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GRAIN SURFACE-LAYER TREATMENT OF DIATOMACEOUS EARTH FOR INSECT CONTROL

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This paper describes an alternative method to synthetic insecticides used for protection of stored agricultural products the purpose of which is to minimise the everyday human exposure to those chemicals. The method uses diatomaceous earth which is practically non-toxic to humans and fully acceptable for the environment. Fifty and 100-cm-deep layers of Hard Red Spring wheat *Triticum aestivum* (L.) in metal containers (cylinders), 30 cm in diameter and 150 cm in height were treated with 0.5 and 0.75 g of diatomaceous earth Protect-It® per kg of wheat. The treatment reduced the population of *Sitophilus oryzae* (L.), *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (Fabricius) by 98 to 100% with respect to controls. The conclusion is that a 100-cm-surface layer treated with 0.5 g/kg of Protect-It® is sufficient to control these insects, and that no more than 20% of the total grain mass should be treated to minimise bulk density reduction. A field test using a similar design is essential to confirm the laboratory findings.

Key words:
bulk density, grain insects, inert dust, non-chemical control

There are various methods devised to protect stored grain from insects. Most involve man-made chemicals which leave residues in food and are a matter of concern for all those who are responsible for human health. This is why we decided to investigate the efficacy of an alternative method with diatomaceous earth (DE) which is practically non-toxic to humans and fully acceptable for the environment.

Diatomaceous earth has long been known as a potentially useful grain protectant because it is safe to use, does not affect the end-use quality of grain, provides long-term protection, and is comparable in cost to other methods of grain protection (1).

Diatomaceous earth is composed almost entirely of amorphous silicon dioxide and is formed from fossilised diatoms (single-cell algae). Amorphous silicon dioxide is non-toxic to mammals (2) and is registered in many countries as a food additive (3, 4). Diatomaceous earth is probably the most efficacious natural dust used as an insecticide. Diatomaceous earth adheres to the body of the insect and damages the protective waxy layer of the insect cuticle by sorption and to a lesser degree by abrasion. The result is the loss of water from the insect's body and death (5). Diatomaceous earth also repels some insects (6).

The use of diatomaceous earth was limited because the required dose rates of 1.0 to 3.5 grams per kilogram of grain for most DE products significantly reduced the grain bulk density and flowability, and left visible dust residues (7, 8). A few newer DE formulations such as Insecto® and Dryacide® are effective at lower concentrations (0.5 to 1.0 g/kg). Hedley Technologies, Mississauga, ON, Canada, in conjunction with Agriculture and Agri-Food Canada, Cereal Research Center, Winnipeg, has developed a new diatomaceous-earth-based insecticide Protect-It® that can be used at even lower concentrations (0.1 to 0.5 g/kg) with acceptable efficacy against insects and with reduced adverse effects on grain handling and bulk density (9).

Certain factors have generated renewed interest in using diatomaceous earth as a component of Integrated Pest Management (IPM), including consumer demand for food free of pesticide residues, development of resistance to synthetic insecticides in insects, and potential loss or restricted application of currently available stored-grain pesticides due to new regulations (7).

In the Proceedings of the 6th International Working Conference on Stored-Product Protection (Inert Dusts Workshop Summary) in Canberra, Australia in 1994, one of the conclusions was that inert dusts, mainly DE, are now part of the mainstream of stored product protection. Therefore, when determining how to solve stored-grain pest problems, DE should be considered along with other tools, such as fumigants, trapping, and physical methods. It is generally thought that DE should be used as a preventive measure for grain protection and not as a curative measure or means of disinfestation. At the working conference, three areas of DE use were outlined: admixture of DE with grain, use of DE as a structural treatment on walls and floors, and addition of DE to the surface of bulk grain.

Recommended dosage rates of DE (0.5 to 3.5 g/kg) have adverse effects on the physical and mechanical properties of grain including reduced bulk density (test weight), reduced grain flowability, visible dust residues on the grain (at 33.0 g/kg), and the production of airborne dust during handling (1, 7, 8, 10). The concentrations of the new developed DE Protect-It® required to achieve 90% mortality range from as low as 0.05 g/kg for *Cryptolestes ferrugineus* (Stephens) on wheat, to as high as 1.5 g/kg for *Rhyzopertha dominica* (Fabricius) on milled brown rice *Oryza sativa* (L.) (11). The dosage rates required for the control of many pest species on specific commodities well exceed 0.3 g/kg and are therefore less acceptable to the grain industry.

