of organic cereals with stored-product insects from the beginning of storage, which could have originated from: 1) a facility in which the commodities were briefly stored before their transfer to the bulk grain warehouse in which the study was conducted, 2) transport or 3) inadequate maintenance of the storage facility so that insects were able to move from inaccessible corners into organic wheat (winter and spring), rye and maize grain. However, the combination of applied measures and methods ensured a high degree of efficacy of the applied traps and sticky tapes that were used for catching storage insects because only a low number of insects were detected in the cereal samples.

Under the conditions described, and based on the stored-product insects found and degree of their infestation in the warehouse, there was no need for undertaking any form of chemical protection of the organic cereals. On the other hand, if conditions for development of storage insects were to be favorable over an extended period of time, and especially if primary pests of the order Coleopteran were present, such an approach would be significantly less effective, and either control measures would have to be applied or the commodities processed or used over a brief period of time, which is consistent with a conclusion made by Bevan et al. (1997).

Table 3. Average percentage of undamaged and broken grain, impurities and dust, infested grain and loss of grain weight in samples of organic cereals after 60 days of incubation in the laboratory

Cereals	Sampling date	Average percentage (% ± SE)				
		Undamaged grain	Broken grain	Impurities and dust	Infested grain	Loss of grain weight
Wheat (winter)	23. 7. 2019.	96.2±0.2 a[a]	3.5±0.2 a	0.2±0.1 b	0.0±0.0 c	0.00±0.00 b
	18. 12. 2019.	96.0±0.3 a	3.2±0.2 a	0.4±0.1 b	0.1±0.0 b	0.05±0.03 b
	19. 5. 2020.	94.9±0.5 b	3.6±0.4 a	0.8±0.1 a	0.2±0.1 a	0.94±0.93 a
Wheat (spring)	23. 7. 2019.	95.1±0.6 a	4.0±0.5 a	0.9±0.5 a	0.0±0.0 b	0.00±0.00 b
	18. 12. 2019.	95.4±0.5 a	3.8±0.5 a	0.5±0.1 a	0.3±0.1 a	0.07±0.03 a
	19. 5. 2020.	/ [b]	/	/	/	/
Rye	23. 7. 2019.	96.0±0.0 a	3.2±0.2 c	0.8±0.2 b	0.0±0.0 b	0.00±0.00 a
	18. 12. 2019.	94.5±0.1 b	4.7±0.1 a	0.6±0.1 b	0.1±0.0 a	0.22±0.15 b
	19. 5. 2020.	94.8±0.6 b	3.8±0.4 b	1.1±0.2 a	0.1±0.1 a	0.96±0.60 a
Maize	23. 7. 2019.	/ [c]	/	/	/	/
	18. 12. 2019.	90.0±0.5 b	9.1±0.6 a	0.3±0.1 a	0.6±0.3 a	0.24±0.12 a
	19. 5. 2020.	92.7±0.6 a	6.6±0.9 b	0.2±0.1 a	0.6±0.3 a	0.01±0.01 b

[a] Values marked with different letters per cereal differ significantly (Tukey-Kramer HSD test, significant at P=0.05); [b] Wheat (spring) issued from storage; [c] Maize stored later

Effects of measures applied to rodents

Clear evidence, i.e. feces findings and direct catches on sticky tapes and in snap traps, indicated that only the house mouse, *Mus musculus,* was present in the warehouse. The results were consistent with the species biology and ecology, and with structural and spatial arrangements inside the warehouse. Figure 3 shows the catching results for house mice, comparing two trapping approaches, i.e. the use of rodent boxes for snap trapping, and sticky tapes. No hair or feces were found in the stored products during sampling and sieving in the facility or during sample inspection in the laboratory. The results infer that sticky tape barriers were more efficient in capturing rodents than snap traps, while their combined application enabled full protection of cereals stored in the warehouse.

