THE CHEMICAL CONTROL OF PESTS OF STORED AGRICULTURAL PRODUCE

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Summary

Throughout the history of agriculture, stored produce pests have inhabited man's granaries. The result has been their world-wide distribution. In New Zealand, many, if not all, have been recorded from time to time and numbers have become established, but the cool, temperate, insular climate has prevented most of them from rising to plague numbers. In recent times, however, the introduction of farm grain-storage silos has seen an increase in mite infestations and that of certain Coleoptera. Control of these pests has been largely confined to sound hygiene and fumigation.

INTRODUCTION

EVER SINCE the storage of agricultural produce began, man has been plagued with insect pests which between harvest and consumption devour as much as 25 to 30% of the crops he grows. These pests of stored products are now ubiquitous, having been transferred from country to country in the course of commerce. New Zealand is no exception, and now many cosmopolitan species of insects and mites infest our produce stores and bulk grain silos. Tetley (1950-51), Morrison (1956), and French (1965) have described various aspects of the problem, but the introduction in recent times of large numbers of grain-storage silos on farms, where much of the grain crops are now stored, has introduced a new facet. Fortunately, many of the pests are warm-climate insects, and as New Zealand is for the most part in the cool, temperate zone, its climate is not ideal for their development. Here their development is slowed down when compared with that in warmer climates, and this reduces the number of generations per year. Thus, the problem has not been as great as in some other countries.

CHECK LIST OF SPECIES PRESENT IN NEW ZEALAND

The following is a list of many of the pests of stored products known to occur in New Zealand (there may be others not listed here):

<i>Anagasta kuehniella</i>	Mediterranean flour moth
<i>Acarus siro</i>	meal mite
<i>Acanthoscelides obtectus</i>	bean weevil
<i>Ahasverus advena</i>	foreign grain weevil
<i>Blatella germanica</i>	German cockroach
<i>Cadra cautella</i>	dried-fruit moth
<i>Carpophilus dimidiatus</i>	
<i>Cryptolestes ferrugineus</i>	rust-red grain beetle
<i>Dermestes maculatus</i>	hide beetle
<i>Dermestes lardarius</i>	larder beetle
<i>Ephestia elutella</i>	tobacco moth

<i>Glycyphagus</i> spp.	grain mite
<i>Gnoringoschema operculella</i>	potato tuber moth
<i>Lasioderma serricorne</i>	tobacco beetle
<i>Liposcelis</i> spp.	psocids
<i>Lepinotus</i> spp.	psocids
<i>Mezium affine</i>	spider beetle
<i>Necrobia rufipes</i>	red-legged ham beetle
<i>Oryzaephilus surinamensis</i>	saw-toothed grain beetle
<i>Periplaneta americana</i>	American cockroach
<i>Plodia interpunctella</i>	Indian meal moth
<i>Ptinus clavipes</i>	spider beetle
<i>Ptinus tectus</i>	spider beetle
<i>Rhizopertha dominica</i>	lesser grain beetle
<i>Stegobium paniceum</i>	drug-store beetle
<i>Sitophilus granarius</i>	grain weevil
<i>Sitophilus oryzae</i>	rice weevil
<i>Sitotroga cerealella</i>	Angoumois maize moth
<i>Tenebrio molitor</i>	yellow mealworm
<i>Tribolium confusum</i>	confused flour moth
<i>Tribolium castaneum</i>	flour moth
<i>Tenebroides mauritanicus</i>	cadelle
<i>Trigonogenius globulus</i>	spider beetle
<i>Tyrophagus putrescentiae</i>	Tyroglyphid mite

PLACES OF INFESTATION

Apart from the spoilage of agricultural produce in store for home consumption, pest-free agricultural produce is important to New Zealand internationally; for example, small seeds for export must be pest-free before export to obtain an international health certificate required by most importing countries. Again, mites taint grain, which makes it useless for fowl feed, though in some cases it might be suitable to feed to pigs. A survey carried out by French (1965) showed that a proportion of farm bulk wheat silos had mite infestations in the wheat. The survey also showed that mites were more prevalent than insect infestation in bulk grain, and that the two most common insect pests were weevils and beetles.

