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INTEGRATED PEST MANAGEMENT STRATEGIES USED IN STORED GRAIN IN BRAZIL TO MANAGE PHOSPHINE RESISTANCE

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ABSTRACT

Managing pests of stored grain has become an increasingly serious problem in Brazil. This is because grain productionhas 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. Our 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 received $10 per tonne 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 companies. To support the programme, Embrapa Wheat has trained 651 stored grain operators and released an IPM manual and website www.cnpt.embrapa.br/armazena .

INTRODUCTION

Grain crops such as wheat, barley, corn, soybeans and beans are grown mainly from southern to central Brazil and they are one of the most economic alternatives to farmers to improve their quality of life. The harvest takes place 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 year, 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 fumigated to prevent stored grain pests damage (Lorini et al. 2002).

If not 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 (Brasil 1993). Among the reasons for these losses are that the buildings are not fitted to reduce pest infestation;lack of knowledge among 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 insecticidal 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 by the Brazilian Authorities as grain protectants to be used, providing the duration of residual treatment is at least six months. The second one is fumigation with phosphine as soon as the pest is seen in the grain and this is repeated during the year as re-infestation occurs

Where failure to control pests during the storage period has occurred, samples of these pests were collected for further investigations into the reasons of failure. Following this 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 over 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 showed malathion resistance by *Rhyzopertha dominica* (F.), *Tribolium castaneum* (Herbst), *Tribolium confusum* (du Val) and *Oryzaephilus surinamensis* (L.) *(*Champ and Dyte, 1976). Later research in the country with regard to control of stored grain pests, showed that resistance to phosphine, malathion, pirimiphos-methyl, fenitrothion, as evaluated by the Food and Agricultural Organization (FAO) discriminating dose methods (Anonymous, 1975), was recorded 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 chrorpyrifos-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, which is the most important protectant used in the grain in Brazil was detected by Lorini and Galley, (1996; 1999) and also *Sitophilus zeamais* (Motsch.) was found to be resistant to deltamethrin (Guedes *et al.*, 1993; 1994; 1995).

Oryzaephilus surinamensis which is becoming a serious pest in stored grain was recently recorded as being 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 storage silos with the best strategies to avoid the development of pest resistance to the pesticides.

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. In accordance with this aim, an IPM "Stored Grain Program" was started in 1999 by Embrapa Wheat, for which the basic rules were published in Lorini (2000) as described below:

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 introduced to, and trained in IPM. This involves the grain operators as well as the head manager of the company. At this stage the aim is to show the damage caused by the pests to the grain and its influence on the image of the company in selling or exporting grain with pests.

Knowledge of the stored grain unit: the inspection of the storage unit should include all its aspects, such as the reception point, silos, elevators, grain-moving equipment and vehicles, cleaning machines, grain expedition etc in order to enable the establishment of cleaning and control strategies against the pests.

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.

Pest identification: the correct identification of grain storage pests will help in the efficacy of the best choice of the insecticide to be 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 perform extremely well in the control of *R. dominica*, but not in the control of *S. oryzae* and *S. zeamais*. Conversely, to control the last two species an organophosphate insecticide is needed despite the fact that it does not give good control against *R. dominica*.

Knowledge of pest resistance to chemicals pesticides: for an example the most important pest in stored wheat in Brazil *R. dominica* has become resistant to the protectant insecticide deltamethrin which was found to be 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 these findings, deltamethrin is the most important pyrethroid insecticide in use in Brazil as a grain protectant and this only emphasises that an efficient integrated pest management program is required to preserve the quality of food.

Potential pest damage: each species of stored grain pest has a different potential for causing damage in grain silos. This depends on several 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. This must be understood in order to avoid problems of pests at the moment when the grain is sold.

Insecticide protection: after having been 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 into the silos is very important. These remain for about four to six months thereby protecting the grain from the pests. They can be regarded as an "insurance" in the grain bulk.

Fumigation: this is used when grain is infested by pests and needs to be fumigated with phosphine. Exposure should be for at least five days. The silos should be perfectly sealed in order to avoid gas leakage and failure of fumigation. This treatment kills all the species of the pests in all their stages, namely - eggs, larvae, pupae and adults.

Monitoring the grain: storing grain requires a continuous process of sampling and monitoring the grain and the pests 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 it should detect the first individual pests coming into the storage facilities to start a new colonisation. Also, the temperature and grain humidity 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 number of generations per year 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 temperatures (pyrethroids), while others are more efficient at higher temperatures (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 above rules, in 1999, Embrapa (National Wheat Research Centre) associated with Cooperativa Integrada (farmers cooperative) located in Londrina, PR, implemented the IPM Stored Grain Program in two stored grain units. 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 units 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 according to 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 infesting insects using insect traps all over the premises.

