



Insect control in stored grain

Agency for Food and Fibre Sciences

Key points

- Most markets want grain free from insects and some want freedom from chemical residues, so check with potential buyers before you treat with chemicals.
- Clean grain handling and storage equipment and dispose of or treat old infested grain.
- Aeration cooling reduces insect activity, but may have to be used with other methods in summer.
- Chemical sprays are registered only for cereal grains, not pulses and oilseeds.
- Bombing with phosphine is fully effective only in a storage that is gas-tight.

Introduction

If insects in grain are left untreated, the grain will:

- be unsaleable to most buyers,
- be reduced to dust by the insects feeding on it, and
- go mouldy because of the heat and moisture released by the insects.

Grain insects are present on most farms in harvesting machinery, stockfeed, grain spills, and old seed. Some of the insects fly between farms and between storages, and others walk or are carried in handling equipment.

Unless insect control measures are applied, grain quality and value is likely to be reduced.

Options for different markets, grains and storages

Market requirements

Always check with potential markets for your grain to ensure that they will accept the pest control methods you intend using. Grain markets increasingly are demanding

- freedom from live insects and,
- freedom from residues that result from chemical treatment of grain.

Chemical sprays are registered only for cereal grains. Some markets will not accept cereal grain treated with these registered chemicals.

Chemical sprays are not registered for pulses or oilseeds. Markets will not knowingly accept pulses or oilseeds contaminated by residues of chemicals sprayed on these grains. Detection of residues could result in loss of markets.



Queensland Government
Department of Primary Industries and Fisheries

Options for different grains and markets

Because of market requirements and chemical registrations that are specific to grain types, the pest control options that can be used for various grain types and markets are limited (Table 1). Details for residual chemicals for particular cereal grains and particular markets are given in Tables 4 to 6.

Table 1. Pest control options for various grain types and markets.

Treatment		Cereal grains* for:			Pulses*or Oil-seeds*	Any grain for organic markets
		On- farm use	Markets accepting residual treatments	Markets not accepting residual treatments		
Hygiene		✓	✓	✓	✓	✓
Aeration		✓	✓	✓	✓	✓
Drying		✓	✓	✓	✓	✓
Controlled atmosphere		✓	✓	✓	✓	✓
Phosphine fumigation		✓	✓	✓	✓ *	✗
Dichlorvos		✓	✓	✗	✗	✗
Treatment of storages & equipment	Amorphous silica	✓	✓	✓	✓	✗?
	Residual chemicals	✓	✓	✗	✗	✗
Mixture with grain	Amorphous silica	✓	✗	✗	✗	✗?
	Residual chemicals	✓	✓	✗	✗	✗

*Cereals include: barley, maize, millets, oats, rice, sorghum, triticale, wheat.

*The **only pulse crop** for which phosphine is registered is **field pea**.

*Oilseeds include: canola, linseed, safflower, sunflower, peanut.

✓ can be used.

✗ cannot be used.

✗? some organic markets are reported to accept this treatment, others do not.

Options for different storages

Best practices for insect control in grain in various storage types are presented in Table 2. Some of the options for insect control can be used successfully only in some types of storages. Obviously aeration can be used only if the storage is equipped with fans, ducts and a power source.

Fumigation is fully effective only in a sealed, gas-tight storage.

If storages and equipment are not suitable for use of pest control methods that are acceptable to markets, either upgrade the storage system or deliver the grain to a bulk handling company or a buyer within six weeks of harvest to avoid pest problems.

Table 2: Best practices for control of insects in grain in storages with or without sealing and aeration.