Figure 4 shows the dynamic of house mouse catches over the season 2019/2020. During seasonal weather change from warm to cold periods of the year, rodents begin to enter storage facilities in significant numbers in search for shelter and accessible food. From November 2019, rodent catches in traps and especially in sticky tape barriers increased, and their highest numbers were recorded in January 2020 when the outside weather was most adverse. The fewest mice were caught at the beginning of spring, which is consistent with rodent reproduction biology and the achieved trapping efficacy over the preceding period. An increase in the number of captured animals in April 2020 was consistent with the dynamic of natural development of house mouse populations (Đukić et al., 2005) and the frequency of grain manipulation in the facility.

Based on the results shown in Figure 5, it can be inferred that the position of traps had a great impact on trapping rate because the highest number of mice were trapped in the vicinity of the entrance. Also, there is a clear difference in trapping rates between sticky tape barriers and traps positioned in the same location around the facility entrance. Barrier tapes were found to be more effective in capturing house mice in the warehouse than snap traps.

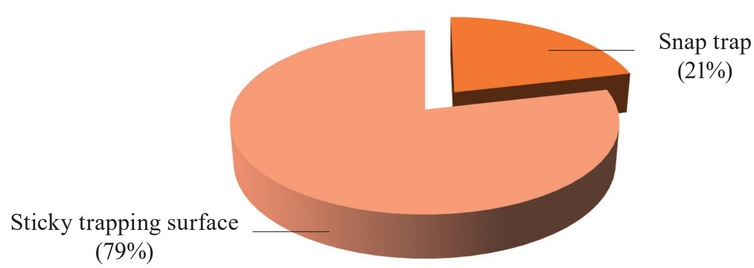

Figure 3. Comparison of methods for catching house mice

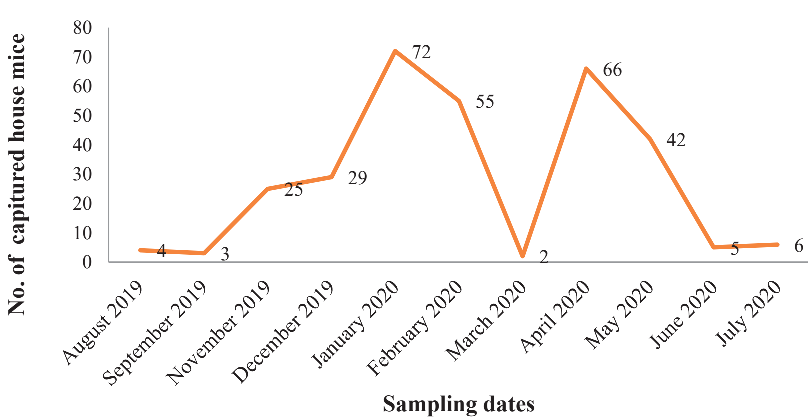

Figure 4. Dynamic of house mouse catches over the season 2019/2020

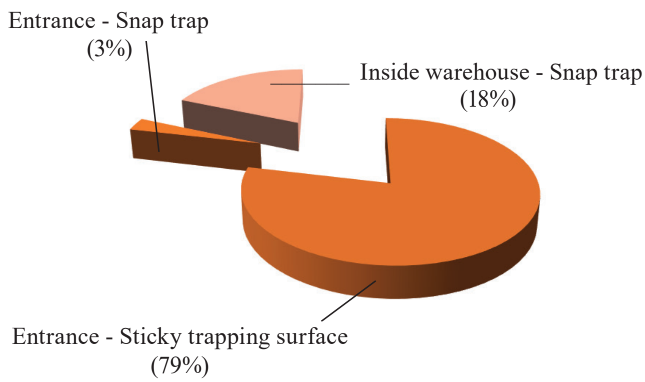

Figure 5. Effectiveness of rodent trapping in terms of trap location in warehouse