Differing groups of storage pests infest the various storehouses of agricultural produce, the main damage being caused by the larval stages of various species of moths and beetles as follows:

Flour mills: a suitable environment for such pests as meal mite, grain mites, Mediterranean flour moth, dried-fruit moth, tobacco moth, Indian meal moth, lesser grain beetle, grain and rice weevils, yellow mealworm, cadelle, and saw-toothed grain beetle. Regular fumigations are carried out for their **control**.

Maize stores and silos: grain mites, Angoumois maize moth, Mediterranean flour moth, Indian meal moth, and grain and rice weevils.

Potatoes in store: attacked by potato tuber moth.

Tobacco stores: tobacco beetle, drug-store beetle, tobacco moth, and mites. **Hide stores:** spider beetles, larder beetles, hide beetle, and mites.

Seed stores: saw-toothed grain beetle, rust-red grain beetle, spider beetles, psocids, flour and meal moths, bean weevil, and mites.

Bulk grain stores (including farm silos): saw-toothed grain beetle, rust-red grain beetle, grain and rice weevils, and mites.

CONTROL MEASURES

PREVENTIVE

Fresh produce should not be mixed with that already in store. Second-hand bags and containers should never be used unless fumigated beforehand. Floors and walls of storerooms should be swept clean, preferably vacuumed with a commercial vacuum cleaner, particular attention being paid to cracks in the floors and walls, and foundations under floors should be cleared of all stored produce debris that may have fallen through cracks in the floorboards. Floors and walls may be sprayed with premium-grade malathion or dichlorvos before the goods are received into store. Grain and seeds should have a moisture content of 15% or less (preferably about 12%) on receipt into store, and in certain areas this will entail the use of driers. Grain or seed from a drier, however, must be cooled before it is stored in bulk (it may take warm bulk grain as long as 3 months to cool down); and grain in storage must be inspected regularly for condition, that is, "hot" spots and insect and mite infestation (Griffith, 1964).

CHEMICAL CONTROL

Chemical control is mostly confined to fumigation, because this is the only form of control which meets the requirements of the New Zealand Food and Drugs Regulations 1946 under the Food and Drugs Act 1969, relating to the treatment of stored foodstuffs offered for sale for human consumption.

Chemicals which can be used to control insects in stored produce include the following:

Fumigants

Methyl bromide: This is a gas at ordinary temperatures and pressures and is stored as a liquid in heavy cylinders under pressure. Its chief advantage is its ability to penetrate quickly and deeply in materials at normal atmospheric pressure, and at the end of the treatment its vapours dissipate rapidly and make possible the handling of bulk quantities.

It is non-inflammable and goods may be treated at temperatures down to 39° F (4° C). In insects its principal toxic effect is on the nervous system.

Precautions in its use are essential because it is a cumulative poison. The Fumigation Regulations 1967 specify that it can only be applied under the supervision of an operator who holds a certificate of competence from a Medical Officer of Health.*

Carbon bisulphide: This is still the only fumigant used in certain parts of the world, but in many places it has been largely replaced by methyl bromide, as in New Zealand, with some exceptions—e.g., fumigation of potatoes in sheds. It is, however, a dangerous fire hazard and, because of its inflammability, naked lights must be kept well away during its use. It penetrates well, and in other countries is often formulated in mixtures with non-inflammable ingredients for fumigating grain. It has a low boiling point and is toxic to man. Precautions in its use include storing cans or drums of liquid in cool, shaded, well-ventilated rooms, never under the direct sun. Contact of vapour with a steam pipe or an electric light bulb may be enough to ignite it. Even heat generated by its being struck by a heavy blow may set off an explosion. The spark from static electricity or from an electric motor is a cause of ignition. Therefore, great care must be used during fumigation (Table 1).