	Storage type			
	Sealed and aerated	Sealed, not aerated	Unsealed and aerated	Unsealed, not aerated
Best practice	<ul style="list-style-type: none"> clean out storages and handling equipment before harvest pressure test storage before harvest and repair leaky seals aerate while loading grain into silo seal and fumigate with phosphine as soon as possible after harvest, but only if grain is at or below standard receival moisture level. resume aeration cooling immediately after fumigation monitor grain moisture and temperature, every 2 weeks in summer and every 4 weeks in winter open hatches when unloading 	<ul style="list-style-type: none"> clean out storages and handling equipment before harvest pressure test storage before harvest and repair leaky seals seal and fumigate with phosphine immediately after harvest leave silo sealed only if grain is at or below standard receival moisture level. monitor grain moisture and temperature, every 2 weeks in summer and every 4 weeks in winter open hatches when unloading 	<ul style="list-style-type: none"> clean out storages and handling equipment before harvest aerate, beginning while loading grain into silo, to cool the grain 	<ul style="list-style-type: none"> clean out storages and handling equipment before harvest spray grain (not pulses, oilseeds) with registered, residual chemicals while loading into silo observe withholding period
If insects are found: immediate remedy	<ul style="list-style-type: none"> pressure test and repair leaky seals fumigate with phosphine aerate before handling grain 	<ul style="list-style-type: none"> pressure test and repair leaky seals fumigate with phosphine open hatches and air before handling grain 	<ul style="list-style-type: none"> spray with dichlorvos (not pulses, oilseeds) observe withholding period 	<ul style="list-style-type: none"> spray with dichlorvos (not pulses, oilseeds) observe withholding period
If insects are found: changes for next season	<ul style="list-style-type: none"> improve clean-up fumigate with phosphine at 3 month intervals during summer/ autumn 	<ul style="list-style-type: none"> improve clean-up fumigate with phosphine at 3 month intervals during summer/ autumn 	<ul style="list-style-type: none"> improve clean-up fit automatic controller spray grain (not pulses, oilseeds) with registered, residual chemicals while loading into silo 	<ul style="list-style-type: none"> improve clean-up use alternative chemicals if problems persist, upgrade storage system, install aeration
Costs	<ul style="list-style-type: none"> extra 10-30% cost of silo to seal \$1-2000 for aeration about 20c/tonne capacity to fumigate about 5-10c/tonne/month to aerate 	<ul style="list-style-type: none"> extra 10-30% cost of silo to seal about 20c/tonne capacity to fumigate 	<ul style="list-style-type: none"> \$1-2000 for aeration about 5-10c/tonne/month to aerate 20-40c/tonne for dichlorvos \$2-3/tonne for residual chemicals 	<ul style="list-style-type: none"> 20-40c/tonne for dichlorvos \$2-3/tonne for residual chemicals
Advantages	<ul style="list-style-type: none"> aeration is residue-free aeration maintains grain quality fumigation is regarded as residue-free acceptable for most markets 	<ul style="list-style-type: none"> fumigation is regarded as residue-free acceptable for most markets 	<ul style="list-style-type: none"> aeration is residue-free aeration maintains grain quality 	<ul style="list-style-type: none"> residual chemicals provide protection up to 9 months
Disadvantages	<ul style="list-style-type: none"> seals require maintenance 	<ul style="list-style-type: none"> mould problems likely in high moisture grain (eg wheat above 12%) seals require maintenance 	<ul style="list-style-type: none"> chemicals are not registered for pulses and oilseeds residues unacceptable for some markets and uses re-treatment requires grain to be moved 	

Management, planning and inspection

Plan for insect control before storage

There are no simple short cuts for storing grain safely. If insects are detected as grain is outloaded for sale, treatment is likely to delay the delivery by two to four weeks. Unless you plan for insect control and have the necessary equipment, you should not be storing grain.

Management plans should include:

- good hygiene as an essential part of insect control,
- methods to try to prevent insect problems developing,
- inspection for insects and other quality problems, and
- methods to control insects if they do develop.

Methods that aim to prevent infestations, including those listed as best practices in Table 2, are:

- cooling grain with aeration,
- treating grain by spraying with residual chemicals, or
- treating grain by mixing amorphous silica powder.

Plan to treat any insects that are detected prior to sale by:

- having at least one sealed silo as a hospital bin for fumigation of infested grain; or
- having a calibrated sprayer and an empty storage into which cereal grain can be turned and treated with dichlorvos.

Inspection

Inspect grain in each storage for insects and other quality problems at least once a month. Use whatever methods are practical and safe. Ideally take samples of a few litres from all access points, using a grain spear for the top surface if it is safe to do so, and also from the bottom hatch. Sieve the grain to separate insects.

If you find more than five live insects per litre in grain for use on-farm, then control is needed to prevent excessive damage and cross infestation. If any live insects are found you should consider treating the grain before delivery to bulk handlers or to most buyers. To ensure that sufficient time is available for treatment if insects are present, the grain should be inspected four weeks before the intended sale or delivery date.

In an aerated silo, the smell of the air coming out of the grain is a guide to the state of the grain. With experience, you will notice that the smell becomes fresher after a few days of aeration at the start of storage. A musty smell later in storage is an indicator of insect and/or moisture problems. Do not use this test just after a storage has been fumigated.

High temperature is an indicator of insect or moisture problems. Push a rod at least one or two meters into the grain, leaving it to equilibrate with the grain for an hour if it is metal or half a day if it is wood. Pull the rod out and feel how warm it is. If it is hot, take spear samples and check for insects and moulds.

Cleaning and treatment of storages and equipment

Cleaning

Before harvest clean out all machinery and equipment used to handle grain, including headers, augers, field bins, truck bins, silos and other storages. Any equipment used to treat or handle pickled seed must be thoroughly cleaned to prevent contamination of new grain.

Special care should also be taken to clean out bags of seed, feed troughs, shed floors, heaps of old bags or any other places where grain and insects may be present. Grain and residues from cleaning should be fumigated with phosphine, buried, burned, or spread thinly over the ground away from

buildings and storages. Grain held over from the previous season should be inspected and treated if insects are found.

Treatment of storages and equipment

Treating the surfaces of storages and equipment before they are used may kill insects walking on those surfaces, but will not control insects in grain placed in the storage or equipment. If the storage or equipment is not cleaned before treatment, the treatment will be much less effective.