Based on the results of rodent frequency checks in the warehouse over the season 2019/2020, it is clear that the number of house mice increased after the warehouse was opened to enable grain handling. Snap trapping of house mice was shown to produce good results during bulk storage free of chemical treatments. Considering the efficacy of trapping and the fact that such means of rodent control are completely safe for humans and the environment, the combination of boxes with snap traps and sticky tape barriers proved effective in protecting stored products from house mice. Evidently, the approach to such activities should be expanded to include arrangements, maintenance and work organization inside the storage facility, as well as good knowledge of rodent biology (primarily reproduction and expansion) and sanitation measures to be undertaken in a wide area around cereal storages (Buckle & Smith, 1994; Đukić et al., 2005). The data on trapped rodents and those caught on sticky tapes around the entrance point evidently indicated a constant danger of rodents penetrating into the storage facility. Laying traps and sticky tapes (which proved the most effective) around the entrance prevents rodents from penetrating the facility and causing damage to stored grain.

In conclusion, a combination of various types of traps (with or without pheromones/attractants) for stored-product insects (beetles and moths) and for rodents (house mouse), applied in greater number and at smaller distance than it is usually practiced for storage monitoring, and sticky tape barriers for pests, provide successful protection of organic cereals, especially when it is practiced in the late autumn-early spring season. Such an approach is certainly a significant contribution to preserving the initial quality of organic cereals of wheat, rye and maize, and to overall improvement of the safety of plant food because chemical protection is avoided.

ACKNOWLEDGEMENT

This research was funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia (grants 451-03-68/2020-14/200214 and 451-03-9/2021-14/200214).

REFERENCES

Almaši, R. (2008). Štetne artropode uskladištenog žita. In P. Kljajić (Ed.), *Zaštita uskladištenih biljnih proizvoda od štetnih organizama (Protection of stored plant products from pests)* (pp 9-38). Belgrade, Serbia: Institut za pesticide i zaštitu životne sredine.

Battersby, S., Hirschhorn, R.B., & Amman, B.R. (2008). Commensal rodents. In: X. Bonnefoy, H. Kampen & K. Sweeney (Eds.), *Public health significance of urban pests* (pp 387-419). Copenhagen, Denmark: *WHO,* Regional Office for Europe.

Bevan, J.R., Firth, C., & Neicho, M. (1997). Storage of organically produced crops. Retrieved from http://orgprints/8241

Buckle, A.P., & Smith, R.H. (1994). *Rodent pests and their control*. CAB International, Wallingford, UK.

Đukić, N., Horvatović, A., Kataronovski, D., Maletin, S., Matavulj, M., Pujin, V., & Sekulić, R. (2005). *Poljoprivredna zoologija sa ekologijom i fiziologija prirode, opšta zoologija i sistematika životinja (Agricultural zoology and ecology, and natural physiology, general zoology and animal systematics).* Novi Sad, Serbia: Poljoprivredni fakultet.

FAO (1992). *Standardized methods for the assessment of losses due to insect pests in storage*. Rome, Italy: Food and Agriculture Organization of the United Nations.

Fields, P., Subramanyam, B., & Hulasare, R. (2012). Extreme temperatures. In D.W. Hagstrum, T.W. Phillips, & G. Cuperus (Eds.), *Stored product protection* (pp 179-190). Manhattan, USA: Kansas State University, Agricultural Experiment Station and Cooperative Extension Service.

Frantz, S.C., & Davis, D.E. (1991). Bionomics and integrated pest management of commensal rodents. In *Ecology and management of food-industry pests* (pp 243-313). Arlington, VA: Association of Official Analytical Chemists.

Grieshop, M.J., Rogers, D.T., & Arthur, F.H. (2012). Organic approaches and regulations for stored product pest management. In D.W. Hagstrum, T.W. Phillips, & G. Cuperus (Eds.), *Stored product protection* (pp 233-242). Manhattan, USA: Kansas State University, Agricultural Experiment Station and Cooperative Extension Service.

Hagstrum, D.W., & Phillips, T.W. (2017). Evolution of stored-product entomology: protecting the world food supply. *Annual Review of Entomology*, *62*, 379-397.

Hill, D.S. (1990). *Pests of stored products and their control*. London, UK: Belhaven Press.

