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Integrated pest management strategies used in stored grain in Brazil to manage pesticide resistance

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Abstract

Managing pests of stored grain has become an increasingly serious problem in Brazil. This is because grain production has more than doubled in the last 10 years and insect pests have become resistant to protectant insecticides. In the same period, use of phosphine fumigation has increased rapidly and is now widely practised. However, control failures with phosphine have become common as fumigations are undertaken in unsealed silos and in situations where sanitation is poor. As a consequence, many parcels of grain are repeatedly fumigated. In response to this situation, Embrapa initiated a programme to introduce IPM into the central grain storage facilities. The program’s strategy included the following elements: (a) changing behaviour through training of the storage facilities personnel; (b) improving knowledge of stored grain unit; (c) cleanliness of the equipment and premises and, after that, spray residual insecticide; (d) identification of grain-stored pests; (e) resistance tests; (f) insecticide treatment and fumigation; (g) sampling and monitoring the grain. The IPM programme was introduced into two storage facilities in Paraná State. Following successful implementation of IPM, these facilities were able to supply insect-free grain and had $10 per ton in bonus from the market. The success of these companies led to the adoption of IPM by other storage companies. IPM systems are now running in 13 separate facilities owned by nine different companies. To support the programme, Embrapa Wheat has trained 651 stored grain operators and released an IPM manual and website http://www.cnpt.embrapa.br/pesquisa/entomologia/mip.

Key words: Stored Grain, IPM strategies, control pests, pesticide resistance.

Introduction

Grain crops such as wheat, barley, corn, soybeans and black beans are grown mainly from southern to central Brazil and they are one of the most economic alternatives for farmers to improve their quality of life. The harvest occurs, normally, twice a year for the summer and winter crops when each single farmer delivers the grain to a cooperative system or a private company. The grain is loaded into silos with capacities varying from one to 120 thousand tonnes. This system is responsible for storing and preserving the grain during the years, releasing it from time to time to the food industry, exports and consumers.

Before loading into silos the grain is cleaned and dried to storage standards. In this procedure most, but not all, of the pests that come with the grain are eliminated so the grain needs to be treated with protectant insecticides or fumigants.

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to prevent stored grain pests damage (Lorini et al., 2002).

If not adequately controlled, the pests cause damage in these commodities and losses have been estimated to be about 10% of total grain stored in Brazil each year. Among the reasons for these losses are the facilities not fitted to reduce pest infestation, lack of knowledge of the store personnel about the pests and their potential damage, low availability of insecticides to control stored grain pests and pesticide resistance of some species.

There are two common types of insecticide treatments on grain. The first one is to spray protectant insecticides directly onto grain when loading the silo. Deltamethrin, bifenthrin, pirimiphos-methyl and fenitrothion are the insecticides registered at Brazilian Authorities as grain protectants to be used, providing residual treatment for at least six months. The second one is fumigation with phosphine as soon as the pest is seen in the grain and repeated along the year as re-infestation occurs.

Where failure to control pests during the storage period occurs, samples of these pests were collected for further investigations of the reasons of failure. Following that procedure, strains of different species from many places were collected and cultured in the Laboratory of Entomology of Embrapa (National Wheat Research Centre) for further investigations from the last 14 years.

The earliest resistant strains detected in Brazil were during the FAO global survey of pesticide susceptibility of stored grain pests that shows malathion resistance on Rhyzopertha dominica (F.), Tribolium castaneum (Herbst), Tribolium confusum (du Val) and Oryzaephilus surinamensis (L.) (Champ and Dyte, 1976). Updating later research in the country regarding control of stored grain pests is seen that resistance to phosphine, malathion, pirimiphos-methyl, fenitrothion, as evaluated by the Food and Agricultural Organization (FAO) discriminating dose methods (Anonymous, 1975), has been reported in some strains of Sitophilus oryzae (L.), R. dominica, T. castaneum and Cryptolestes sp. (Sartori et al., 1990; Pacheco et al., 1990; Sartori, 1993; Pacheco et al., 1994; Sartori et al., 1996). Resistance to chlorpyrifos-methyl was detected by Guedes (Guedes et al., 1996; Guedes et al., 1997) who also reported resistance to malathion and pirimiphos-methyl.

