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Efficacy of a Chinese diatomaceous earth and purpose-built sprayer for control of stored grain insect pests in an empty warehouse

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Abstract

The aim of these trials was to test the efficacy of an 85 % diatomaceous earth (Puliangtai™) sprayed at a rate of 3g/m^2 with a specially developed powder spraying machine. Efficacy was tested by placing 14 empty test dishes spread at intervals on the floor of the warehouse before spraying. Each dish contained 20 live adults of *Oryzaephilis surnamensis* (Linnaeus) and *Sitophilus zeamais* (Motschulsky). After application of DE, mortality of insects was counted every 24 h until endpoint. Complete mortality of both test species was obtained in 4~6 days. The spray powder machine successfully distributed the Puliangtai™ evenly across the floor of the warehouse. We recommend this treatment for control of insects infesting empty warehouses and grain handling facilities.

Key words: diatomaceous earth, stored grain insect pests, spray powder machine, empty warehouse, *Oryzaephilis surnamensis* (Linnaeus); *Sitophilus zeamais* (Motschulsky).

Introduction

Application of residual insecticides such as malathion, fenitrothion, pirimiphos-methyl, deltamethrin has, for many years, been important component of pest management in empty grain storages and food processing facilities in China. These chemicals are applied to the structures of facilities to limit or prevent infestation. Despite the many advantages of chemical pesticides, such as good efficacy and relatively low vertebrate toxicity, there has been a move away from the use of synthetic insecticides because of growing concerns regarding the potential effects of residues on human health and the increasing numbers of stored-grain insects developing resistance.

A potential alternative to the use of chemical pesticides for both treatment of grain and empty storages is insecticidal diatomaceous earth (DE). IDE is composed of the fossilized skeletons of siliceous marine or freshwater organisms, predominantly diatoms. These skeletons are made of amorphous silicon dioxide, which is nontoxic to mammals and is registered as a food additive. Before DE can be used as an insecticide, deposits must be milled to separate individual diatoms. DE is a kind of inert dust. It is used to dilute insecticide dusts, as a carrier, and as an insecticide to control stored grain insect pests. Four thousand years ago, observations of such natural phenomena probably led the Chinese to use diatomaceous earth (diatomite) to control pests (Allen, 1972). Since the 1960s, extensive research has been undertaken on the possibilities of using DE for the protection of stored agricultural products. Today, several commercial insecticidal DE formulations are available on the

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market. DE has the potential to for wide application and can be used as an alternative to chemical insecticides. There are five methods of application: (1) DE may be applied to grain as it enters the auger or conveyer system during transfer of grain into storage facilities or transportation containers. In this case, DE should be mixed thoroughly with grain. (2) Layering or "sandwiches" involves applying DE at intervals to grain as it enters the auger or convey feeder system during transfer of grain into storage facilities or into transportation. (3) Applying DE only to the top 30-100 cm layer of grain. (4) Top dressing. (5) Structural treatment of empty storages, transportation containers and facilities (surface, crack and crevice treatment) (Ebeling, 1971; Aldhryhim, 1993; Korunic, 1994; Quarles, 1992; Quarles and Winn, 1996; Korunic and Ormesher, 1996; Liu, 2005; Bai, 2002; Banks and Fields, 1994; Korunic et al., 1996; McLaughlin, 1994; Subramanyan et al., 1994).

A new diatomaceous earth (Puliangtai™, PLT) was developed in China in 2002. It is as effective or better than some foreign products. However, machinery to apply DE on the large scale was not initially available in China. To solve this problem, we developed a powder spray machine especially for the purpose of applying IDE to empty storages. This approach has the twin advantages of facilitating use of an effective non-chemical treatment and mechanizing the operation.

The objective of this comprehensive trial was to determine the effectiveness of PLT for control of insect pests in an empty warehouse, and to determine usefulness of the new powder spaying machine for applying the IDE.

Materials and methods

IDE application machine

The tested powder spray unit was developed by Henan Weilai Mechanical and Electrical Engineering Co., Ltd. Its operating principle is similar to a Venturi pneumatic jet pump (Figure 1). Main technical parameters include: Max-velocity: 40 kg/h; Reserves: 8 kg; Pressure: 5000 Pa; Power: 1.5 kw; Weight : 130 kg.

Trial warehouse

The trials were conducted in a 2,500 tonne, brick commercial grain storage warehouse in Linli, China. The storage is about 60 m long, 18 m wide, and 10.5 m high and the floor is concrete. Before applying the DE, all doors and windows were sealed with plastic sheeting.