*For a schedule of respirators approved for use consult the local Medical Officer of Health.

TABLE 1: DOSAGES AND RATES OF APPLICATION OF INSECTICIDES FOR THE CONTROL OF STORAGE PESTS

Commodity	Type of Storage	Treatment	Rate of Application	Remarks
Grain	Silos and bins	chloropicrin	1 kg bottle (2.2 lb) per 10,000 kg (10 ton)	Apply immediately after filling the silo following harvest, or when infestation is found later. For method of application see text.
Grain and small seeds	In sacks	methyl bromide	1 lb (262 ml) per 1,000 cu.ft (28.3 m ³) for 24 hr	Tent fumigation under plastic sheets by approved pest control operators only. Affects germination of some small seeds. Vacuum fumigation in approved vacuum fumigation plants at dosages, temperature, and time as specified for various commodities.
Grain (and maize)	Silos, bins and maize cribs	dichlorvos	3 oz (99 ml) in 5 gal (25 l) water for grain and in 2 gal (10 l) for maize cribs.	Apply to every 10 tons (10,000 kg) of grain as directed. Spray grain during loading; for maize spray all exterior surfaces of cobs in crib and under roof with a coarse spray.
Grain	Header harvesters and augers, silos	dichlorvos	Cold fog 1 pt (568 ml) dichlorvos to 19 pt (10.8 l) diesel oil. Impregnated strips.	2 gal (10 l) per 420 sq.ft (40 sq.m) 2-5 (1/2-1 gal) litres per 1,000 m ³ . Suspend in ceilings 1 per 40 m ³ as per instructions.
Grain	Empty silos and storage bins pre-season clean-up	phoxim	1-2 gal (5-10 l) of 0.2% (1 1/2 pt/100 gal of water or 2 floz (60 ml)/5 gal (25 l) water) per 1,000 sq.ft (100 sq.m).	Spray wooden floors and absorbent walls with 10-20 l (2 1/4-4 1/4 gal). Treat floor in poor condition with more than 20 l (4 1/2 gal) of 0.2% dilution per 100 sq.m (1,000 sq.ft).

Grain and small seeds	Empty sacks	methyl bromide	1 lb (262 ml) per 1,000 cu.ft (28.3 m ³) for 24 hr.	Tent fumigation or vacuum fumigation by approved pest control operator only.
"	"	pyrethrum (water-based)	1 fl.oz (30 ml) per 1 gal (5 l) of water.	Spray over sacks with a hard sprayer.
"	"	phoxim	0.2% dilution (as for grain)	400 ml per sq.m.
Grain	Silos, walls, and bins	malidison	1 lb (0.45 kg) 25% wettable premium grade per 1 gal (4.55 l) water at 1-2 gal (5-10 l) per 1,000 sq.ft (100 sq.m)	Spray silo and bin interior walls and floors before refilling with new-season harvest.
Grain	Flour mill chutes, conveyors, etc.	ethylene dichloride 1 pt carbon tetrachloride 3 pt	4-10 fl. oz (150-300 ml) per linear ft (m) depending on location, or 14 fl. oz (6.35 kg) per 1000 cu. ft (28.3m ³)	16-24 hr exposure gas mask essential.
Potatoes	In sacks	carbon bisulphide	5 lb (2.5 kg) per 1,000 cu.ft (28.3 m ³) for 48 hr	For efficient control the temperature should be 65° F (18.3° C). Normally, several fumigations are necessary. <i>Caution:</i> Carbon bisulphide is inflammable and naked flames should be kept away.