Resistance of R. dominica to deltamethrin, the most important protectant used in the grain was detected (Lorini and Galley, 1996; 1999) and also Sitophilus zeamais (Motsch.) was resistant to deltamethrin (Guedes et al., 1993; 1994; 1995). O. surinamensis which is becoming a serious pest in stored grain was recently recorded as resistant to deltamethrin, bifenthrin, pirimiphos-methyl and fenitrothion (Beckel et al., 2002).

### The IPM Strategies Used in Stored Grain in Brazil

The Integrated Pest Management (IPM) of Stored Grain should be carried out as much as is feasible to preserve the grain commodities. The main aim of IPM in Stored Grain is to prevent the grain from the damage caused by the pests that normally infest the store silos with the best strategies to avoid the pest resistance to pesticide.

As the main problem in controlling pests in stored grain is the resistance to pesticides, strategies should be taken to avoid it or at least postpone resistance. Following that an IPM Stored Grain Program was started in 1999 by Embrapa Wheat, having the basic rules published at Lorini (2000) as described below:

- **a) Changing the behaviour of the storage personnel:** this is the most important phase and the beginning of the IPM, where everyone involved with the stored grain unit must be trained and introduced in IPM. This involves the grain operators as well as the head manager of the company. At this moment the aim is to show the damage caused by the pests to the grain and the image of the company in selling or exporting grain with pests.

- **b) Knowledge of stored grain unit:** the inspection of the stored unit should be done in all aspects, such as the reception, silos, elevators,
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internal lorries, cleaning machines, grain expedition etc in order to establish the control and cleaning strategies of pests.

c) Cleanliness of the equipment and premises: the importance of the cleanliness of the equipment and premises used for storing, cleaning and moving the grain as well as that of the vehicles used for transportation, has been known for a long time. However, in Brazil the awareness of the extreme importance of this factor is only starting. The use of simple equipment like vacuum cleaners, brooms and brushes could give an excellent result of residual pest elimination and prevent insect damage in grain. After that the use of a residual insecticide sprayed in the empty bins will prevent the pest infestation.

d) Pest identification: the correct identification of grain store pest will help in the efficacy of the best choice of the insecticide used. Each insecticide doesn’t control all the species and the right choice of the insecticide will result in an efficiency of the control treatment. As an example, the pyrethroids have the best performance in controlling R. dominica species, but not S. oryzae and S. zeamais. Otherwise to control the last two species an organophosphate insecticide is needed despite the fact that it will not control R. dominica.

e) Knowledge of pest resistance to chemicals pesticides: for an example the most important pest in stored wheat in Brazil R. dominica has been resistant to the protectant insecticide deltamethrin which has been ineffective in several parts of the country even when used at high dosages (Lorini, 1992; Lorini and Galley, 1998; 1999; 2000 a; b). Already resistance has been reported in R. dominica to deltamethrin (Lorini and Galley, 1999), to malathion and pirimiphos methyl (Sartori et al., 1990; Pacheco et al., 1990; Sartori 1993; Guedes et al., 1996; 1997), to fenitrothion, phosphine and to chlorpyrifos-methyl. Despite that, deltamethrin is the most important pyrethroid insecticide in use in Brazil as a grain protectant so an efficient integrated pest management is required to preserve the quality of food.

f) Potential pest damage: each species of stored grain has different potential of causing damage in grain silos. That depends on some factors but the knowledge of a particular pest is very important in determining the potential losses in grain stored over a specific period of storage. That must be understood in order to avoid problems of pests at the moment when the grain is sold.

g) Insecticide protection: after dried and cleaned the grain is stored and can be protected with insecticides that prevent later infestations. The perfect mixture of the insecticide sprayed on grain during the loading process in the silos is very important. Those remain about four to six months protecting the grain from the pests. They are like an insurance in the grain bulk.

h) Fumigation: this is used when grain is infested by pests and need to be fumigate with phosphine exposure for at least five days. The silos should be perfectly sealed in order to avoid gas leaking and failure of fumigation. This treatment kills all the species of the pests as well as eggs, larvae, pupae and adults of each stored grain pest.

