

Reproduction of confused flour beetle *Tribolium confusum* Du Val (Coleoptera: Tenebrionidae) on common and spelt wheat and their products

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Received: July 21, 2014

Accepted: October 2, 2014

SUMMARY

The interest in spelt wheat production has grown in recent years but there is hardly any information on pest development on that wheat species in storehouses. The influence of common and spelt wheat and their products on the reproduction and offspring of confused flour beetles *Tribolium confusum* Du Val was studied under laboratory conditions (22–25 °C and 40–60% RH). The experiment was carried out in four replications with four, 10 and 20 insects over a period of six months. The reproduction of confused flour beetles significantly varied depending on the wheat species and product. The highest reproduction rate was recorded on spelt wheat (*Triticum spelta* L.). The greatest number of offspring beetles appeared on spelt wheat flour (23469). The number of offspring beetles was higher on common (7044) than on spelt wheat kernels (5469). No offspring developed on common wheat pasta while only 4 young beetles were found on spelt wheat pasta. Offspring numbers increased with storage period up to a point but further on they depended on insect number. The number of insects increased over the first four months but decreased later on and the mortality rate was higher. Initial population density affected the offspring numbers but offspring numbers did not rise proportionally with the rising initial population density. Considering the species of wheat, higher mortality was recorded in common wheat. Regarding the type of product, the highest mortality was recorded in pasta, then in kernels and the lowest in flour. The paper shows that confused flour beetles develop extremely well on spelt wheat, even better than on common wheat which is widely grown in Serbia.

Keywords: Wheat; Reproduction; *Tribolium confusum*

INTRODUCTION

Common wheat (*Triticum aestivum* L.) is a soft wheat species and one of three leading staple crops in the world besides maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Based on statistical data for the past 45 years, 604 million tons of common wheat is produced each year on 214 million ha (Schulte et al., 2009). Common wheat is a staple diet for the majority of world population. At the same time, insects, mites, rodents and birds also feed on common wheat, its flour and other products during storage and processing. It is estimated that average losses in storehouses all over the world caused by pests amount to 5-10%. Losses caused by insects are of various proportions and depend largely on the shape and size of kernels, density, protein content, carbohydrates and fats, as well as the presence of enzymes and antioxidants (McGaughey et al., 1990).

Spelt wheat (*Triticum spelta* L.) is an old soft wheat species which had been grown on considerably large areas in Europe before 1850 (Oyekanmi, 2011). It originated in the southern regions of the Caspian Sea, dating back to 5000 B.C. It was brought to Europe by Spaniards in 1529. An interest in growing spelt wheat is now rising again due to its nutritiveness, and contents of proteins, carbohydrates, fats, mineral matter, vitamins and cellulose (Malešević et al., 2010). As it can be stored in spikes, which may be considered a form of protection against pests (Kordan et al., 2008), it is now increasingly grown as an organic crop.

The fact that pests can find food on various types of wheat in storehouses has been examined in a great number of papers (Ahmed et al., 2002; Ciepielewska & Fornal, 2004; Muhammad et al., 2006; Koleva & Ganeva, 2009; Kordan & Gabrys, 2013) but research has rarely focused on pest development in stored spelt wheat products (Laszczak-Dawid et al., 2007; Almaši et al., 2010; Bodroža-Solarov et al., 2010; Almaši & Poslončec, 2011). It is therefore necessary to investigate pest development on that wheat species in storehouses.

In Serbia and neighboring countries, the confused flour beetle *Tribolium confusum* Du Val, besides many other beetles, is a rather significant pest in flours and flour products. It is a polyphagous species that easily penetrates products, has a relatively short development cycle, decreases the quality of colonized products and causes enormous economic losses each year. It can be found in all countries and its biology requires great attention. Its adults and larvae feed on oil plants, corn, dried fruits, nuts, leguminosae, cocoa, coffee

and various other products. The confused flour beetle cannot feed on intact kernels but it may become a significant pest when stored wheat kernels are damp or a high percentage of them is broken (Li & Arbogast, 1991). Its adults and larvae feed on flour and the flour may become greyish from their profuseness, have an unpleasant smell and its baking and technological properties may deteriorate.

The objective of this research study was to compare the development and reproduction of confused flour beetles in kernels, flour and pasta from common and spelt wheat using indicators of nutrition, offspring numbers, mortality and speed of generation development depending on storage period.

MATERIAL AND METHODS

Experiments were carried out at the Entomology Laboratory of the Faculty of Agriculture in Novi Sad after harvest in 2012, and the conditions were similar to those in storehouses.