Many of the obstacles associated with the use of DE at practical concentrations may be overcome by only treating the top layer of the grain mass in a storage facility (i.e. layer treatment). However, few studies have investigated the effectiveness of layer treatments with DE-based grain protectants in preventing insect infestation (7, *Allen, personal communication*). Layer treatment prevents insects from entering grain mass via surface without reducing the value of the commodity. Mixing of treated and untreated grain during unloading will distribute the dust throughout the grain mass, minimizing the influence of diatomaceous earth on bulk density and handling properties to an acceptable level.

The objectives of our study were to assess the efficacy of Protect-It® applied in surface layer treatment and to determine the layer depth and concentration required to control the rice weevil *Sitophilus oryzae* (L.), the lesser grain borer *R. dominica* (Fabricius), and the red flour beetle *Tribolium castaneum* (Herbst) and their progeny in Hard Red Spring wheat. An attempt was also made to determine the dilution ratio of treated and untreated grain required to mitigate the adverse effects of 0.5 and 0.75 g of Protect-It® per kg on bulk density of wheat.

MATERIALS AND METHODS

Adult insects of mixed age and gender were taken from cultures maintained at 30±1 °C and 70±2% relative humidity. All cultures had been maintained in the laboratory for over three years.

Tests were conducted with Canadian Grade No. 1 Hard Red Spring wheat »Quantum variety« with an initial moisture content of 14.3%, a mean bulk density of 79.14±1.1 kg/hl, and 0.9% dockage. Bulk density was measured using the Canadian Grain Commission procedure (12).

Tests were conducted in containers 30 cm in diameter and 1.5 m high (tubes, spiral construction, 26 gauge galvanized steel duct). The base of each container was capped. Depending on the depth of the layer to be treated, a 6.8-cm-diameter hole (sampling hole) was placed either 40 or 90 cm from the base. A reference container had holes 2.5 cm in diameter and was placed 40 and 90 cm from the base. It was used to monitor grain temperature and moisture content throughout the experiment. Rubber stoppers were used to seal the holes in each container (Figures 1 and 2).

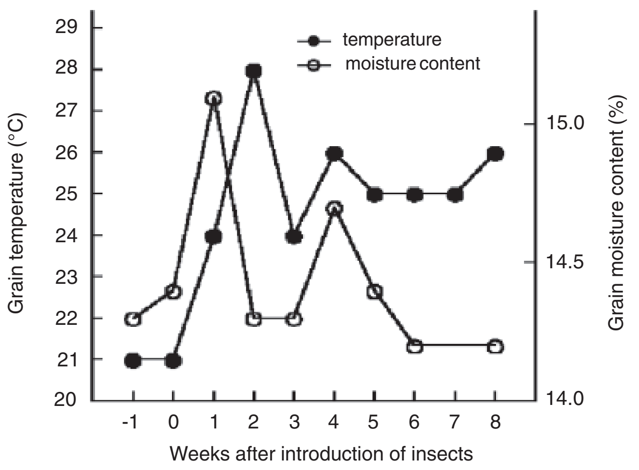

Figure 1 *Weekly grain temperature and moisture content in the reference container*

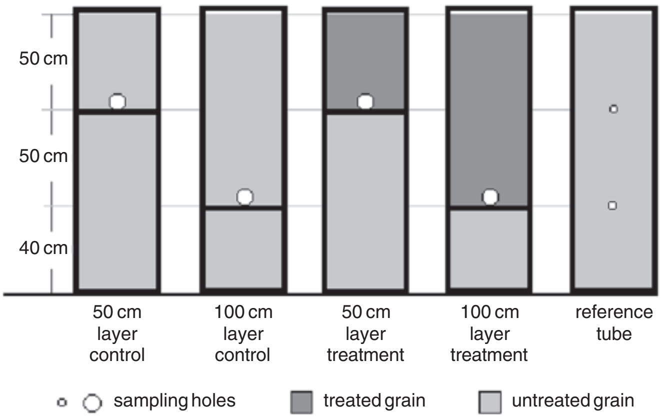

Figure 2 *Experimental design of different treatment conditions*

Protect-It® was used in the experiments. Protect-It® is a patented formulation of diatomaceous earth produced by Hedley Technologies, Inc., Mississauga, ON, Canada (9).