i) Monitoring the grain: storing grain means a continuous process of sampling and monitoring the grain and the pest that can infest the storage facilities. A sampling procedure should be taken weekly in a stored grain unit, whatever the type of pest trap used to detect the first individual pest coming into the storage facilities to start a new colonisation. Also, the temperature and grain moisture should be monitored in order to help taking decisions about pest control strategies. It is known that a reduction in temperature and humidity affects the development rate of insects by reducing the generations selected and the number of insects in each generation. Temperature also affects the speed of degradation of pesticides during storage time. In addition, some pesticides are more efficient at lower temperature (pyrethroids), while others are more efficient at higher temperature (organophosphates). Lower moisture contents are beneficial for both groups of pesticides. In spite of the fact that most storage
units in Brazil do have aeration systems, in most cases they are used in a curative rather than in a preventive way. A better use of aeration or cooling lowers the temperature enough to prevent the multiplication of insects, as well as using this in conjunction with chemical treatments.

**Practical application**

Following the rules above, in 1999, Embrapa (National Wheat Research Centre) associated with Cooperativa Integrada (farmers cooperative) with main office located in Londrina, PR, implemented in two stored grain units the IPM Stored Grain Program. The first storage unit was in Cornélio Procópio and the second one in Assaí, both in Paraná state.

The people involved in the stored grain unit attended training courses about IPM Stored Grain at Embrapa regarding the rules and procedures to be undertaken at their facilities. The storage facilities were washed, cleaned and sprayed with insecticides to avoid pests, including the interior of the silos. Wheat grain harvested from the farmers was dried and cleaned properly as Brazilian’s standard and 5,000 tons were stored at one silo for ten months. The wheat was treated with the protectant insecticides bifenthrin plus pirimiphos-methyl to prevent pests and the grain was monitored in the storage unit weekly measuring the temperature and humidity of the grain, and the presence of any insect infesting using insect traps all over the premises.

At both storage units in the two years of Stored Grain IPM implementation the wheat remained without any insect damage and no losses were registered in wheat commercialisation to the milling industry. Consequently, the flour and other wheat products were exempt of any insect fragments and better food quality for the consumers was achieved.

Following successful implementation of IPM, these facilities were able to supply insect-free grain and had $ 10 per tonne in bonus from the market.

Selling the wheat without any pest meant better quality for the storage company, better price for the wheat grain in the market, better confidence in the company and of course money saved.

The success of that led other storage companies to adopt the IPM Stored Grain Program in the country and now it is running in 13 stored units from nine companies in different grain production areas in the country (Figure 1). These IPM Stored Grain units are located at: Paraná State - Cooperative Integrada (Londrina, Maringa, Assai, Cornélio Procópio and Ubiratã), Cooperative Cocari (Kaloré), Cooperative Coopervale (Palotina), Cotriguaçu (Palotina), Cooperative Coopavel (Cascavel); Mato Grosso do Sul State - Cooperative Copasul (Naviraí); Goiás State - Caramuru (Rio Verde), Rio Grande do Sul State - Cooperative Cotrijal (Não-Me-Toque) and Cooperative Cotripal (Panambi).

**IPM Stored Grain Support**

From the beginning of Stored Grain IPM Embrapa Wheat (National Wheat Research Centre) started training the personnel involved in stored grain facilities in order to introduce the idea and basic rules of IPM. During the last six years, 805 stored grain operators and managers were trained at Embrapa Wheat in 26 courses of 16 hours each dealing with the IPM procedures. Some publications such as The Manual of Stored Grain Integrated Pest Management was published as a guidebook to storage personnel (Lorini, 1999, 2003). Also two booklet editions about the key pests in stored grain were published to provide information to the operators and managers.

An Internet site http://www.cnpt.embrapa.br/pesquisa/entomologia/mip was released making easier access for everyone to check the new results about controlling the stored grain pests.
References


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Figure 1. Places in Brazil where the Integrated Pest Management of Stored Grain Program was implemented from 1999 to 2006. Each name means one store unit, except Coop. Integrada that has five stored units.