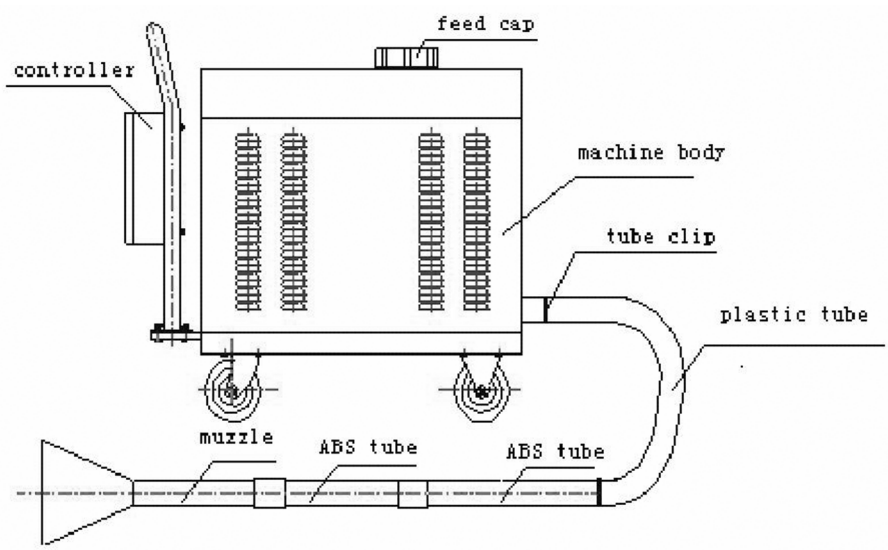

Figure 1. Spray powder machine structure.

Test insects

Test insects were laboratory cultures of *Oryzaephilis surnamensis* (Linnaeus) and *Sitophilus zeamais* (Motschulsky) maintained at the Insect Pest Control Laboratory of Henan University of Technology, Zhengzhou.

Method

Effectiveness of IDE against insects

14 glass dishes, 70 mm diameter and internally coated with Teflon®, were placed evenly across the floor as described in Figure 2. 20 live adults of *O. surnamensis* and *S. zeamais* were then put into each dish. The locations of plates were flagged to prevent workers treading on them.

Application of PLT was measured by observing the amount collected in each of the experimental plates 24 h after application. Its effectiveness was tested by observing the insects confined to the dishes.

Operation of sprayer

To begin operation, the pipes of the machine are joined together and the tube clip is connected to the tank and the plastic tube. The acrylonitrile butadiene styrene (ABS) pipe is then connected to the plastic hoop-tube at one end and the muzzle at the other. Extensions can be added to the ABS pipe to reach high places. Prior to loading the PLT, it is absolutely essential to ensure that the PLT has no impurities or agglomeration. The PLT is loaded into the container through a funnel. All doors and windows of the grain bin should be closed before the spray operation.

Dosage of PLT can be controlled by adjusting spray velocity. It is important for the applicator to wear respiratory protection or an approved nose mask and goggles during this treatment to prevent inhalation of the air-borne amorphous particles. If the width of the area to be treated is less than 18 m, then the PLT need only be applied to the walls as enough dust will fall on the floor during the process. However, if the width of the storage is greater than 18 m, then PLT should also be sprayer into the middle of the storage.

Calculating the dosage

Total dosage = application rate x the area of the total surface x excess coefficient.

Total area of the surface to be treated is calculated (i.e., floors, walls, ceilings) and multiplied by an excess coefficient of between 1.05 and 1.25. If the site is large and well sealed, then the lesser value is chosen, otherwise the upper value is appropriate.

The application rate is 3 g/ m^2. In this trial, dosage was calculated as: 3 g/m^2 x 2740 m^2 x 1.25 = 10275 g

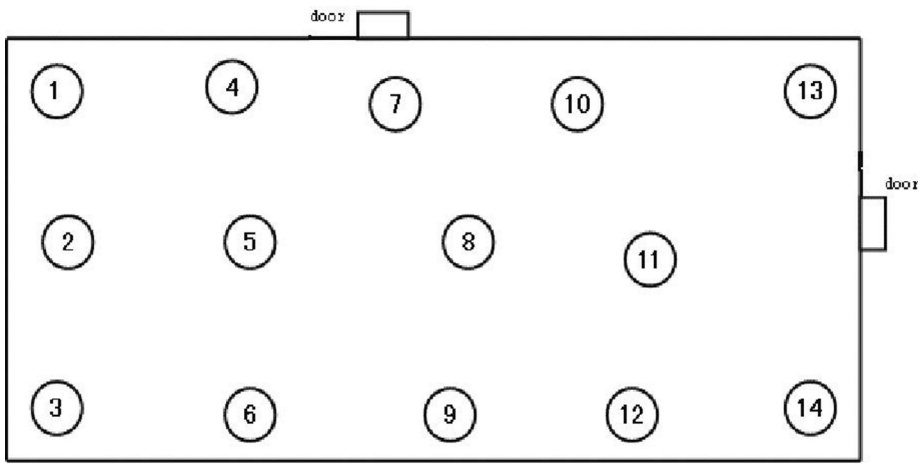

Figure 2. The map of dishes distribution.

Results

Effectiveness of spray application and insect control

The PLT was distributed well using the powder sprayer and did not agglomerate. All areas of the bin were evenly coated with a thin lay of PLT powder sufficient to be lethal to insects. This treatment acts as a barrier reducing insect infestation rates, and preventing insect colonization from outside of the storage.

