

Efficacy of propionic acid against the granary weevil *Sitophilus granarius* (L.)

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Abstract

Propionic acid is used to preserve feed grain, especially against fungal attack, and is known to affect stored product insects as well. In the study presented here, the effect of wheat treated with different amounts of pure propionic acid on both adult *Sitophilus granarius* and its progeny was investigated. Propionic acid (99.5% purity) was added to samples of 150 g of wheat at the doses of 0.5, 0.7 and 1% by weight. Subsequently, 100 adult *S. granarius* were released into each vial with treated wheat. Each trial was repeated three times. The untreated controls received water instead of propionic acid. Dead weevils were counted after 7 and 14 days. Insects surviving 7 days were placed back into the vials, all adults were removed after 14 days. During the period of 8 and 11 weeks after start of the experiment, the number of progeny was counted weekly. In the trials with 0.5%, 0.7% and 1% by weight, after 14 days 73.7, 37.3 and 3.7% of the adults were alive, respectively. While the mean number of progeny was 1549 in the untreated control, 1.3 and 0.3 progeny on average emerged from the grain treated with 0.5% and 0.7% propionic acid, respectively. No progeny survived in the treatment with 1% by weight. Even though complete control of adult *S. granarius* could not be achieved with the tested conditions, under practical situations of storage of feed grain, the described application of propionic acid will effectively suppress the mass-development of *S. granarius*.

Keywords: Granary weevil, *Sitophilus granarius*, Propionic acid, Control, Feed storage

1. Introduction

Propionic acid serves for prevention of fungal growth and control of insects especially in storage of moist feed grain (Reichmuth and Richter, 1991). The acid occurs in grain also naturally at low content (Mara, 1978) and has a repellent effect (Germinara et al., 2007; 2008) as well as a toxic effect on *Sitophilus granarius* (L.) (Reichmuth and Richter, 1991; Germinara et al., 2007). Aim of the presented study was to demonstrate the possible lethal effect of wheat treated with various amounts of propionic acid on adult granary weevils and their progeny. The lethal content of the acid was to be identified.

2. Materials and methods

Pure propionic acid with a purity of 99.5% served for the treatment of the wheat. The test comprised three dosages: 0.5, 0.7 and 1.0% by weight. Dosages of 5, 7 and 10 mL/kg, respectively, were added as portions of 0.75, 1.05 and 1.5 mL to wheat samples of 150 g insect-free whole wheat kernels *Triticum aestivum*. Exposure of the grain to -18°C for 10 days prior to the experiments ensured that the grain was free of living pests. The grain was adjusted to 14% mc before starting the experiments.

The insects originated from cultures maintained at the Julius Kühn-Institute in Berlin. One hundred 2-3 week old granary weevils per 400 mL glass jar served as test insects for the experiments. Throughout the experiments, temperature was kept at $22 \pm 2^\circ\text{C}$ and relative humidity at $67 \pm 4\%$ in a climatic chamber.

The temperature in untreated wheat samples (without granary weevils) was $22.5 \pm 0.6^\circ\text{C}$ and the relative humidity in the grain $70.4 \pm 2.1\%$. Data loggers (MINIDAN CLIMA, ESYS GmbH, Berlin, Germany) served to determine the climatic conditions in the grain samples with four measurements per day. Figure 1 contains the data for temperature and relative humidity in reference glass jars.

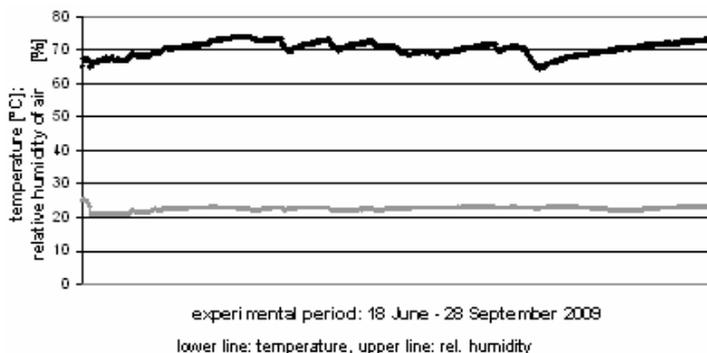


Figure 1 Temperature and relative humidity in grain samples throughout the experimental period; recorded with data loggers of the MINIDAN CLIMA company; 4 data points per day, linear scale.

The required amount of acid was pipetted to the grain (Table 1). To ensure equal distribution of the acid in the grain sample, the glass jars with grain were closed with plastic cap and rotated for one hour on a special device (Multifix, Alfred Schwinherr, Feinmechanische Spezialgeräte, Schwäbisch Gmünd, Germany). Subsequently, 100 adult *S. granarius* were added to the grain, and the glass jar was closed with a piece of cotton cloth and rubber bands. Three jars with 150 g wheat and 100 insects served as references at the same climatic conditions. Instead of the acid, water was added to the grain and the jar rotated as described above.

Seven and 14 days later, wheat samples were checked for surviving weevils. After the first period of 7 days, the surviving adults were counted and transferred back into the jars. Dead insects were removed. After 14 days, surviving weevils were counted again and all insects were removed from the jars.