There were five treatments: untreated (control), top 50 cm of grain treated with 0.5 g/kg, top 50 cm of grain treated with 0.75 g/kg, top 100 cm of grain treated with 0.5 g/kg, and top 100 cm of grain treated with 0.75 g/kg. Each treatment was replicated twice. Grain was spread on a large polyethylene sheet and its surface dusted with either 0.5 or 0.75 grams of DE per kilogram of wheat. The grain and dust were mixed thoroughly with shovels.

Untreated grain was added to the reference container to a height of 140 cm and to the lower layers of all other containers to just below the sampling hole. A 29-cm-diameter screen (3-mm^2 mesh) was placed on top of the untreated grain (interface) to prevent mixing of the untreated and treated layers. A 50- or 100-cm layer of untreated (controls) or treated grain was then added to each tube. The total mass of grain added to each container was approximately 85 kg.

Liquid Fluon® was applied around the inner rim to prevent insects from climbing out of the tubes. Each tested insect species was released onto the grain surface of each container at a rate of 4.7 insect species per kilogram of grain (in total 400 adults of each species per container). After the introduction of the test insects, the top of each tube was sealed with a layer of fine screen and then a layer of cotton fabric.

Three samples of treated and untreated grain were collected immediately after treatment for determining bulk density, grain moisture content and percentage of dockage. Every seven days, grain temperature was measured in the reference container and a 250-g sample was collected from the reference tube to monitor grain moisture content.

Fifty-nine days after insect introduction, three 1-kg samples of grain were collected from each container, 1 kg from the surface (top few centimetres), and two consecutive samples from the sampling hole (unmixed samples). The grain was then removed from the containers in 2 stages beginning with the upper layer (top 50 or 100 cm), and ending with the lower layer (bottom 90 or 40 cm). After a thorough mix, three 1-kg samples were collected from each layer (mixed samples). One-kilogram samples of 0.5 and 0.75 g/kg treated grain (100 cm top layer treatment containers), and a 2-kg sample of untreated grain (from control container) were also collected to determine the optimum dilution ratio of untreated and treated grain for minimizing test weight reduction. Grain moisture content was determined for one mixed sample from each layer. All samples were sieved (No. 10 laboratory sieve) to determine the number of dead and live insects. Insect densities were compared among treatments by one-way ANOVA.

To estimate the ratio of untreated and treated wheat required to minimize the bulk density reduction produced by treatment with 0.5 or 0.75 g per kilogram of grain, wheat was treated with diatomaceous earth with 0.5 and 0.75 g/kg of Protect-It® in both the laboratory and field (collected immediately after treatment) and mixed with untreated grain at ratios of 1:4, 1:9, and 1:19 (treated:untreated). Comparisons were made with wheat treated in the laboratory with Protect-It® at 25, 37.5, 50, 75, 100, and 150 mg/kg. Three 500-g wheat samples (replications) were prepared for each treatment.

Samples were mixed by hand for one minute after adding the appropriate amount of Protect-It® or Protect-It®-treated grain to untreated wheat. Each 500-g sample was sieved (No. 10 laboratory sieve with 2-mm openings) for 45 seconds prior to measuring bulk density.

RESULTS AND DISCUSSION

Table 1 shows the grain conditions at the start of the experiment. The grain moisture content in the reference container was >14.0% throughout the 8 weeks of the experiment (Figure 1). With one exception, all untreated Hard Red Spring wheat samples collected from the test containers at the end of the experiment had >15.0% moisture content (Table 2). Although the grain temperature in the reference container was low (21 °C) during the first week after the introduction of the test insects, it remained over 24 °C throughout the remainder of the experiment (Figure 1).