Treatment with amorphous silica / diatomaceous earth powder

All surfaces of walls, floors, ledges, and machinery may be treated with amorphous silica yearly, or twice yearly in heavy traffic areas. It can be applied to surfaces in two ways:

1. As a slurry - this is a very efficient method and is applied at the rate of 6 g/m².
2. As a dust - amorphous silica powder requires an air stream to move it into surfaces and into crevices at the rate of 2 g/m². When applying the dust to large areas, use a power duster such as a Stihl SR400. Operators of such equipment should wear disposable dust masks. Treating small storages can be achieved using a bellows type dust blower (from horticultural suppliers) or a venturi type gun. Dust treatment of headers after cleaning is recommended - follow the directions on the label.

Treatment with residual chemicals

Residual chemicals can be sprayed onto the surfaces of storages and equipment to kill walking insects, but only if the grain to be handled and stored is a cereal destined for a market that accepts residues on the grain. Do not use these chemicals if oilseeds or pulses are to be stored, or if potential buyers will not accept treated grain (**Table 3**).

Aeration cooling

Temperature effects on grain insects

The common grain pests increase by 20-25 times a month at high temperatures (30-35°C) and moistures (14-16% grain moisture for wheat, equivalent to 70-80% relative humidity (RH)).

Table 3. Insecticide application rates to treat clean surfaces of storages and equipment to kill walking insects. Except for amorphous silica / diatomaceous earth, apply only if the grain to be handled and stored is a cereal destined for a market that accepts residues on the grain. For other grains, clean and leave, or clean and apply amorphous silica / diatomaceous earth powder.

Select one of these options:	Insecticide	Dilution rate per L water	Application rate
Spray a mixture of two insecticides diluted in water *	mix <u>either</u> Actellic®	11 mL/L	Apply 1 L of diluted mixture for every 20 m ² of surface area
	<u>or</u> Reldan®	20 mL/L	
	<u>or</u> fenitrothion	10 mL/L	
	<u>with</u> carbaryl	20 mL/L	
Spray a single insecticide diluted in water	<u>either</u> Alfacron® (may not be currently available)	10 g/L	Apply 1 L of diluted insecticide for every 20 m ² of surface area
	<u>or</u> dichlorvos 500 g/L	10 mL/L	
	<u>or</u> amorphous silica powder	120 g/L (slurry)	
	<u>or</u> diatomaceous earth	200g/L	
Apply a dust	amorphous silica powder	—	Apply 40 g dust for every 20 m ² of surface area

* Dilute each concentrate in a small amount of water before mixing together the insecticides in the spray vat and making up the total volume with water.

Reducing grain temperature slows insect development. For example, flour beetles can complete their development in three weeks at 35°C and 70%RH, but take ten weeks at 22.5°C and 70%RH.

Although adult grain insects live a long time at cool temperatures, their young stages stop developing at temperatures below 15°C for weevils or 20°C for most other species.



Flour beetles

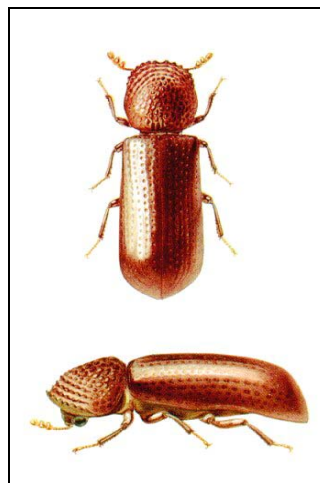


Rice weevil

Reducing moisture also slows development. Weevils cannot reproduce in wheat below 10-10.5% grain moisture, but the lesser grain borer will build up in numbers at moistures as low as 8%.



Lesser grain borer



Cooling with aeration

Controlled aeration cooling can greatly reduce insect and mould activity in stored grain, as well as preserving grain quality. Aeration cooling lowers the temperature of grain by blowing cool air through it. An automatic controller is more effective than thermostats, timers or manual switches in selecting the coldest air available.

Some growers find that a combination of good hygiene and controlled aeration cooling prevents development of problem insect infestations. However other growers have insect problems in aerated grain, particularly in summer. Therefore, aeration may need to be used in conjunction with other pest control methods.

Aeration may fail to control insects because of heating of the surface layer, particularly in summer, or because of insects flying into the surface layer. Both these problems can be overcome by mixing amorphous silica into the top 30 cm of grain at the rate of 1 kg/tonne of grain. The amorphous silica is diluted when out-loading to levels that are acceptable to buyers. Painting the roof and north-western side of the storage white can reduce the effects of surface heating.

Aeration cooling is strongly recommended for seed or malting barley to maintain germination and malting quality.

Grain protectant chemicals for cereal grains

Protectant chemicals are sprayed on grain to protect it for up to nine months from insect infestation during storage. Protectants are registered for application only to cereal grains.

Many buyers are now requiring that grain and grain products have nil chemical residues. All markets do not necessarily accept residues that comply with legal restrictions. Check with potential buyers before you treat with chemicals. Bulk handlers and buyers may require a declaration of chemicals used to treat grain.

Maltsters prefer to have no protectant residues on malting barley. If protectants are the only pest control option available, only two protectants are accepted for use on malting barley – fenitrothion and methoprene (IGR[®], Diacon[®]). Other chemicals either taint the flavour of beer or interfere with fermentation.

Carbaryl can be used on feed grain or grain used on the farm but should not be used for any other grain. Residues are not acceptable in grain for human consumption.

