APPLICATION OF LOW TEMPERATURES FOR PESTS CONTROL IN STORED MAIZE

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ABSTRACT

F_1 generation test insects *Sitophilus zeamais* Motsch. – maize weevil, and *Rhyzopertha dominica* F. – lesser grain borer were grown in laboratory conditions. In 2007, experiments with the test insects were set up in silo chamber filled with maize cooled at 6 °C. Mean mortality value of 100% maize weevils was obtained after 43 days, while lesser grain borer attained the same results after 33 days. This species is more sensitive to low temperature due to the termophility in ecology of growth. Insect mortality in control samples was not significant. In the process of conducting experiments economic costs index for storing 750 t maize grain by cooling was slightly higher than the costs of single fumigation by a.i. phosphine (PH_3). By pest reinfestation in practice in the season of storing, 2 fumigation treatments are carried out, which double costs of chemical treatment, and contaminate products and the environment.

Key words: cooling, stored maize, *S. zeamais, R. dominica,* physical measures, chemical measures, economic costs index.

INTRODUCTION

Application of low temperatures in stored maize preservation in silo chambers is a physical measure of pests control. The purpose of cooling is to even temperature level in grain with the temperature in the environment where live organisms including pests and their growth stages have no ecologically favourable conditions for development and exhibit no negative effects. Besides, grain respiration is reduced, disabling all negative physiological traits like increased temperature and moisture, as well as self-heating of stored mass and all adverse processes while storing. In accordance with [1], losses following respiration in cooled stored grain are decreased by application of cooled air by 80-90%. Devices for grain cooling can be stationery and mobile. In warehouses and silos it is necessary to build tubes for aeration during cooling process. When introducing cool air, i.e. by preserving grain at low temperatures, dry grain with 12 – 13% moisture is needed. Nowadays, this method of grain preservation has been used worldwide [2, 3, 4, 5, 6, 7, 8, 9, 10, 11], as opposed to Croatia with application in 30-40% cases, to our knowledge. The reason is expensive power source and construction of storage facilities. However, many recently built silos in Croatia use cooling treatment of dry grain by applying stationery or mobile devices of «Granifrigor» type, or other. Air of low relative humidity, and 6 °C to 10 °C have been blown in stored grain mass from the bottom of the silo chamber. The aim and assignments of the research were: to examine influence of low temperature of 6 °C in silo-chambers with stored maize grain on the length of live adult activity until the absolute mortality of the pests, species *Sitophilus zeamais* Motsch. (maize weevil) and *Rhyzopertha dominica* F. (lesser grain borer). In the practice of maize preservation in Croatia these insect species are most prevalent pests, inducing considerable damage in maize grain in non-controlled conditions of storing. Furthermore, we determined economic costs index during maize preservation by cooling, and made comparison between cost-effective grain preservation applying low temperatures with the costs of conventional, direct measures for pest control that were applied by fumigation with active substance PH_3 (phosphin). This pesticide measure for pest control has been unfortunately the most frequently applied in practice in Croatia.

MATERIALS AND METHODS

F_1 generation test insects, order *Coleoptera*, species *S. zeamais* and *R. dominica* were reared in clime-chamber in the laboratory of the Department for Plant Protection, Faculty of Agriculture in Osijek. The species were selected due to the resistant property against conventional insecticides – fumigants, and are considered as primary pests of stored grain products [9].

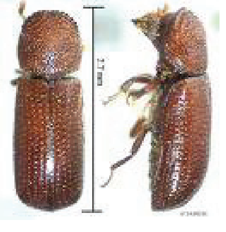

Figure 1. *Rhyzopertha dominica*

Figure 2. *Sitophilus zeamais*

Investigations were carried out in metal, zinc-coated silo, property of Farming Cooperative «Landia» d.o.o. in Tordinci. Total storage capacity of the silo was 5000 t of grain, with silo-chambers having capacity of 750 t to 2500 t. It was built on concrete base with openings and tubes for introducing cool air. Maize grain having moisture of 25-30%

was directly transported from the field with no prior drying, and placed in silo-chambers (Figure 3).

Figure 3. Test-silo-chamber

Figure 4. Cooling part of «Granifrigor» device

Basic characteristics of the cooling device are: mobile type of German production «Goldsaat 160/404 S», made in 2003, capacity of tolerable pressure 28 bar/- 1 bar, capacity of tolerable temperature +100 °C to -50 °C, costs 33000 EUR. Performances of «Granifrigor» cooling device (Figure 4) are: high-pressure ventilator is used to pull in the air through cooling part of device to be cooled in fridge. Such cold air of low relative humidity is introduced through the air-separator to the basis of silo-chamber and flows up to the layer of stored grain. Heat in stored mass is pushed up the top of silo-chamber and then pushed out. Cooling temperature is determined by «Higrotherm» scale, independently of conditions in the environment. For air separation inside the chamber and air resistance in mass, input-cold air is dispersed over the cross-section of silo-chamber, i.e. flowing through the whole stored pile. On the top of the silo appropriately large opening is needed to enable warm air from stored product mass to flow out in the atmosphere.