Chloropicrin: This is a powerful tear gas and one of the most toxic to insects of the fumigants commonly used today. It is added in small quantities to methyl bromide to serve as a warning agent. Its disadvantage is that fumigated commodities are unpleasant to handle for some time after fumigation. For this reason, it is only used for fumigating bulk farm grain silos. It penetrates effectively into many materials, but it is corrosive to metals and care should be taken to protect metal surfaces and equipment during treatment. It is sold in bottles (1 kg) and these should be stored in a cool, safe, lock-up poison cupboard out of reach of children and not likely to get broken.

To fumigate a grain silo use a 1 kg (2.2 lb) bottle per 10 tons (10,000 kg) of grain. Drive five ½ in. (12.7 mm) to ¾ in. (19 mm) pipes 8 ft (2.5 m) long, plus five more pipes 4 ft (1.22 m) long, down through the grain. Divide the total volume of chemical into 15 equal parts. Pour one part down each pipe, starting at the one farthest from the silo hatch and work toward the hatch. Use five parts as a surface application. Leave the grain undisturbed for at least 2 weeks.

Caution. At all times a respirator fitted with the correct canister must be worn.* While working inside the silo, have a companion outside to give help if required.

Sprays

Maldison: This is an organophosphate which can only be used to spray the walls of empty silos which have been thoroughly cleaned out of last season's remains before they are refilled with new-season grain. Premium grade should be used. Care must be taken not to apply it to grain, and in handling, because, like all organophosphates, it is poisonous to man. A respirator with the correct canister and fully protective clothing must be worn when using it. Doses are given in Table 1. If preferred, a 50% emulsifiable concentrate spray may be used at the rate of 1 pint (570 ml) per 27 gal (123 l) of water per 1,000 sq.ft (100 sq.m) (Table 1).

Dichlorvos: This is another organophosphate which is extremely volatile and toxic to man. It has a fumigant as well as a contact effect, and can be used to spray the inside walls of silos before they are filled in the same way as is maldison. It can also be metered into the auger stream during filling at the rate shown in Table 1. Precautions include the wearing of fully protective clothing and a respirator equipped with the correct canister.* It must be stored away from foodstuffs and kept out of reach of children in a locked poison cupboard. Empty containers must be destroyed by being buried 2 ft deep. Dichlorvos cold fog can be used in the pre-season clean-up of header harvesters and augers. Impregnated strips can also be suspended from ceilings of silos and empty bins (Table 1).

Phoxim: This is a phosphoric ester which is effective against a wide spectrum of storage insects and has a long residual effect. It lacks odour, but cannot be used for the direct treatment of foodstuffs for stock or human consumption. It can only be used for a pre-season clean-up of empty granaries, silos, warehouses, and flour mills. Industrial products like hides and textiles can be treated directly. Before treatment, silos and storage places must be thoroughly cleaned of remains of last season's harvest. It is poisonous if swallowed or absorbed through the skin, and fully protective clothing of gloves, overalls, and face mask* must be worn during mixture and application, and operators must wash thoroughly with soap and water immediately after application. Operators should work to

*For a schedule of respirators approved for use consult the local Medical Officer of Health.

the windward as much as possible when applying phoxim outdoors. Again, as with other poisons, it must be kept in a locked poison cupboard and all empty containers immediately destroyed or buried 2 ft underground. Dosages are given in Table 1.

REFERENCES

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ADDENDUM

Since this paper was written, two new facts have become known. The first is that smoke generators containing 45% lindane are now commercially available, and at least one large roller mill is using them experimentally. If successful this will be a cheap and easy method of treating enclosed premises like flour mills and warehouses for stored pests. The second is that a stored product mite, *Suidasia medanensis*, (det. A. M. Cunnington) (Fig. 1), has been reported from New Zealand for the first time, collected by B. Cornere, Green Lane Hospital, in mite colonies being raised on dog biscuits.

FIG. 1: *Suidasia medanensis*. Scanning electronmicrograph by courtesy Dr N. E. Flower, Physics and Engineering Laboratory, DSIR. Carbon coated magnification $\times 325$.