Test insect

Confused flour beetles aged 14 days were used as test insects in the experiments. The insects were grown on food prepared according to Harein and Soderstrom (1966) and Davis and Bry (1985) (a mixture of soft wheat and corn flour at 1:1 ratio with 5% dried yeast added). The food with insects was placed in 2.5 l jars and kept in a thermostat at the temperature of 27 ± 1 °C and relative air humidity of 40-60%, and sieved 7 days later to make sure that the insects used in experiments were of a new generation.

Products

Common and spelt wheat kernels (with 20% broken kernels in each variety), common and spelt wheat flour, and pasta from common and spelt wheat were tested as products.

Two wheat species, the soft common wheat variety Pobeda and the spelt wheat variety Nirvana, yielded at a Bajmok farm in 2012, were used in the experiment. Bajmok is located in northern Serbia, in a region of widespread cultivation of Pobeda, which is a typical representative of soft wheat varieties. The spelt wheat variety Nirvana is also increasingly cultivated in the region. Prior to our experiment, wheat samples were kept in a freezer for two weeks and then conditioned

for several days at room temperature. Soft common wheat flour type 400 and spelt wheat flour, as well as pasta made from common wheat flour (“spiral pasta”) and spelt wheat flour (“spelt pasta”) were purchased in a supermarket. Moisture content of all products was 13–14%.

Experimental work

The experiments were prepared as follows: 250 g of each product was placed in each of 12 plastic dishes of 1.5 l volume; 4 replications were done for each evaluation (2, 4 and 6 months) and each initial population density (4, 10 and 20 insects of both sexes). The plastic dishes were closed with linen and kept at room temperature of 22–25°C, air humidity of 40–60% and under a day/night cycle of 14/10 h. Four insects were considered as a slight attack, 10 insects as a moderate one, and 20 insects as a severe initial attack of confused flour beetles (Stojanović, 1965). Offspring numbers were checked after the first generation (two months). The experiment continued by checking the number of second generation beetles after four months and a third generation after six months, and they were analyzed separately.

Offspring counts were made by deducting the initial number of insects at the beginning of trial from the total number of insects counted, living and dead. Dead insects showed the mortality.

Statistical analysis

The influence of product type and initial population density on offspring counts in kernels, flour and pasta was analyzed by variance analysis (ANOVA) in the program *Statistica 9.1* and the significance of differences among counts after 2, 4 and 6 months on common and spelt wheat was confirmed by Fisher’s LSD test ($p > 0.05$). The reproduction of confused flour beetles on common and spelt wheat and their products is shown in Figures 1–3 as percentages and absolute numbers after six months of storage. Mortality of adults was calculated using Abbott’s (1925) formula.

RESULTS

Food quality is essential for nutrition, life expectancy and reproduction of a species. This research work shows that confused flour beetles feed on kernels and all other tested products of common and spelt wheat.

Influence of common and spelt wheat and their products on total offspring

The influence of the type of food is very significant and can present a limiting factor. Figure 1 shows the total number of offspring beetles on all products of two wheat species tested in the experiment.

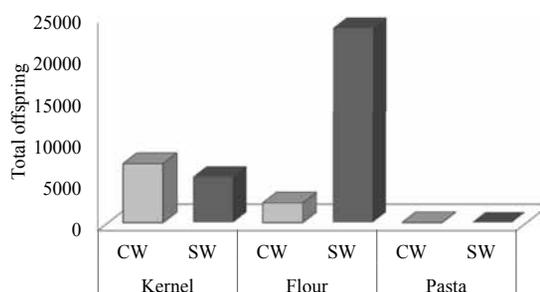


Figure 1. Total number of offspring beetles after six months of storage on different types of products of common (CW) and spelt wheat (SW)

Spelt wheat flour proved to be the most favourable and pasta from both wheat species the least favourable food for confused flour beetles (Figure 1). Insects developed extremely poorly on common wheat flour in comparison with spelt wheat flour. The maximum number of offspring adults developing on spelt wheat flour was 23,469 or 61.23%. On common wheat flour, 2,343 adults developed, or 6.11%. The lowest number of adults (4) developed on spelt wheat pasta, which amounts to only 0.01%. No offspring was found on common wheat pasta.

Offspring dynamic over six months of storage on common and spelt wheat kernels and flours

The storage period had a positive effect on the increase in offspring numbers up to a certain point while it depended on the number of insects further on. The offspring of the initial population density of 10 insects in relation to total offspring on kernels and flour of common and spelt wheat is shown as percentages.