Registered grain protectants and their application rates are shown for:

- Most cereal grains, if they are to be used on-farm or sold to a buyer accepting residues on the grain (Table 4).
- Cereal grains, if they are to be used on-farm for feed or seed (Tables 4 and 5);
- Malting barley, if it is to be sold to a buyer accepting residues on the barley (Table 6).

Table 4. Insecticide application rates to protect stored cereal grain, except malting barley. If grain is to be sold, use insecticides only if approved by your buyer. Cereal grains include: barley, maize, millets, oats, rice, sorghum⁵, triticale, wheat.

Insecticide ¹	Storage period				Withholding period (WHP) ⁴ and restrictions on use
	6 weeks - 3 months		3 months - 9 months		
	Rate/ tonne ²	Cost ³	Rate/ tonne ²	Cost ³	
Apply a mixture of -					
Actellic [®]	4.5 mL	37-40 c	4.5 mL	37-40 c	no WHP
<u>or</u> Reldan [®]	10 mL	65-70 c	20 mL	130-140c	no WHP, do not apply to rice or malting barley
<u>or</u> fenitrothion	6 mL	20-30 c	12 mL	40-60 c	WHP 90 days for the high rate
<u>With either</u>					
IGR [®] 200 g/L,	5 mL	150-180c	5 mL	150-180c	no WHP
<u>or</u> Diacon [®] 50 g/L	20 mL	100-140c	20 mL	100-140c	no WHP
<u>or</u> Diacon S [®] 30 g/L	20 mL	120-195c	20 mL	120-195c	no WHP
<p>Some mixtures are available together as grain protection packs. These packs are similar in price to buying the insecticides separately. If used for more than 3 months protection the proportions of the two insecticides are inappropriate and some of one will be left over.</p> <p>Dilute liquid concentrates in water at the specified rate per litre, then spray 1 litre of the mixture per tonne of grain while auguring the grain.</p> <p>Costs (cents per tonne in 2003) for chemicals only are presented as an approximate guide. Large pack sizes are cheaper per tonne treated than small packs.</p> <p>Insecticide residues must not exceed Maximum Residue Limits (MRL). Where application rates exceed MRL withholding periods are required to allow residues to decay to less than the MRL.</p> <p>Seedlings of some sorghum varieties are susceptible to toxicity from organophosphorus insecticides such as Actellic[®], fenitrothion and Reldan[®].</p>					

Table 5. Insecticide application rates for cereal grains for use on farm for seed or animal feed, or for sale for animal feed. Alternatives in **Table 4** can also be used. If grain is to be sold, use insecticides only if approved by your buyer or handler. Cereal grains include: barley, maize, millets, oats, rice, sorghum⁴, triticale, wheat.

Insecticide	Storage period				Withholding period (WHP) ³ and restrictions on use
	6 weeks - 3 months		3 months - 9 months		
	Rate/tonne ¹	Cost ²	Rate/tonne ¹	Cost ²	
Apply a <u>mixture</u> of Actellic [®]	4.5 mL	37-40 c	4.5 mL	37-40 c	no WHP
<u>or</u> Reldan [®]	10 mL	65-70 c	20 mL	130-140c	no WHP
<u>or</u> fenitrothion	6 mL	20-30 c	12 mL	40-60 c	WHP 90 days for the high rate
<u>With</u> carbaryl (check with buyer)	10 mL	15 c	16 mL	25 c	WHP 90 days for the high rate Do not use on malting barley, milling wheat, or grain for bulk handlers
1. Dilute liquid concentrates in water at the specified rate per litre, then spray 1 litre of the mixture per tonne of grain while auguring the grain. Add dusts directly to the grain.					
2. Costs (cents per tonne in 2003) for chemicals only are presented as an approximate guide. Large pack sizes are cheaper per tonne treated than small packs.					
3. Insecticide residues must not exceed Maximum Residue Limits (MRL). Where application rates exceed MRL withholding periods are required to allow residues to decay to less than the MRL.					
4. Seedlings of some sorghum varieties are susceptible to toxicity from organophosphorus insecticides such as Actellic [®] , fenitrothion and Reldan [®] .					

Table 6. Insecticide application rates for protection of **malting barley**. Use insecticides only if approved by your buyer or handler. Maltsters prefer barley without residual treatments, and some insects are resistant to all listed protectants, so consider non-chemical alternatives.

Insecticide ¹	Storage period				Withholding period ⁴
	6 weeks - 3 months		3 months - 9 months		
	Rate/ tonne ²	Cost ³	Rate/ tonne ²	Cost ³	
Apply a mixture of - fenitrothion With <u>either</u>	6 mL	20-30 c	12 mL	40-60 c	90 days for high rate
IGR [®] 200 g/L	5 mL	150-180c	5 mL	150-180c	none
<u>or</u> Diacon [®] 50 g/L	20 mL	100-140c	20 mL	100-140c	none
<u>or</u> Diacon S [®] 30 g/L	20 mL	120-195c	20 mL	120-195c	none
<div>1. Some mixtures are available together as grain protection packs. These packs are similar in price to buying the insecticides separately. If used for more than 3 months protection the proportions of the two insecticides are inappropriate and some of one will be left over.</div> <div>2. Dilute liquid concentrates in water at the specified rate per litre, then spray 1 litre of the mixture per tonne of grain while auguring the grain.</div> <div>3. Costs (cents per tonne in 2003) for chemicals only are presented as an approximate guide. Large pack sizes are cheaper per tonne treated than small packs.</div> <div>4. Insecticide residues must not exceed Maximum Residue Limits (MRL). Where application rates exceed MRL withholding periods are required to allow residues to decay to less than the MRL.</div>					

Brand names and pack sizes are shown in Table 9. These registrations were current at the time of writing, but are subject to change.