After 8 weeks, emerging progeny were counted and removed together with dead insects for the first time, followed by further weekly counting for another 6 weeks. Each dosage was tested in three replicates.

Table 1 Survival rate of 100 adult *Sitophilus granarius* after treatment of wheat (mc = 14%) with propionic acid at dosages of 0.5, 0.7 and 1.0% by weight and in untreated reference samples at $22 \pm 2^\circ\text{C}$ and $67 \pm 4\%$ r.h.; number of surviving *Sitophilus granarius* after 7 and 14 days and percentage of survivors in relation to the number of progeny in untreated reference samples, three replicates per dosage.

Days after start	Glass jar No.	Number of surviving <i>Sitophilus granarius</i>			
		Propionic acid in % by weight on wheat			
		0	0.5	0.7	1.0
7	1	100	91	79	12
	2	100	90	68	10
	3	98	90	74	11
	Total	298	271	221	33
	Survival rate (%)	99.3	90.3	73.7	11.0
14	1	96	78	44	2
	2	100	62	33	5
	3	98	81	35	4
	Total	294	221	112	11
	Survival rate (%)	98.0	73.7	37.3	3.7

3. Results and discussion

3.1. Survival of adults

Table 1 contains the results on the efficacy of propionic acid against adult *S. granarius* after 1 and 2 weeks of exposure at $22 \pm 2^\circ\text{C}$. After the treatment with 1% by weight of propionic acid per kg wheat only few insects (11.0 and 3.7%) had survived 7 days and 14 days, respectively.

Figure 2 reveals that the influence of the exposure time on the survival rate of adult *S. granarius* with 1% content of propionic acid in wheat is not very pronounced. This is different with lower contents of acid. An expansion of the exposure of a few days beyond 2 weeks should have controlled all adult weevils with 1% propionic acid. In the situation of a feed store, full control might be achieved with 1% by weight of propionic acid since the grain is often stored for a period of months. Conversely longer exposure at lower dose did not give complete control. A slight increase in dose might as well improve the situation significantly and give full control.

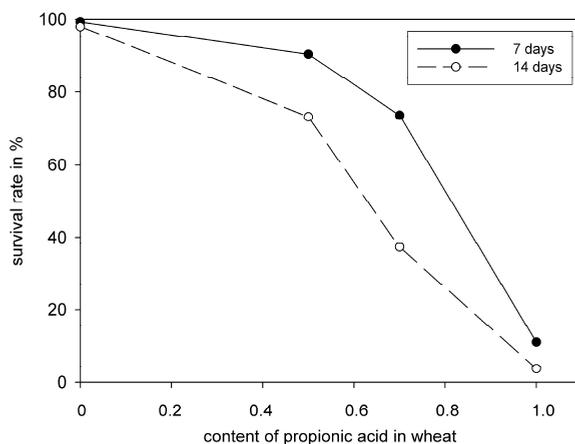


Figure 2 Survival rate [% of numbers in untreated samples] of adult *Sitophilus granarius* after treatment of wheat with propionic acid at dosages of 0.5, 0.7 and 1% by weight and in untreated reference samples after 7 days and 14 days of exposure at $22 \pm 2^\circ\text{C}$ and $67 \pm 4\%$ r.h., three replicates.

3.2. Production of offspring

Table 2 contains the results for the numbers of progeny of *S. granarius* (F_1 generation), that were collected 8 to 11 weeks after the beginning of the experiment with parent weevils and treated wheat. Only a few single eggs managed to survive and develop into adults in kernels of wheat that had been treated with 0.5 and 0.7% by weight, respectively. An acid content of 1% by weight totally interrupted the development of any F_1 imago. The lethal effect of this dose was very pronounced.

Table 2 Number of progeny of *Sitophilus granarius* (F_1 -generation) after 11 weeks of exposure at $22^\circ \pm 2^\circ\text{C}$ and $67 \pm 4\%$ r.h. on wheat treated with either 0.5, 0.7 or 1% by weight.

Weeks after start	Glass jar No.	Number of <i>Sitophilus granarius</i> progeny			
		Propionic acid in % by weight on wheat			
		0	0.5	0.7	1.0
11	1	1435	1	1	0
	2	1681	2	0	0
	3	1532	1	0	0
	Total	4648	4	1	0
	Average	1549.3	1.3	0.3	0
	Standard deviation	123.9	0.6	0.6	0

4. Conclusions

Control of adult granary weevils in stored wheat at $22 \pm 2^\circ\text{C}$ with propionic acid requires contents of about 1% by weight. A little bit more than 2 weeks are needed for this effect. The progeny is affected, too, and will not survive these conditions, even though the exposed adults may lay some eggs before dying. In so far, stored wheat is protected also against invading granary weevils by this treatment. Beside the fungicidal effect this acid brings along a lethal effect against this important insect pest. The progeny may also be suppressed at lower contents like 0.5% by weight because only few weevils survived this treatment, but this aspect requires further studies. Reichmuth and Richter (1991) mentioned that moist grain can be protected against mould growth and infestation by *S. granarius* at costs of about 0.3 €/t without loss of the quality of the grain for feeding purpose. An interesting question might be how long the treated grain is protected against newly invading weevils and development of progeny some weeks after treatment.

References

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