More numerous offspring developed on common wheat kernels (56.29%) than on spelt wheat kernels (43.71%). The maximum population number on common wheat kernels was registered in the second generation (4 months) whereas a great number died after six months (Figure 2). After four months of being fed on kernels the number of adults rapidly dropped on both wheat species and the number of deaths rose.

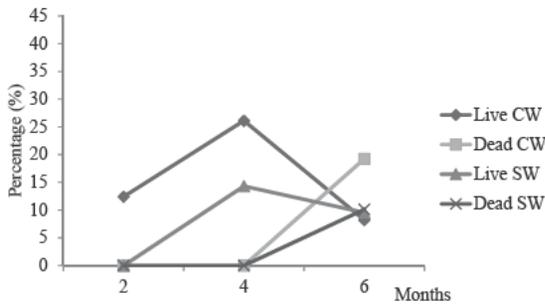


Figure 2. Offspring dynamic over six months of storage on common (CW) and spelt wheat (SW) kernels

In contrast to kernels, more offspring developed on spelt wheat flour (90.92%) than on common wheat flour (9.08%). Figure 3 shows that spelt wheat flour was much more favourable for development of confused flour beetles and that multiple offspring developed in the first, second and third generations. In the flours of both wheat species, the most numerous offspring was recorded after four months of development. After six months, their numbers decreased but not rapidly, which indicates that confused flour beetles can find food and develop in flours even after that period.

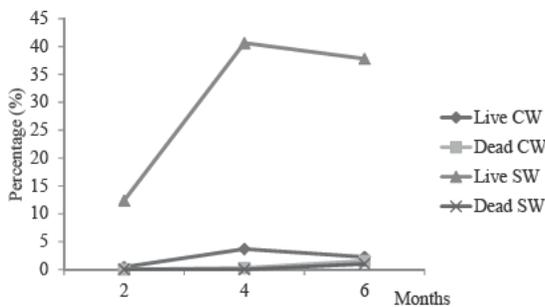


Figure 3. Offspring dynamic over six months of storage on common (CW) and spelt wheat (SW) flours

Regarding spelt wheat pasta, only 4 young individuals developed from the initial population density of 20 insects. No offspring developed in common wheat pasta, although insect parents lived up to 4 months and some even up to 6 months.

Influence of initial population density on offspring counts on common and spelt wheat and their products

The most numerous offspring developed from the smallest initial population density (4 insects) after two months of storage on all products (Table 1). The offspring on spelt wheat flour was significantly more prolific than it was on any other product, while kernels of both varieties and common wheat flour followed.

After four months (F_2 generation), the population of confused flour beetle significantly increased, compared with F_1 generation, on all products except pasta, where no offspring was found. The most numerous offspring, and statistically significantly different, was recorded on spelt wheat flour from the initial population density of four insects, followed by a less numerous F_2 on the same flour developing from the initial population density of ten insects, and one developing on common wheat kernels from the smallest initial population density (Table 2). The most numerous offspring on all products grew from the smallest initial population density.

After six months of product storage, the number of confused flour beetles decreased compared to previous evaluation on common and spelt wheat flour, regardless of their initial population density. On kernels, their numbers increased, except on common wheat kernels at the highest initial population density (Table 3). As in the previous evaluation, the highest number of offspring insects developed from the lowest initial population density on all products.

Table 1. The influence of initial population density of confused flour beetles on offspring counts after two months

Species of wheat	Product	Average number of offspring (\pm SD)		
		4	10	20
<i>Triticum aestivum</i>	kernel	52.0 \pm 9.76 c	29.50 \pm 5.23 d	19.02 \pm 3.73 de
	flour	12.06 \pm 7.39 ef	2.35 \pm 1.53 f	0.97 \pm 0.93 f
	pasta	0.0 \pm 0.0 f	0.0 \pm 0.0 f	0.0 \pm 0.0 f
<i>Triticum spelta</i>	kernel	0.0 \pm 0.0 f	0.0 \pm 0.0 f	0.0 \pm 0.0 f
	flour	104.75 \pm 30.61 a	65.37 \pm 11.97 c	81.51 \pm 18.90 b
	pasta	0.0 \pm 0.0 f	0.0 \pm 0.0 f	0.0 \pm 0.0 f

Means marked with the same letter are not significantly ($P > 0.05$) different as determined by Fisher's LSD-test

Considering the results shown in Tables 1, 2 and 3 it is evident that offspring numbers are influenced not only by the type of food but the initial population density as well. It is obvious that the average offspring of each insect does not increase proportionally with the increase in initial population density.

Influence of wheat species and their products on offspring mortality

The quality of food can also be evaluated based on insect life expectancy (Table 4). Insects died on common and spelt wheat kernels after 6 months.