Protectants will not reliably disinfest grain; i.e. they will not always kill adult insects present at the time of treatment. Methoprene, the active ingredient in IGR[®] and Diacon[®], is an 'insect growth regulator' - it controls only immature stages and will not kill adults. If protectants are to be added to infested grain then the grain should be treated with phosphine before adding the protectants or, alternatively, dichlorvos (Table 7) can be applied at the same time as the protectants.

Maximum residue limits and withholding periods

The Maximum Residue Limit (MRL) is the maximum concentration of a residue that is legally permitted in or on a food, agricultural commodity or animal feedstuff. Where application rates exceed the MRL, withholding periods must be observed to ensure that residues decay to acceptable levels. Observe the withholding periods on the labels.

The only withholding periods for grain treated with protectant insecticides is 90 days for the higher rates of fenitrothion and carbaryl. There is no withholding period for other protectant treatments, but withholding periods for dichlorvos and phosphine are discussed in later sections.

Managing resistance to protectants

Resistance of grain insects to protectants has become a major problem in Australia. Mixtures of protectants (Tables 4 to 6) are recommended because no single protectant will give long-term protection against all resistant species.

Resistance to protectants is of major concern in two species in the eastern states of Australia:

- Saw-toothed grain beetle is resistant to fenitrothion and some resistance to Reldan and Actellic has been found.
- Lesser grain borer is resistant to fenitrothion, Reldan and Actellic, and some cases of resistance to IGR/Diacon have been found. For further information click on "[Stored Grain – Identification of Insect Pests](#)"



Saw toothed grain beetles

Resistance should be suspected when obvious numbers of insects appear in a well-treated bulk before the end of the storage period claimed on the label for the protectant, especially if insects of one type only are involved. If this occurs use different insecticides for future treatments. Don't, however, jump to the conclusion that every control failure is caused by resistance - most are not. Usually the reason for control failure is a problem with the dose rate or application technique.

You can affect the build up of resistance by the control methods you use. Repeated use of the same chemicals will speed up resistance development. We also recommend amorphous silica powder instead of chemical insecticides for treating silo surfaces and storage areas after cleanup because this reduces selection for resistance to the chemicals. Selection for resistance can also be minimised by using the non-chemical control methods such as hygiene and aeration.

Applying protectants

Protectant chemicals are effective in all types and standards of storage - no modifications to storages are needed. However they must be applied evenly to grain to be fully effective. Simple, correctly calibrated application equipment is needed.

- Apply the correct dose - underdosing will result in reduced protection; overdosing is wasteful and may cause grain to be rejected by buyers or held longer until residues decline to levels accepted by markets.
- Mix the concentrated insecticide in clean containers with rainwater if possible - alkaline water causes insecticides to break down very quickly; don't mix concentrates directly, dilute first, then mix; don't hold mixed pesticides for more than a few days - mix just enough spray and use it as soon as possible.

- Apply protectants to grain while it is being augured, spraying into the auger hopper or into the auger casing; use a flow meter.
- High-volume pumps allow bypass to agitate liquid spray mixtures; other pump types may be used with care; thoroughly wash equipment with water after use.
- Calibrate your application equipment before every use. The spray equipment must be calibrated to spray 1 litre of solution per tonne of grain; that is, the spray rate, measured in litres per hour, must equal the auger or elevator uptake in tonnes per hour.
- Wear protective clothing - goggles, gloves and overalls when handling protectants; avoid breathing the fumes; don't eat, smoke or put your fingers in your mouth; wash well and change your clothes when you finish.

Mixing amorphous silica / diatomaceous earth powder with grain

Amorphous silica powder (Dryacide® or Absorbacide®) can be mixed with grain as an alternative to the chemical sprays. It can be used on feed grain or grain used on the farm, but should not be used for any other grain unless potential buyers approve of its use. A new diatomaceous earth product Perma-Gard D10® is available and is recommended for use in a similar fashion.

The major advantages of these inert dusts are that they leave no chemical residue, have no withholding period and minimise selection for resistance. They are accepted by some organic markets. However they have some serious disadvantages for mixing with grain. They are far more expensive than any other chemical treatments. Bulk handlers and some buyers will not accept grain treated with amorphous silica / diatomaceous earth because they change the angle of repose of grain and slow movement of grain through augers.