Hubert, J., Stejskal, V., Athanassiou, C.G., & Throne, J.E. (2018). Health hazards associated with arthropod infestation of stored products. *Annual Review of Entomology*, *63*, 553-573.

Kljajić, P., Andrić, G., & Pražić-Golić, M. (2019). Primena pesticida u zaštiti uskladištenih proizvoda (Use of pesticides in stored products protection). In *Proceeding of the symposium „Korišćenje pesticida u biljnoj proizvodnji i zaštita životne sredine“ (Use of pesticides in plant production and environment protection)* (pp 99-118). Belgrade, Serbia: SANU.

Kljajić, P., Andrić, G., Pražić-Golić, M., Jokić, G., & Vuković, S. (2016). Štetočine uskladištenog žita i njihovo suzbijanje (Pests of the stored grains and their control). *Biljni lekar*, *44*(5-6), 527-540.

Lund, M. (1994). Commensal rodents. In: A.P. Buckle & RH Smith (Eds.), *Rodent pests and their control* (pp 23-43). Oxon, UK: CAB International.

Mastilović, J., Janić Hajnal, E., Torbica, A., Pojić, M., Živančev, D., Kevrešan, Ž. ... Radusin, T. (2011). *Savremeni pristup upravljanju skladištem za zrnaste kulture: priručnik za rad javnih skladišta za zrnaste strukture (Modern approach in managing grain storages: Manual for public grain storages)*. Novi Sad, Serbia: Univerzitet u Novom Sadu, Institut za prehrambene tehnologije.

Meyer, A.N. (1994). Rodent control in practice: food stores. In: A.P. Buckle & R.H. Smith (Eds.), *Rodent pests and their control*. CAB International, UK, Oxon.

Morrison, W.R., Grosdidier, R.F., Arthur, F.H., Myers, S.W., & Domingue, M.J. (2020). Attraction, arrestment, and preference by immature *Trogoderma variabile* and *Trogoderma granarium* to food and pheromonal stimuli. *Journal of Pest Science*, *93*, 135-147.

Nayak, M.K., & Daglish, G.J. (2018). Importance of stored product insects. In *Recent advances in stored product protection* (pp. 1-17). Berlin, Heidelberg, Germany: Springer.

OMRI, 2020. OMRI Canada product list, processing and handling products by category. Retrieved from Organic Materials Review Institute (OMRI), p. 1-2, at https://www.omri.org/sites/default/files/opl_pdf/ProcessingByCategory-COR.pdf

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'connell, C., ... & Tsomondo, T. (2001). Economic and environmental threats of alien plant, animal, and microbe invasions. *Agriculture, ecosystems & environment*, *84*(1), 1-20. doi: https://doi.org/10.1016/S0167-8809(00)00178-X

Pravilnik o kontroli i sertifikaciji u organskoj proizvodnji i metodama organske proizvodnje (Code on Control and Certification in Organic Production and Methods of Organic Production) (2011). *Službeni glasnik RS, 48/2011.*

Rees, D. (2004). *Insects of stored products*. Canberra: Australia: CSIRO Publishing.

Reichmuth, C., Schöller, M., & Ulrichs, C. (2007). *Stored product pests in grain: Morphology, biology, damage, control*. Bonn, Germany: AgroConcept Verlagsgesellschaft.

Sokal, R.R., & Rohlf, F.J. (1995). Biometry: The principles and practice of statistics in biological research, 3rd edition. New York, USA: W.H. Freeman and Co.

StatSoft (2005). STATISTICA (data analysis software system), version 7.1.,Tulsa, OK, USA: StatSoft.

Stejskal, V., Hubert, J., Aulicky, R., & Kucerova, Z. (2015). Overview of present and past and pest-associated risks in stored food and feed products: European perspective. *Journal of Stored Products Research*, *64*, 122-132.

Stejskal, V., Hubert, J., & Li, Z. (2018). Human health problems and accidents associated with occurrence and control of storage arthropods and rodents. In C.G. **Athanassiou and** F.H. **Arthur** (Eds.), *Recent advances in stored product protection* (pp 19-43). Berlin, Heidelberg. Germany: Springer.