Table 2. The influence of initial population density of confused flour beetles on offspring counts after four months

Species of wheat	Product	Average number of offspring (\pm SD)		
		4	10	20
<i>Triticum aestivum</i>	kernel	110.12 \pm 14.03 c	62.05 \pm 3.93 cde	38.03 \pm 5.50 ef
	flour	49.12 \pm 11.79 def	20.85 \pm 1.77 ef	13.57 \pm 3.96 ef
	pasta	0.0 \pm 0.0 f	0.0 \pm 0.0 f	0.0 \pm 0.0 f
<i>Triticum spelta</i>	kernel	46.25 \pm 8.07 def	34.02 \pm 0.53 ef	18.63 \pm 2.42 ef
	flour	511.12 \pm 167.18 a	214.55 \pm 38.76 b	96.80 \pm 9.33 cd
	pasta	0.0 \pm 0.0 f	0.0 \pm 0.0 f	0.0 \pm 0.0 f

Means marked with the same letter are not significantly ($P > 0.05$) different as determined by Fisher's LSD-test

Table 3. The influence of initial population density of confused flour beetles on offspring counts after six months

Species of wheat	Product	Average number of offspring (\pm SD)		
		4	10	20
<i>Triticum aestivum</i>	Kernel	164.12 \pm 18.70 c	65.25 \pm 3.38 ef	33.83 \pm 3.68 gh
	Flour	43.18 \pm 7.15 fg	20.05 \pm 1.88 ghi	11.98 \pm 2.01 hi
	Pasta	0.0 \pm 0.0 i	0.0 \pm 0.0 i	0.0 \pm 0.0 i
<i>Triticum spelta</i>	Kernel	90.50 \pm 16.01 de	44.27 \pm 9.89 fg	26.87 \pm 6.69 gh
	Flour	467.68 \pm 58.23 a	204.95 \pm 33.13 b	100.05 \pm 30.91 d
	Pasta	0.0 \pm 0.0 i	0.0 \pm 0.0 i	0.0 \pm 0.0 i

Means marked with the same letter are not significantly ($P > 0.05$) different as determined by Fisher's LSD-test

Table 4. The mortality of confused flour beetles on different products

Product	Initial population	Average mortality (%) after months					
		<i>Triticum aestivum</i>			<i>Triticum spelta</i>		
		2	4	6	2	4	6
Kernel	4	0	0	29.28	0	0	33.29
	10	0	0	70.10	0	0	51.47
	20	0	0	65.09	0	0	36.09
Flour	4	0	6.08	24.46	0	0	2.44
	10	0	7.07	40.48	0	0	2.6
	20	0	5.52	19.67	0	0	4.02
Pasta	4	0	87.5	100	6.25	81.25	100
	10	2.5	100	100	10.0	90.0	100
	20	68.75	100	100	12.5	97.5	100

On common wheat flour, a part of the insect population died after 4 months, while mortality occurred on spelt wheat flour after 6 months. On common wheat pasta, all insects died after 4 months and on spelt wheat pasta after 6 months.

DISCUSSION

We have inferred from our previous research that some insects cannot develop equally well on different species of wheat. Our examination of the development and reproduction of rice weevil *Sitophilus oryzae* L. and lesser grain borer *Rhizopertha dominica* F. on spelt wheat has confirmed such a conclusion. Rice weevils do not feed or develop on spelt wheat when it is stored with the husk (Almaši et al., 2010; Bodroža-Solarov et al. 2010). Because spelt wheat is increasingly grown in organic production in our country and the confused flour beetle has been recently detected as a significant pest of stored grain, we decided to examine the reproduction of that species on spelt. A great number of researchers have studied similar problems but few of them have dealt with spelt wheat and the confused flour beetle (Laszczak-Dawid et al., 2007).

Studying the influence of offspring numbers on weight loss and the influence of weight loss on life expectancy of the angoumois grain moth *Sitotroga cerealella*, Oliv., Ahmed et al. (2002) concluded that the losses caused by that species depended on a great number of factors. The time that confused flour beetles need to develop on spelt wheat kernels is longer than on common wheat kernels (no offspring was found after two months) but many beetles persisted much longer. Studying the development of angoumois grain moth larvae, Koleva and Ganeva (2009) concluded that there was not a significant difference between the number of eggs and hatched out larvae on various genotypes of common wheat but their survival depended on development duration, which agrees with our results.