Table 1 *Mean bulk density, moisture content and percentage of dockage of Hard Red Spring wheat at start of experiment (1 week prior to introduction of insects)*

Treatment	Mean bulk density ±SD (kg/hl)	Moisture content (%)[a]	Dockage (%)[a]
Untreated	79.14 ± 1.12[b]	14.3	0.87
500 mg/kg	74.21 ± 0.13	14.0	1.14
750 mg/kg	73.95 ± 0.31	13.8	0.98

[a] One measurement was taken.
[b] P>0.05; N=3

In spite of almost optimal environmental conditions for insect survival and development, insect densities were significantly lower in the treated test containers relative to the untreated controls for all Protect-It® layer treatments (Table 2). Layer treatments with Protect-It® reduced all species of insects numbers by >95% relative to their respective controls.

Table 2 *Mean number of live, adult insects extracted from mixed 1-kg Hard Red Spring wheat samples collected 59 days after introduction and grain moisture content*

Layer depth (cm)	Concentration (g/kg)	Mean moisture content±SD (%)	Mean number of live adults/kg ±SD		
			Sitophilus oryzae	*Rhyzopertha dominica*	*Tribolium castaneum*
50	0	15.2[a]	539 ± 152[b]	145 ± 20	189 ± 30
(treated	0.5	14.1 ± 0.1	18 ± 16	0.4 ± 1	0
layer)	0.75	13.8 ± 0.0	1 ± 1	0	1 ± 1
50–140	0 (<0)	15.4	38 ± 13	15 ± 5	7±3
(untreated	0 (<0.5)	15.4 ± 0.1	11 ± 4	0	1 ± 1
layer)	0 (<0.75)	15.5 ± 0.2	2 ± 3	0	4 ± 4
0–100	0 (<0)	14.9	329 ± 60	181 ± 39	110 ± 25
(treated	0 (<0.5)	14.1 ± 0.1	1 ± 2	3 ± 2	0
layer)	0 (<0.75)	14.0 ± 0.1	0	0	0.3 ± 1
100–140	0 (<0)	15.4	3 ± 1	27 ± 5	1 ± 1
(untreated	0 (<0.5)	15.4 ± 0.1	1 ± 1	0	1 ± 1
layer)	0 (<0.75)	15.4 ± 0.0	1 ± 2	0	1 ± 2

[a] Moisture content was only measured in one sample for each layer depth in control (untreated) containers.
[b] P>0.05 (N=3)

In the control (untreated) containers, all three species were predominantly found in the upper layers (0–50 and 0–100 cm, in depth) (Table 2). A few adults of *S. oryzae* and *T. castaneum* were able to disperse through 50 and 100 cm of wheat treated with 0.5 or 0.75 g/kg of Protect-It® (Table 2). It seems that *R. dominica* adults, after exposure to dust, are less capable to disperse in grain treated with diatomaceous earth than the other two species. This may explain why layer depth appears to have been a less important factor than concentration in controlling *R. dominica*. No live *R. dominica* adults were extracted from mixed samples collected from the upper layer of containers treated with 0.75 g/kg or from untreated grain collected from the lower layers of any of the treated containers (Table 2). These results suggest that a 50-cm surface-layer treatment of 0.5 g/kg of Protect-It® is sufficient to control *R. dominica* in wheat.

Both treatment layer depth and concentration are important factors in limiting the number of *S. oryzae* reaching the lower (untreated) layer. In the 50-cm-deep, 0.5 g/kg, 50-cm-deep, 0.75 g/kg, 100-cm-deep, 0.5 g/kg, and 100-cm-deep, 0.75 g/kg layer treatments, the respective mean number of live *S. oryzae* extracted from the lower (untreated) layer was 11, 2, 1, and 1 per kilogram (Table 2). Thus, either a 100-cm surface-layer treatment with 0.5 g/kg of Protect-It® or a 50-cm surface-layer treatment with 0.75 g/kg of Protect-It® would be adequate to control *S. oryzae* in wheat, but would not provide a 100% control.