In practice of cooling, temperature of 8-10 °C is usually applied; however, we wanted to prove that lower temperatures (6-8 °C) in shorter period can obtain mortality of the test-insect species.

Experiment with insects in silo-chamber was done as follows: in separately designed cages (test-tubes) of silk (Figure 5) we placed 20 test-insects adults (*S. zeamais* and *R. dominica)* together with maize grain from silo. They were introduced in plastic perforated vials of in capacity for aeration, and to provide test insects with temperature and humidity. Plastic vials with test-insects were fixed at the end of the wooden probe (Figure 6).

Figure 5. Test-insects in test-tubes

Figure 6. Probes with PVC-vials and test-insects

Probes with 120 cm in length were stuck from upper side of silo-chamber through the opening for grain products into the mass of cooled stored maize with temperature of 6 °C (Figure 7). Silo-chamber was closed. In total, 160 test samples were set up (20 adults – treatments x 2 species x 8 replications). Temperature in the environment, relative humidity, and temperature of the maize at the top of silo-chamber were measured. «Dickey John» apparatus was used to measure moisture, temperature and percentage of admixture in maize grain. Control was set up in clime-chamber in laboratory conditions with the same insect species (29 °C, 70% relative humidity).

Figure 7. Probes with test-insects in silo-chamber

Tests – mortality control of test-insect adults in silo and laboratory (control samples) were done each 7 days from the beginning of the experiment until 100% mortality.

Results of mortality percentage for test-insects in silo and laboratory were obtained by the methods of counting and calculating mean values. Determination of economic costs indices in time of storing maize by cooling, and comparison between cost-effective maize preservation by non-pesticide measure and by cooling with pesticide application – fumigation with active substance phosphin (PH_3), will be shown in the results section.

RESULTS AND DISCUSSION

In the following text we show results of insects mortality obtained in the experiments in silo and laboratory.

Results of mortality in test-insect species in silo with cooled maize grain are shown in Figure 8.

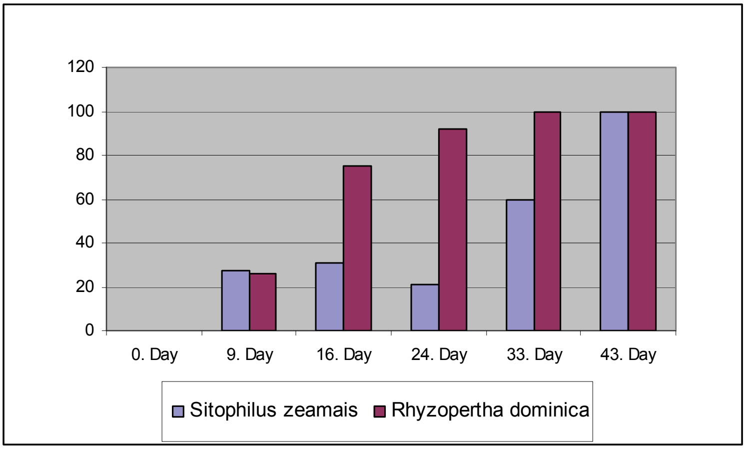

Figure 8. Mortality of tested species in silos (%)

It can be seen that *R. dominica* achieved mortality time (92.25% mortality) after 24 days, more rapidly than *S. zemais* that showed mortality of 21% in the same period. This proved *R. dominica* as considerably thermophilus species that was killed earlier than *S. Zeamais* at low temperatures. Total mortality of 100% with first species was achieved after 33 days of exposition, and with the second after 43 days of exposition at low temperature of 6 °C.

Mortality results of test insects in laboratory conditions (control) (Figure 9) showed insignificant mortality in both test-insect species. Analyses showed 2 killed adults in both species.

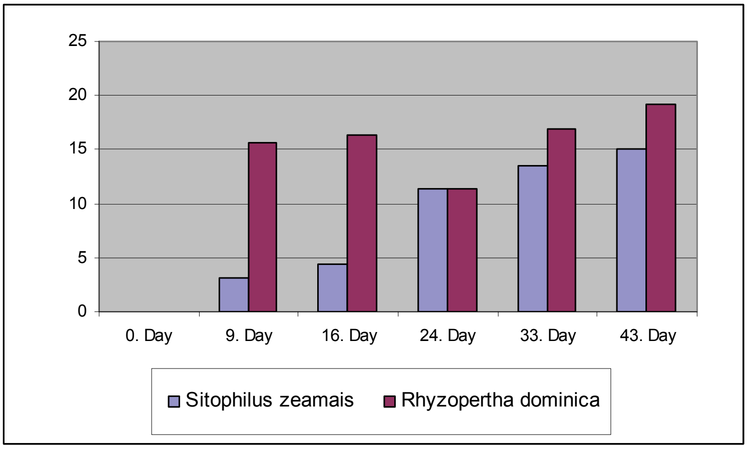

Figure 9. Mortality in laboratory conditions

Economic costs indices, i. e. bill of costs for cooling during maize grain preservation in test-silo-chamber with capacity of 750 t in silo «Landia» d.o.o. in Tordinci are shown in Table 1.