Mortality of test insects was complete in all dishes except for no. 6 and no. 8 (Figure 3). However, after five days there were only 2 and 3% survival of insects in these dishes, respectively. This result indicates that the powder sprayer is also useful for applying PLT to control insects living in empty warehouses.

Efficacy of PLT against two species of insect pest

Mortality of both insect test species increased with time (Figure 4). The slope of the mortality curves for both species are similar showing a shallow response to the toxicant. However, the Y-intercepts at time 0 were positive for *O. surnamensis* and negative for *S. zeamais*. After 1 d exposure the mortality rates were 30 % for *O. surnamensis* and 0% for *S. zeamais*. Complete mortalities were achieved for *O. surnamensis* and *S. zeamais* at days 4 and 6, respectively demonstrating that *O. surnamensis* is more susceptible to PLT than *S. zeamais*. Numerous factors influence activity of PLT such as physical properties, insect morphology and physiology and so on. The mode of action of PLT is poorly understood and research is needed address this problem.

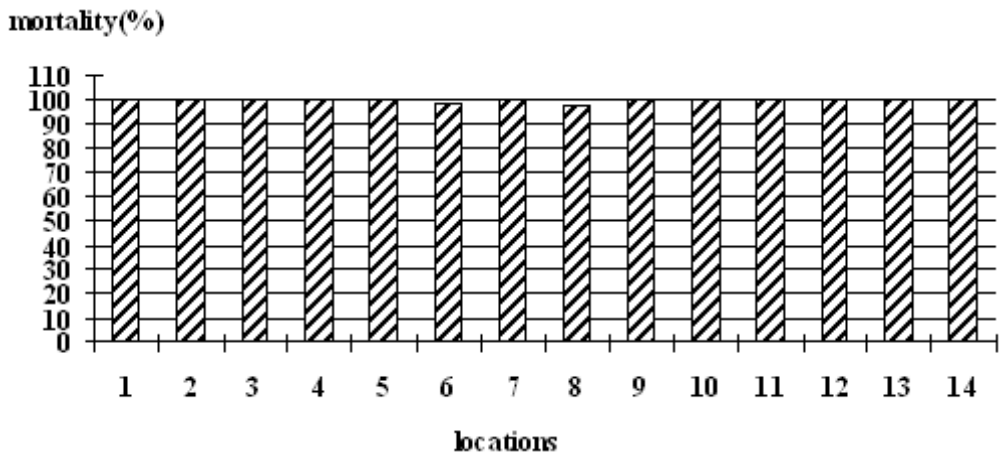

Figure 3. mortality of two species insects in 14 locations.

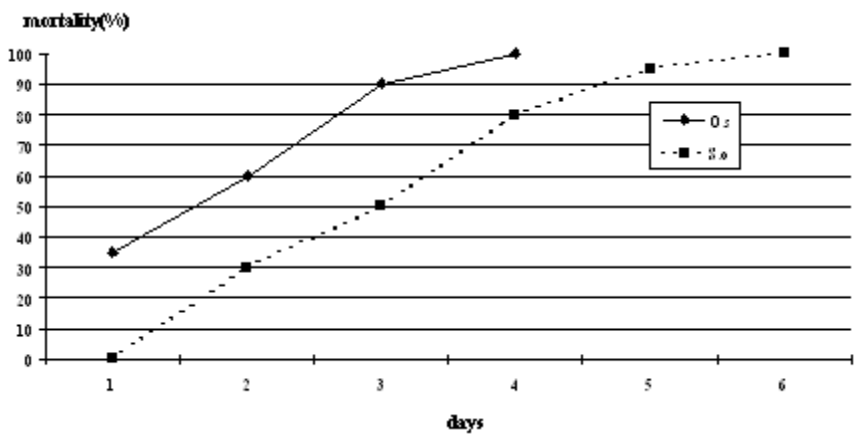

Figure 4. Mean mortality of *O. surnamensis* and *S. zeamais* exposure to dishes coating Puliangtai by sprayed machine.

Discussion

PLT has very low mammalian toxicity. It is stable on the grain, and provides protection as long as the dust remains dry. Grain treated with PLT can be cleaned prior to milling to remove most of the dust particles. This will not affect milling, baking, and malting properties of treated grains. IDE is predominantly made up of amorphous silica, which has not been implicated as an animal or human carcinogen. It can be applied to empty facilities as well as to grain as a dry powder. We have demonstrated that it has the potential to be used as an alternative to synthetic chemical pesticides. Further research will be needed to optimize use of PLT in integrated pest management programs for grain storages.

In USA, where the application rate is 5 g/m^2, it has been suggested that DE could be applied through aeration systems. Treatment of surfaces of storage facilities with DE slurry, applied at the rate of 6-8 g/m^2, is a well established practice in Australia (Desmarchelier et al., 1992). Specially adapted pumps, such as a Hydra-Cell slurry pump (Anonymous, 1994; Bridgeman, 1991), have been developed. However, these methods are not appropriate for use in the Chinese grain storage system as our label rate is only 3 g/m^2. Nevertheless, we have found this rate to be insecticidal if applied as dry powder. The powder sprayer used in this trial was highly effective and should receive broad application in grain storage systems in China.

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