The influence of treatment layer depth and concentration on *T. castaneum* density was not as clear. Unlike the other two species, more live *T. castaneum* adults were extracted from lower-layer samples than in the upper-layer samples in the treated containers (Table 2). There were significantly more live *T. castaneum* adults in the 50-cm-deep, 0.75 g/kg layer treatment than in the other 3 layer treatments. *T. castaneum* may be partially excluded from the treated layer due to the repellent properties of diatomaceous earth (6) and probably has very good dispersal capacity in the grain mass. This repellency may be greater at the higher concentration (0.75 g/kg), enhancing the dispersal of *T. castaneum* through the treated grain mass to the lower, untreated layers. However, our results suggest that a 100-cm surface-layer treatment with 0.5 g/kg of Protect-It®, would be sufficient to control *T. castaneum* in wheat but would not completely prevent the adults from invading the untreated layer.

Subramanyam and co-workers (7) tested the effectiveness of DE Insecto® in suppressing populations of six stored grain insect species during an 8.2-m test period in 12 metal barrels by using 109 kg of wheat per barrel. In the treatments tested, the top 27 kg of wheat, the top 54 kg of wheat, and the entire grain mass (109 kg) were treated with 0.5 g of Insecto® per kilogram of wheat. In all three treatments, the grain surface in each barrel was treated with a top dressing of 153, 102, and 20 g of Insecto® per square meter, respectively. The number of beetles captured by trapping during the test indicated that the three Insecto® treatments were equally effective in suppressing *Cryptolestes* spp. (99.5 to 100% suppression), followed by *Oryzaephilus surinamensis* (L.) (94.8 to 97.1%), *S. oryzae* (L.) (82.5 to 93.4%), *T. castaneum* (57.4 to 98.7%), and *R. dominica* (55.5 to 70.4%).

The results of a field test carried out in Manitoba in 1994 and 1995 indicated that a successful layer treatment (1 m, in depth) using Protect-It® against *C. ferrugineus* and *T. castaneum*, requires higher concentrations than those that achieved >90% mortality in the laboratory (0.1 and 0.3 g/kg, respectively) (Fields, personal communication).

Allen in 1998 (*personal communication*) carried out laboratory tests to compare two procedures for preventing insect invasion of the grain bulk. She concluded that the dry blown application of diatomaceous earth Dryacide® to the surface layer (100 g/m^2) did not prevent insect species from penetrating into the grain mass. Admixture of Dryacide® (2 g/kg) to the top 30 cm of the grain mass prevented reinfestation of the grain by *Sitophilus*, *Rhyzopertha*, and *Tribolium* species. The admixture layer (2 g/kg) used 500 g/m^2 to a depth of 30 cm. For *Cryptolestes* spp. and *Oryzaephilus* spp., 1-m and 1.5-m layer depths were required, respectively.

The effect of diatomaceous earth Protect-It® was studied at different concentrations on the bulk density of wheat, corn, barley, rye, and oats at three moisture contents (12%, 14%, and 15% moisture content, dry basis). The greatest changes in bulk densities occurred when the concentrations of Protect-It® ranged from 0.05 to 0.2 g/kg. At concentrations greater than 0.5 g/kg, bulk density decreased little with increased diatomaceous earth concentration (13).

In our study the reduction in bulk density of wheat (test weight) treated with 0.5 and 0.75 g/kg of Protect-It® was 4.9 and 5.2 kg/hl, respectively (Table 3). This demonstrates

Table 3 *Effect of dilution with untreated grain on the bulk density of Hard Red Spring wheat treated with diatomaceous earth Protect-It®*