Timm, R.M. (1994). House mice. In S.E. Hygnstrom, R.M. Timm & G.E. Larson (Eds.), *Prevention and control of wildlife damage,* (pp 31-46). Lincoln, USA: University of Nebraska.

Toews, M. D., & Nansen, C. (2012). Trapping and interpreting captures of stored grain insects. In D.W. Hagstrum, T.W. Phillips, & G. Cuperus (Eds.), *Stored product protection* (pp 243-261). Manhattan, USA: Kansas State University, Agricultural Experiment Station and Cooperative Extension Service.

Trematerra, P., Athanassiou, C., Stejskal, V., Sciarretta, A., Kavallieratos, N., & Palyvos, N. (2011). Large-scale mating disruption of *Ephestia* spp. and *Plodia interpunctella* in Czech Republic, Greece and Italy. *Journal of Applied Entomology*, *135*(10), 749-762.

Trematerra, P., & Colacci, M. (2020). Auto-confusion of *Ephestia cautella* (Walker) infesting dried fruits in a confectionery factory store. *Journal of Stored Products Research*, *89*, 101706.

Trematerra, P., & Gentile, P. (2010). Five years of mass trapping of *Ephestia kuehniella* Zeller: a component of IPM in a flour mill. *Journal of Applied Entomology*, *134*(2), 149-156.

USDA National Organic Program (NOP) (2020). *Standard manual*. CCOF Certification Services, LLC. Retrieved from www.ccof.org

Zakon o organskoj proizvodnji (Organic Production Act) (2010). *Službeni glasnik RS, 30/2010).*

Efekti zaštite organskih cerealija od štetnih insekata i glodara u podnom skladištu kombinovanom primenom klopki i lepljivih traka

REZIME

U periodu leto 2019 – proleće 2020. godine je ispitana mogućnost zaštite organskih cerealija (ozime i jare pšenice, raži i kukuruza) od štetnih insekata i glodara u podnom skladištu bez upotrebe hemikalija, kombinovanom primenom klopki i lepljivih traka. Temperatura vazduha u skladištu je bila 14-29°C, a relativna vlažnost vazduha oko 50%. Prosečan sadržaj vode u zrnima svih organskih cerealija je tokom celog perioda skladištenja bio 10-11% u zrnima pšenice (ozime i jare) i raži, a 12-14% u zrnima kukuruza, a prosečna temperatura zrna 13-27°C. Od skladišnih insekata je primenom klopki (sa i bez feromona/atraktanata) i lepljivih traka zabeleženo prisustvo pet vrsta tvrdokrilaca, dve vrste leptira i jedne vrste prašnih vaši, a dominantni su bili tvrdokrilci (98,5%) i sekundarne vrste štetnih insekata (94,0%). Od glodara je tokom celog perioda zabeleženo samo prisustvo jedinki vrste *Mus musculus*. Utvrđeno je da je kombinovana primena klopki, sa i bez feromona/atraktanata, i lepljivih traka - barijera, vrlo efikasna mera u hvatanju skladišnih insekata. Takođe, konstatovano je da su mehaničke klopke i lepljiva traka u kutijama za deratizaciju, zajedno sa lepljivom trakom - barijerom, vrlo efikasne u zaštiti cerealija od domaćeg miša. Postignut je i efekat "suzbijanja" štetočina, jer u uzetim uzorcima nije detektovano brojno prisustvo skladišnih insekata i nije utvrđeno značajnije oštećenje zrna organskih cerealija. Dobijeni rezultati pokazuju veliki potencijal kombinovane primene klopki i lepljivih traka u zaštiti organskih cerealija u podnom skladištu, s tim da bi u slučaju dužeg perioda skladištenja bila neophodna primena hemikalija koje imaju dozvolu za primenu u organskoj proizvodnji hrane.

Ključne reči: cerealije, insekti, glodari, klopke, lepljive trake, skladište