Unlike other protectants that are applied as a liquid spray, amorphous silica / diatomaceous earth are applied as a dust. The dust collects on insects and dries them out. A pickle applicator or a special Dryacide® applicator, available from rural supply houses, is the best way to apply such products. Add amorphous silica / diatomaceous earth powder at the rate of 1 kg/tonne of grain. At this application rate it costs \$5-10 per tonne of grain. If grain is dusty or infested, increasing the application rate to 1.5-2 kg/ tonne will increase its effectiveness. Amorphous silica is not effective on high moisture grain over 12%.

Treating infested cereal grain with dichlorvos

Application of dichlorvos (other names: Divap®, DDVP®, Vapona®) at the rates specified in Table 7 can be used to kill insects in grain. Allow three days for all insects to die after treatment, and observe the withholding periods before sale. If grain is to be delivered to a bulk handler or sold, it should be inspected weekly for the month before the intended date of sale or delivery to allow time for a disinfestation treatment if insects are found.

Table 7. Dichlorvos application rates for **treatment of infested cereal grain.**

If grain is to be sold, use insecticides only if approved by your buyer or handler. Cereal grains include: barley, maize, millets, oats, rice, sorghum, triticale, wheat.

Insects	Insecticide	Dilution rate ¹	Application rate	Cost ²	Withholding period
most species	dichlorvos 1.14 kg/L 500 g/L	5.3 mL 12 mL	Apply 1 L of diluted insecticide per tonne as grain is augured	12-15c 30-35c	7 days 7 days
lesser grain borer	dichlorvos 1.14 kg/L	10.5 mL	Apply 1 L of diluted insecticide per tonne as grain is augured	24-30c	28 days
moths only	dichlorvos 1.14 kg/L 500 g/L	4.4 mL 10 mL	Apply 1 L of diluted insecticide for every 20m ² of grain surface area	10-15c 24-30c	7 days 7 days

1. Dilute liquid concentrates in water at the specified rate per litre, then spray 1 litre of the mixture per tonne of grain while auguring the grain or spray 1 litre per 20 square metres of grain surface to control moths.
2. Costs (cents per tonne or cents per 20 square metres in 2003) for chemicals only are presented as an approximate guide.

If grain is infested with lesser grain borers then a higher rate of dichlorvos is recommended because of resistance in these insects. A withholding period of 28 days applies to this treatment. Observe the recommendations given for applying protectants when applying dichlorvos.

Fumigation with phosphine

The major advantage of fumigation with phosphine, commonly called “bombing with phostoxin”, is that insects can be controlled without moving the grain. Phosphine gas moves readily through grain from the point of application.

Phosphine leaks quickly through holes in silos or sheeting. Wind and large temperature changes accelerate phosphine loss. Most phosphine is lost within 4 days from fumigations in ordinary, unsealed storages.

Insects are killed slowly by phosphine. The fumigant must be kept in contact with the insects for at least 7 days to kill all stages. Fumigation in ordinary, unsealed storages will kill most adults. However, most eggs and pupae will survive to continue the breeding cycle. A sealed, gas-tight silo is needed to contain phosphine for long enough to kill all stages of the insects.

Fumigation gives no residual protection to stored grain. In other words, insects flying or walking into the grain after the fumigant concentration has dropped to low levels will begin breeding.

Phosphine fumigant itself leaves minimal residues, and is acceptable to most markets. However, the residues left by tablets mixed with the grain are a concern to some markets.

Phosphine is effective against insects in most types of grain. But some commodities (for example, linseed and cottonseed) soak up phosphine very quickly, leaving little to kill insects. Phosphine does not control insects effectively in these materials.

Applying phosphine

Most farmers use phosphine generating tablets when fumigating. These tablets react with moisture in the air to release phosphine gas. Up to two days is needed to release all the gas - longer if the grain is cool or very dry. The gas then moves through the grain, usually within a day in bulks up to a hundred tonnes.

The problem of residues from tablets can be avoided by suspending bag, chain, belt or blanket formulations, or tablets spread on trays, in the headspace. Do not place tablets in heaps on trays – the reaction of the tablets generates heat that must be allowed to dissipate.

Do not enter a fumigated storage to retrieve the spent fumigant formulation – phosphine is toxic to humans. Once the full exposure period plus airing period has passed, the spent formulation can be removed from outside the silo and buried. Some phosphine will be given off by the spent formulation, so do not carry it in a confined space.

Phosphine is now available in gas cylinders. It can and can be applied at a high concentration using the SIROFLO® technique as explained below. Contact Cytec Australia Holdings, Baulkham Hills, NSW, Ph: 02 98 466 200.

Application rate and exposure periods for solid formulations

Effective fumigation of grain usually needs 1.5 grams of phosphine per cubic metre of total storage capacity. This application rate is equivalent to:

- 1.5 grams per cubic metre; or
- 5.5 grams per 100 bushels; or
- 2 grams per tonne capacity of wheat.

A tablet releases 1 gram of phosphine, so 1.5 tablets per cubic metre is equivalent to 1.5 grams per cubic metre. Examples of application rates of tablets for storages of various sizes are shown in Table 8. Phosphine moves through the whole air space, so apply the same number of tablets whether the storage is full or partly full.

Other solid formulations release various quantities of phosphine ranging from 0.2 grams to one kilogram. Follow label recommendations for those formulations.

Minimum exposure periods following application of phosphine are:

- 7 days at grain temperatures above 25°C;
- 10 days at 15 to 25°C.