At both storage units over 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 received $10 per tonne in bonus from the market. Selling the wheat without any pests meant better quality for the storage company, better prices for the wheat grain in the market, better confidence in the company and of course money saved. The success of this enterprise led other storage companies to adopt the IPM Stored Grain Program in the country and now it is running in 13 storage units from nine companies in different grain production areas in the country (Figure 1). These IPM Stored Grain units are located at: Cooperative Integrada (Londrina, Maringa, Assai, Cornélio Procópio and Ubiratã), Cooperative Cocari (Kaloré), Cooperative Coopervale (Palotina), Cotriguaçu (Palotina), Cooperative Coopavel (Cascavel), Cooperative Copasul (Naviraí), Caramuru (Rio Verde), Cooperative Cotrijal (Não-Me-Toque), Cooperative Cotripal (Panambi).

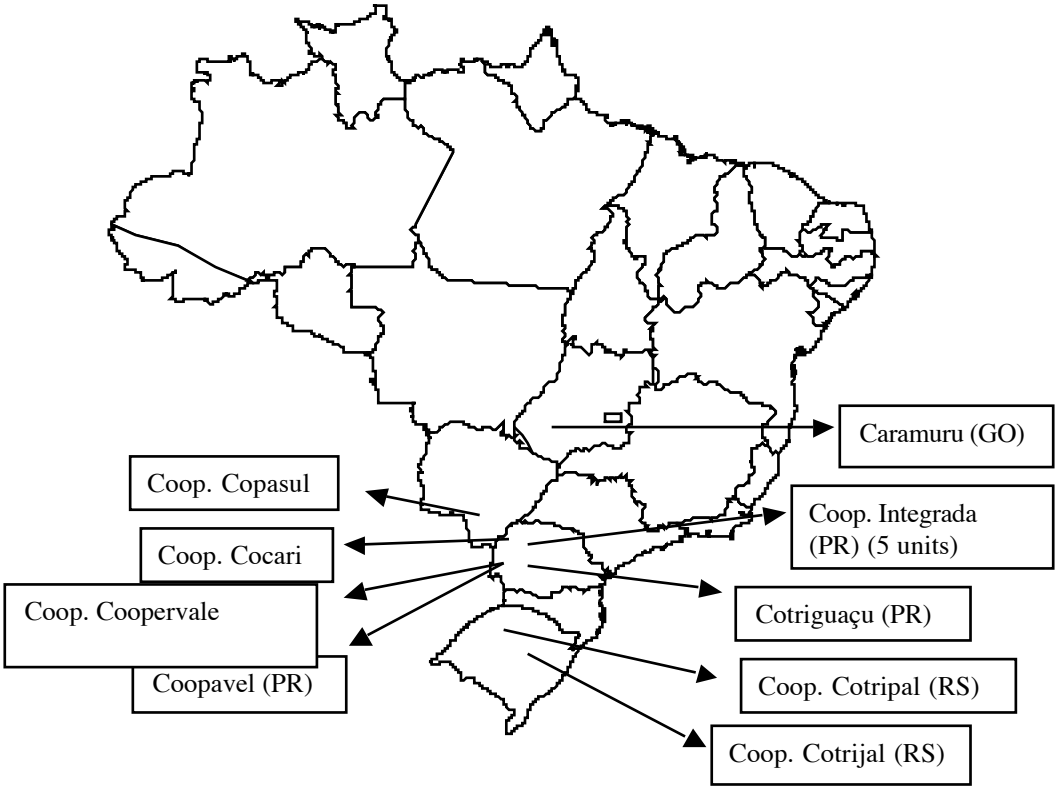

Fig. 1. Places in Brazil where the Integrated Pest Management of Stored Grain Program was implemented from 1999 to 2004. Each name means one store unit, except Coop. Integrada that has five stored units

IPM STORED GRAIN SUPPORT

From the beginning of the "Stored Grain IPM", Embrapa (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, 651 stored grain operators and managers were trained at Embrapa in 21 courses of 16 hours each dealing with the IPM procedures. Some publications such as "The Manual of Stored Grain Integrated Pest Management" were published as guidebooks to storage personnel (Lorini, 1999, 2003). Also two booklet editions about the key pests in stored grain were written to provide information to the operators and managers.

An Internet site http://www.cnpt.embrapa.br/armazena was released making easier access for every one to check the new results about controlling the pests.

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