Initial dose (g/kg)	Dilution ratio (treated: untreated)	Dose after dilution (g/kg)	Field-treated wheat[A] diluted		Laboratory-treated wheat[B] diluted		Laboratory-treated wheat[C] undiluted	
			Bulk density mean±SD (kg/hl)	Loss in bulk density (kg/hl)	Bulk density mean±SD (kg/hl)	Loss in bulk density (kg/hl)	Bulk density mean±SD (kg/hl)	Loss in bulk density (kg/hl)
0	0:1	0	79.7 ± 0.04[a]	–	79.7 ± 0.04[a]	–	79.7 ± 0.04[a]	–
0.5	1:19	25	78.5 ± 0.1[b] *	1.2	78.4 ± 0.1[b] **	1.3	78.2 ± 0.1[b] ***	1.5
0.75	1:19	37.5	78.1 ± 0.1[c] *	1.6	77.9 ± 0.2[c] **	1.8	77.4 ± 0.1[c] ***	2.3
0.5	1:9	50	77.6 ± 0.1[d] *	2.1	77.1 ± 0.4[d] **	2.6	77.0 ± 0.1[d] **	2.7
0.75	1:9	75	77.2 ± 0.4[e] *	2.5	76.3 ± 0.2[e] **	3.4	76.1 ± 0.2[e] **	3.6
0.5	1:4	100	76.2 ± 0.2[f] *	3.5	75.8 ± 0.1[f] **	3.9	75.2 ± 0.1[f] ***	4.5
0.75	1:4	150	75.3 ± 0.2[g] *	4.4	74.8 ± 0.2[g] **	4.9	74.5 ± 0.1[g] ***	5.2
0.5	1:0	500	72.9 ± 0.2[h] **	6.8	73.2 ± 0.1[h] *	6.5	73.2 ± 0.1[h] *	6.5
0.75	1:0	750	72.7 ± 0.1[h] **	7.1	73.3 ± 0.0[h] *	6.6	73.3 ± 0.0[h] *	6.6

[A] Treated wheat samples collected from the bins and diluted with untreated wheat from the reference tube
[B] Untreated wheat collected from the reference tube, treated in the laboratory with 0.5 and 0.75 g/kg of Protect-It®, then diluted with untreated wheat
[C] Untreated wheat collected from the reference tube and treated in the laboratory with 25, 37.5, 50, 75, 100, and 150 mg/kg of Protect-It®
Means within columns followed by the same letter were not significantly different. $P>0.05$ ($N\geq3$)
Means within rows followed by the same number of stars were not significantly different. $P>0.05$ ($N\geq3$)

one of the primary obstacles to the use of DE-based grain protectants for mass grain treatment. A loss of 5 kg/hl is likely to result in a reduction in the grade value of the grain.

Table 3 shows the effect of diluting treated wheat with untreated wheat. The mean bulk density of grain treated with 0.5 and 0.75 g/kg under field conditions was slightly, yet significantly lower than bulk density of wheat treated in the laboratory, probably due to loss of dust to air during mixing (Table 3). However, the dilution ratios of 1:4 and 1:9 (treated:untreated) using wheat treated with 0.5 g/kg of Protect-It® in the field produced significantly higher mean bulk density than when the grain was treated directly at the same final concentrations (0.1 and 0.05 g/kg, respectively) in the laboratory. Also, using wheat treated with 0.75 g/kg in the field, dilution ratios of 1:4, 1:9, and 1:19 produced significantly higher mean test weights than their respective direct treatments (150, 75, and 37.5 mg/kg). Based on these results, a 1:4 dilution of wheat treated at 0.5 g/kg, and a 1:9 dilution of wheat treated at 75 mg/kg should be sufficient to minimize the bulk density reduction of the total grain mass to a level comparable with a mass grain treatment with 75 mg/kg of Protect-It®. Therefore, when using layer treatment, no more than 10 or 20% of the total grain mass should be treated with 0.75 or 0.5 g/kg of Protect-It®, respectively.

In addition to using DE in combined treatments (diatomaceous earth and heat, cooling and grain surface treatment with DE, fumigation with phosphine, and grain surface treatment with DE) (13–15), there are at least 4 potential strategies of using DE to reduce the magnitude of these adverse effects using 0.1 g/kg or lower concentrations for grain mass treatment (concentrations effective only for DE-sensitive insects) (11), treating the surface layer of grain with insecticidal concentrations of DE to prevent infestation, by top dressing (i.e., application to the grain surface) (7, *Allen, personal communication*), and combinations of any of the above.