Grain below 15°C should not be fumigated with phosphine - insects are very hard to kill at low temperatures.

Fumigant takes longer to distribute in storages with more than a few hundred tonnes capacity, unless forced circulation is used. Longer exposure periods are required in larger storages.

Table 8. Application rates for phosphine tablets in storages of various sizes.

Storage capacity			Number of tablets required
Tonnes wheat	Bushels	Cubic metres	
20	730	27	40
50	1830	65	100
100	3660	130	200
300	11000	400	600

Note: A storage needs the same amount of fumigant regardless of whether it is full, partly full, or empty. For example, a storage with enough space to hold 100 tonnes of wheat always needs 200 tablets no matter how much grain is in it.

Airing and withholding periods

Fumigated grain must be aired before handling to remove toxic gas and to minimise residues. Flow-through ventilation aided by a fan usually allows completion of airing in 24 hours. Without a fan this could take 5 days.

A withholding period of two days after the airing period applies before the grain is used for human food or stockfeed. Grain can be transported during this period.

Total fumigation time

The minimum period allowable between application of phosphine and use of the treated grain is 7 days exposure + 1 day airing with fans + 2 days withholding period, or 10 days total. If grain temperature is less than 25°C, so that a longer exposure period is needed, or airing is done without fans, so that a longer airing period is needed, the minimum allowable period between application and use of the grain can be as long as 17 days. In storages larger than 300 tonnes, an exposure period of 20 days is required, so total fumigation time is up to 27 days.

Safety

Phosphine is very toxic to people and farm animals. Health workers specify a concentration of 0.3 ppm as acceptable in work areas. Gas detector tubes are one method of monitoring workplace concentrations.

Use the following guidelines to stay safe when using phosphine:

- Don't inhale phosphine gas.
- Open tablet containers in open air and away from your face.
- Do not apply tablets from inside a confined space – apply from outside a silo.
- Fumigate only in areas where gas can't leak into living or working areas.
- Ventilate fumigated areas before the grain is handled.
- Do not transport grain while it is being fumigated. This is illegal.
- Spread tablets thinly to avoid fire risk.
- Never place tablets in water.
- Display a clear warning sign: **Danger – Poison Gas – Keep Away.**
- Dispose of the residue by burying 50 cm deep.
- Phosphine corrodes electrical wiring in vehicles and buildings.

Improving fumigation

Fumigation is fully effective only if it is done in a gas-tight enclosure. Silos can be made gas-tight for fumigation, preferably during manufacture.

Gas-tight bag stacks should be built by laying a plastic sheet on the floor, building and covering the stack with another sheet, then tightly rolling and clamping the top and bottom sheets together. Old sheets that have been folded or rolled many times, or roughly handled are unlikely to be gas-tight.

Measuring the phosphine concentration shows you whether the fumigation enclosure is sufficiently gas-tight. At the end of a 7 day fumigation if temperatures are above 25°C, or a 10 day fumigation at temperatures between 15 and 25°C, the concentration should still be at least 500 ppm to kill all stages and prevent development of resistance. You can measure phosphine concentration with a hand pump and gas detector tube. Several companies sell suitable gear and prices vary.

SIROFLO®

The SIROFLO® application system continually introduces a low concentration of phosphine into a silo from a cylinder for up to 21 days. The gas flows through the silo and out, usually at the top of the silo. Originally developed for very large silos, SIROFLO® is now available for small-scale storages. The advantage of this method is that the silo does not have to be sealed to the high standard required for conventional fumigation.

Although much more expensive than using tablets, in the longer term a SIROFLO® system may be cheaper than investing in the sealed silos required for conventional fumigation. The system is available through Cytec Australia Holdings, Baulkham Hills, NSW, Ph: 02 98 466 200

Controlled atmospheres

Controlled or modified atmosphere (CA) refers to the process of altering the proportion of atmospheric gases oxygen, nitrogen and carbon dioxide (CO₂) to give an insecticidal gas. The advantage of the CA technique is that it provides a disinfestation method that is chemical-free and suitable for "organic" grain. A major disadvantage is that it is several times more expensive than fumigation with phosphine.

In practice, use of CAs is little different to fumigating with phosphine. Currently, the only practical method available to farmers is to introduce carbon dioxide from a gas cylinder into a gas-tight silo. A very high standard of gas-tightness is required, often with a supplementary bleed of gas, to hold at least 60% carbon dioxide for at least 10 days or 30-40% carbon dioxide for 14 days to kill all stages of the insects' life cycle.

Further information on controlled atmosphere fumigation and commercial suppliers of appropriate gas and equipment, contact GRAINCO Call Centre Ph 07 4639 9222 or BOC Gases Australia Ltd, Ph on 13 12 62.

Further information

Details of insect control methods are available in "*Insect pests in stored grain*" by Eric Sinclair and Graham White (QI90021).

More general information on grain storage is available in "*Storing, handling & drying grain: A management guide for farms*" by Alan Andrews and Troy Jensen (QI 96081).

Further information on grain quality including detailed colour photos is available in "*GRAIN QUALITY Winter grain Crops: The Ute Guide*" by Michael Wurst, Stephen Parker and Kris Panagiotopoulos.