Table 1. Bill of costs for maize grain cooling in silo-chamber of 750 t capacity (10 °C and 12-13% humidity)

Treatment of grain cooling by »Granifrigor» device	**Amount in KN**
1. Costs for electric power necessary for cooling treatment, on average 4.5 kW, costs – 0.45KN/kW	1.350,00
2. Amortization and maintaining costs (1.000,00 KN) for one silo-chamber per year	5.043,00
3. Costs for cooling device 222.000,00 KN	
Total	6.393,00

Annually, in tested silo 3.500 t of grain products is cooled. Annual amortization costs for entire silo is 23.200,00 KN, i. e. 6.393,00 KN per one silo-chamber (750 t in capacity) (Table 1). These are rough calculations being based on the estimate of the device producers and data that were obtained from chemical engineers in «Landia» d.o.o. Moreover, the calculations depend on many variables: grain moisture of stored maize after combine-harvesting (22-30%) does not necessarily decrease to the level of the humidity in warehouse (12.5%), which means definite increase in storage capacity; energy costs (grain drying up to 17%) are reduced, and grain mass volume increases up to 30-40 t per silo-chamber. This also has impact on final yields gained by selling products; air temperature and temperature of stored grain directly influence costs of cooling.

Table 2 shows costs of pest control by fumigation (active substance phosphin – PH_3), aiming to compare non-pesticide (Table 1) and pesticide measures of pest control.

Table 2. Bill of costs of pest control by fumigation in one silo-chamber of 750 t capacity

Fumigation treatment by pellet formulation	**Amounts in KN**
1. Fumigation of 1 t maize amounted to 7 KN, averagely (6-8)=5.250,00 KN	1 treatment 5.250,00
2. By grain turning in fumigation 2 kW were consumed	2kW = 75,00
3. Grain breakage due turning (averagely 225 kg x 0.80 KN)	180,00
Total	6.105,00

It can be seen that costs of one fumigation treatment amount to 6.105,00 KN. In practice, reinfestation occurs due to the slight fumigant activity against developmental stages of insects, (eggs, larvae, pupae), and because of the insect resistance, i. e. lesser grain borer [10], which requires another fumigation. This results in double costs. Grain temperature during fumigation should be at least 20 °C, with humidity in warehouse of 12.5%. On the contrary, non-pesticide, physical measures, in this case grain cooling is more suitable measure, causing no reinfestation. By lowering grain temperature for cooling at 10 °C (Table 1) aiming to prevent pest development, we obtained costs amount approximate the costs of applying pest control measures in one silo-chamber (Table 2). Investigations of maize grain cooling were done at 6 °C to achieve more rapid and total mortality of test-insects, which would in practice increase costs for cooling. Costs of application of non-pesticide measures by cooling maize grain and costs of fumigation treatment are approximately same. Cooling treatment is preferable to the pest control by pesticide measures due to the many deficiencies, but above all, contamination of products and environment by chemical products.

CONCLUSIONS

Low temperatures by cooling stored maize grain at 6 °C showed different mortality of test adult species, *S. zeamais* and *R. dominica*, depending on exposition time (days). *S .zeamais* obtained first higher mortality (88.75%) after 33 days, with 100% mortality obtained 43 days after being exposed to the low temperatures. *R. dominica* first higher mortality achieved 16 days after being exposed to low temperatures, with 100% mortality achieved 33 days after exposition – 10 days before *S. zeamais.* We came to the conclusion that *R. dominica* was more sensitive species to the low temperatures during grain cooling than *S. zeamais* due to the thermophility of the pest [10]. Mean values for both test-species in controlled, laboratory conditions showed insignificant mortality. Economic costs index i. e. costs of maize grain cooling in tested silo-chamber of 750 t in capacity was 6.393,00 KN. These costs were compared with the costs of chemical pest control by fumigation with active substance phosphin (PH_3), with pellet formulation, but no cooling treatment. They amounted to 6.105,00 KN, lower amount than costs for grain cooling. However, cooling treatment is preferable for many advantages, since grain being cooled at silo-chamber retain the temperature during the season of storing and keep safe from harmful insects that could be introduced in silo. Cooled grain is naturally preserved, and pests (insects and mites) are not able to develop and damage grain; quality and quantity losses are lowered, with no possibility for contamination of products, or environment. One pest control by fumigation after at least 2-3 months would induce reinfestation in stored grain from developmental stages of adults due to their resistance against applied fumigant. Fumigation treatment should be repeated, which would double costs, and contaminate products and the environment by residues of chemical product applied. Unfortunately, in our country non-pesticide, physical measure of product preservation has not been sufficiently applied in comparison with the remaining developed countries in the world.

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