After the grain is initially transported upon storage, the overall concentration of DE in the entire grain mass will be greatly reduced because of dilution with untreated grain and some dust loss to the air. It is possible that the amount of diatomaceous earth remaining would continue to provide some insecticidal effect. Layer application and top dressing with effective concentrations of DE may be safe and useful alternatives to the use of man-made, more toxic and dangerous insecticides. This method offers a significant risk reduction to human health with no reduction in the effectiveness in grain protection. For all species of insects tested, layer treatment with Protect-It® reduced the number of insects by >95% relative to their respective controls. These results are acceptable from the regulatory point of view in many countries and insecticides with the efficacy of 90% or above are registered (for example in Canada efficacy of at least 90%, in the USA there is a tolerance for two weevils or three different species of stored insect number per kg of grain, etc.). The results of our layer treatment test show that the efficacy against all three tested insects were above 95%. It should be emphasized that the main purpose of using DE is not to achieve a 100% kill, but to protect grain from damage and to prevent the establishment and increase of insect population. Our experiments show that this can be achieved. It is our opinion that the layer application with effective concentrations of DE is a safe and useful alternative to the use of more toxic and dangerous insecticides. Diatomaceous earth can be used only for the protection (as a preventive measure) and not for disinfestation (as a curative measure). The advantages of using DE are: easy application, long life in grain storage, and fewer environmental concerns. The disadvantages are: undesirable effects on handling characteristics of grain, possibility of damage to equipment due to residue carryover to milling process, and possible adverse effects of dusts on workers. However, it is essential to conduct a field test using a similar design to confirm these laboratory findings.

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Sažetak

OBRADA POVRŠINSKOG SLOJA ZRNENE ROBE S POMOĆU DIJATOMEJSKE ZEMLJE RADI SUZBIJANJA KUKACA

Koncentracije dijatomejske zemlje potrebne za uspješno suzbijanje kukaca štetnih za uskladišteno žito imaju neželjen, negativan utjecaj na određena svojstva žita, primjerice na hektolitarsku masu i sipkavost, vrlo važne čimbenike koji određuju kakvoću žita. U namjeri da se negativni utjecaj dijatomejske zemlje na žitnu masu smanji, predlaže se obrada samo dijelova žitne mase (obrada slojeva) umjesto obrade cjelokupne mase žita. Pedesetcentimetarski i stocentimetarski površinski slojevi pšenice *Triticum aestivum* (L.) (Hard Red Spring) u metalnim posudama promjera 30 cm i visokim 150 cm, obrađeni s 0,5 i 0,75 grama Protect-It® po kilogramu pšenice nisu bili dostatni da potpuno spriječe prodor *Sitophilus oryzae* (L.) i *Tribolium castaneum* (Herbst) u neobrađeni sloj ispod obrađenog sloja pšenice. Međutim, u usporedbi s neobrađenom masom pšenice (kontrolnim ponavljanjima) populacija obiju vrsta bila je smanjena za više od 99%. Isto tako je u pšenici obrađenoj s Protect-It®, populacija *Rhyzopertha dominica* (Fabricius) bila smanjena za više od 98%, a istodobno je prodor kukaca u donji neobrađeni sloj pšenice bio potpuno spriječen. Zaključuje se da se obradom 100 cm dubine površinskog sloja pšenice s 0,5 g dijatomejske zemlje Protect-It® po kilogramu postiže zadovoljavajuća zaštita i sprječava infestacija robe sa *S. oryzae*, *T. castaneum* i *R. dominica.* Da bi se znatno umanjio negativni utjecaj dijatomejske zemlje na smanjenje hektolitarske mase, predlaže se obrada samo dijela zrnene mase, ne više od 20% od ukupne mase robe. Smatra se da se ovim postupkom uskladištena neinfestirana pšenica može na zadovoljavajući način zaštititi od štetnika skladišta i da ovaj postupak može uspješno zamijeniti obradu cjelokupne mase robe s dijatomejskom zemljom. S obzirom na gotovo zanemarivu toksičnost i opasnost dijatomejske zemlje za ljudsko zdravlje, uz djelotvornost na kukce koja je usporediva s djelotvornošću znatno otrovnijih i opasnijih sintetskih insekticida koji se rabe u skladištima, važno je naglasiti da je uporaba dijatomejske zemlje u zaštiti uskladištenih žitarica prihvatljiva kako za zaštitu ljudskog zdravlja tako i za očuvanje okoliša.

Ključne riječi:
fizikalna borba, hektolitarska masa, inertni prah, skladišni kukci

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