These books are available from Queensland DPI Client Service Centres. You can also order any DPI publications by contacting the DPI Call Centre in Brisbane, Ph: 13 25 23 or by calling the Toowoomba Client Service Centre on 07 4688 1415.

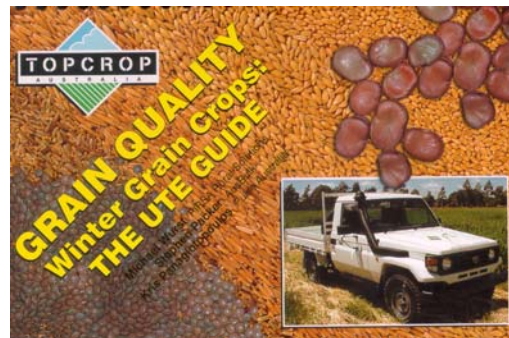


Table 9. Commercial preparations of insecticides and fumigants. This list was complete at the time of printing, but registrations, trade names and availability are all subject to change.

Active constituent	Concentration of active	Commercial preparation (® full trade name)	Pack sizes
Amorphous silica (g,s)	800 g/kg	Dryacide Sorptive Dust Insecticide®	15 kg
		Absorbacide Sorptive Dust Insecticide®	1, 15 kg
Azamethiphos	500g/L	Novartis Alfacron 500 Residual Insect Spray® (currently unavailable).	0.2, 5 kg
Carbaryl (g)	500 g/L	David Gray's Carbaryl 500 Flowable®	1, 5, 20 L
		Nufarm Flowable Carbaryl 500®	1, 5, 20 L
Chlorpyrifos-methyl (g)	500g/l	Aventis Reldan Grain Protectant	1, 20 L
		Chemag Diplomat Grain Protectant	1, 5, 20, 200L
		Dow Agrosiences Reldan Grain Protector	1, 20 L
Diatomaceous earth (g, s)	1000g/kg	Perma-Gard D-10 Insecticide®	25kg
Dichlorvos (g,s)	500 g/L	Barmac Dichlorvos 500 Insecticide	1, 5, 20 L
		ChemAg Dichlorvos 500EC Insecticide®	1,5,20,200 L
		Chemical Enterprises Dichlorvos 500 EC Insecticide®	5 L
		David Grays D.D.V.P. 500 Insecticide®	5 L
		Garrards DDVP 500EC Insecticide	1, 5, 10, 20 L
	1140 g/L	Nufarm Dichlorvos 1140 Insecticide®	0.5,2.4,20 L
		United Phosphorus Divap 1140 Insecticide®	2.4, 5, 20L
Fenitrothion (g)	1 kg/L	David Gray's Fenitrothion 1000 insecticide®	5, 20 L
		Rentokil Fenitrothion 1000 Insecticide	
		Farmoz Fenitrothion 1000 Insecticide®	0.3,5,20,200L
		Nevweb Fenitrothion 1000 Insecticide®	0.3,1.8,20 L
		Nufarm Fenitrothion 1000 Insecticide®	0.5,2.4,20 L
Methoprene (g)	50 g/L	Nevweb IGR Grain Protectant Aqueous	20, 200 L
		Farmoz Grain-Star 50 IGR Grain Protectant®	5, 20 L
	200 g/L	Nevweb IGR 200 Grain Protectant Aqueous®	0.25, 5 L
		Farmoz Grain-Star 200 IGR Grain Protectant®	0.25, 1, 5 L
Phosphine (f)	Tablets release 1g phosphine	Bayer Quickphos Phosphine Fumigation Tablets®	100, 330, 500 tablets
		ChemAg Fostoxin Fumigation Tablets®	100, 500 tablets
		CM Alphos Fumigation Tablets®	100, 500 tablets
		Excel Celphide Fumigation Tablets®	330 tablets
		Farmoz Pestex Fumigation Tablets	100, 330, 500 tablets
		Fumaphos Fumigation Tablets®	500 tablets
		Nufarm Fumitoxin Coated Fumigation Tablets®	100, 500 tablets
		Nufarm Fumitoxin Coated Fumigation Tablets®	100, 500 tablets
		Rentokil Gastion Phosphine Fumigation Tablets®	100, 500 tablets
		Sanphos Fumigation Tablets®	100 tablets

	Bag chain, belt release 110 g phosphine	Bayer Quickphos Phosphine Fumigation Bag Chain®	340, 680 g
		Rentokil Gastion Phosphine Fumigation Belt®	340 g
	Blanket releases 1.1 kg phosphine	Rentokil Gastion Phosphine Fumigation Belt®	3.4 kg
		Bayer Quickphos Fumigation Blanket®	3.4 kg
		Celphide Fumigation Blanket®	3.4 kg
		Fumaphos Fumigation Blanket®	3.4 kg
Pirimiphos-methyl (g)	900g/L	Syngenta Actellic 900 SF Solvent Free Liquid Insecticide®	1, 5 L

g - approved grain additive

s - approved treatment for storages and handling equipment

f – approved fumigant

FS0268. Last reviewed January 2004