The development and reproduction of red flour beetle is much more intensive on flour and broken maze kernels than on intact kernels (Li & Arbogast, 1991). In our experiments, confused flour beetles developed well but there were 20% broken kernels, which agrees with findings in the former study. When studying the attractiveness of food for red flour beetle, its larvae developed best in the common flour grade 1, maida and bran. The lowest feeding preference of beetles was for dry and tempered wheat (Muhammad et al., 2006).

Khattak et al. (1986) showed that the reproductive potential and eclosion of red flour beetle adults were higher in common wheat flour made from whole grains with 5 % yeast than in mixtures with 15, 10, 2 and 1% yeast in common wheat flour from whole grains. We did not add any yeast in our experiments but abundant offspring developed in the spelt wheat flour nevertheless, which means that flour contains all nutrients necessary for the development of confused flour beetles. Meagher et al. (1982) found that a population of red flour beetle in cracked millet increased faster than in whole grain millet, while insects were abounding in millet flour, which is consistent with our results. Studying the development period of the confused flour beetle on kernels, flakes, bran, flour and pasta, Laszczak-Dawid et al. (2007) came to a conclusion that the beetle adapted well to new food, which we confirmed in our experiment, especially when food was ground like spelt wheat flour.

While sieving the flours we detected no cannibalism, although we are aware of its existence in the species. This finding has been reported by many other authors as well (Alabi et al., 2008; Flinn & Campbell, 2012).

The initial number of insects in the products affected the number of offspring beetles. The greatest number of offspring insects was identified from the initial population density of four insects in all three evaluations and all products. Our results showed that larger initial populations of confused flour beetle produced less offspring. The same tendency had been observed by Stojanović (1965) while studying the development of grain and rice weevils on wheat, and Almaši and Poslončec (2011) in studying the offspring abundance of lesser grain borers. Examining the influence of the amount of food on red flour beetles *Tribolium castaneum* Herbst offspring, Sastawa et al. (2009) concluded that the differences in initial amounts of food did not significantly affect the number of red flour beetle adults, which was not confirmed in our studies of *T. confusum*.

These studies have shown that more abundant offspring developed on common wheat kernel than on spelt wheat kernel. However, spelt flour is much better for the development of confused flour beetles than common wheat flour, and the best of all tested products. The smallest initial population of confused flour beetles in all products produced the most numerous offspring. Regardless of an initial population density, the smallest adult mortality rate was found in the flours, and the largest on pasta of both varieties of wheat.

ACKNOWLEDGEMENT

The authors acknowledge the financial support of the Ministry of Education, Science and Technological Development, the Republic of Serbia, Project Ref. BT-46005.

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Razmnožavanje malog brašnara, *Tribolium confusum* Du Val (Coleoptera: Tenebrionidae) na običnoj pšenici i spelti i njihovim prerađevinama

REZIME

Poslednjih godina povećan je interes za proizvodnju pšenice spelte. Malo je informacija o mogućnosti razvića štetočina u skladištima na ovoj vrsti pšenice. Ispitivan je uticaj vrste pšenice i njenih prerađevina na reprodukciju i formiranje potomstva malog brašnara *Tribolium confusum* Du Val u laboratorijskim uslovima (22-25 °C i 40-60% RVV). Ogled je postavljen u četiri ponavljanja sa po četiri, 10 i 20 insekata i praćen šest meseci. Razmnožavanje malog brašnara se značajno razlikovalo u zavisnosti od vrste pšenice. Najveća reprodukcija zabeležena je na spelti (*Triticum spelta* L.). Najveći broj potomaka se razvio na brašnu od spelte (23469). Na zrnu pšenice dobijen je veći broj potomaka (7044) od broja potomaka na zrnu spelte (5469). Na testeninama od pšenice nije dobijeno potomstvo, dok je na testeninama od spelte dobijeno samo 4 potomka. Dužina čuvanja utiče na povećanje brojnosti potomstva pozitivno, do određene granice, a dalje zavisi od brojnosti insekata i količine dostupne hrane. Do četiri meseca brojnost insekata se povećavala, a kasnije opadala i povećavala se smrtnost. Osim vrste hrane i početna gustina populacije utiče na brojnost potomstva, ali se brojnost potomstva ne povećava srazmerno povećanju početne gustine populacije. U zavisnosti od vrste pšenice najveća smrtnost zabeležena je na običnoj pšenici. U odnosu na vrstu proizvoda najveća smrtnost bila je na testeninama, zatim na zrnu, a najmanja na brašnu. Ovaj rad ukazuje da se mali brašnar odlično razvija na spelti i svim proizvodima od spelte, čak bolje nego na mekoj pšenici koja se gaji u našoj zemlji.

Ključne reči: Pšenica; razmnožavanje; *Tribolium confusum*