

Insect Control in Stored Grain



Compiled February, 2007 by: Ken BULLEN, DPI&F, Plant Science, Toowoomba, Queensland.

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Key points

- Most markets want grain free from insects and some want freedom from chemical residues, so check with potential buyers before treating with chemicals.
- Clean grain handling and storage equipment and dispose of, or treat old infested grain.
- Aeration cooling reduces insect breeding activity, but does not guarantee storage pests will not be seen and may require treatment especially in the warmer period of the year.
- Chemical protectant insecticide sprays are registered only for cereal grains, not pulses and oilseeds.
- Fumigating 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.

1. 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, particularly insecticides, 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 can result in loss of 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 (see **Table 1**). Details of residual insecticides for treating storages and equipment are given in **Table 3**, and for particular cereal grains and particular markets are given in **Tables 4 to 8**.

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	Yes	Yes	Yes	Yes	Yes
Aeration	Yes	Yes	Yes	Yes	Yes
Drying	Yes	Yes	Yes	Yes	Yes
Controlled atmosphere	Yes	Yes	Yes	Yes	Yes
Phosphine fumigation	Yes	Yes	Yes	Yes*	✗
Dichlorvos	Yes	Yes	✗	✗	✗
Treatment of storages & equipment	Amorphous silica	Yes	Yes	Yes	✗?
	Residual chemicals	Yes	Yes	✗	✗
Mixture with grain	Amorphous silica	Yes	✗	✗	✗?
	Residual chemicals	Yes	Yes	✗	✗

Notes:
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.
Yes can be used.
✗ cannot be used.
✗ ? some organic markets are reported to accept this treatment, others do not. Check with potential buyer and organic certifying body.

2. Grain storage insect management

Plan for insect control before storage

There are no simple short cuts for storing grain safely. If insects are detected as grain is out-loaded 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 to treat infested grain with dichlorvos as it goes up an auger

Best stored grain management practice and recommended equipment:

- Fumigation e.g. Phosphine tablets of stored grain can only be successful against all insect life-cycle stages if carried out in a gas tight, sealed silo.
- In most circumstances, silos should only be sealed during fumigation. Leaving a silo sealed over extended periods in Australia's warm climatic conditions with no aeration may lead to conditions

suitable for development of insect pests, moisture migration, moulds and grain quality deterioration. Grain that is very dry or cool is less at risk.

- When purchasing a sealed silo it is worth including an aeration cooling system. Aeration fans not only achieve the benefits listed below but also assist with silo pressure testing and allow for faster gas ventilation times following a fumigation. Pressure test a sealable silo once a year and carry out maintenance to ensure it is able to hold fumigation gas concentrations for the required time.
- Freshly harvested grain benefits from aeration designed to reduce grain temperature and creating uniform grain moisture conditions throughout the silo. These two factors combined with good hygiene will significantly reduce problems with grain quality and storage pests.
- Following this initial post-harvest aeration cooling for a 2-3 week period, a decision to seal the silo and fumigate may be appropriate if it was the first silo filled or there are other hygiene factors that may have increased the risk of storage pest development.
- Over the medium and long term, grain is best held under aeration cooling, aiming to achieve grain temperatures of 20^o or less. Automatic aeration controllers assist in achieving reliable results.
- Check the silo monthly, sampling grain from the headspace and outlet for insect pests and quality. Insect traps placed in the grain surface will aid insect pest monitoring. When storage pests are detected, seal the silo and fumigate. Once fumigation is completed, release the silo sealing points and return silo to aeration cooling management.

Inspection of stored grain

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 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, grain should be inspected four weeks before the intended sale or delivery date.

In an aerated silo, the smell of the air blowing 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. A probe fitted with a protected thermometer or thermocouple sensor can also be used to determine grain temperature.

Cleaning of storages and equipment

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.

3. Storages and equipment - treating for insects

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

Treating 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, or Blovac BV22. 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.

Treating with 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 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).

Table 3: Insecticides to treat clean surfaces of storages and equipment to kill walking insects. Apply these only if the grain is destined for a market that accepts residues on the grain. If the market does not accept grain residues, clean and leave, or clean and apply amorphous silica / diatomaceous earth powder.

Select one of these options:	Insecticide (for Trade names - see Table 9)	Dilution rate per L water	Application rate
Spray a mixture of two insecticides diluted in water *	Mix either: pirimiphos-methyl®	11 mL/L	Apply 1 L of diluted mixture for every 20 m ² of surface area
	or chlorpyrifos-methyl®	20 mL/L	
	or fenitrothion	10 mL/L	
	with carbaryl	20 mL/L	
Spray a single insecticide diluted in water	Either azamethiphos® (may not be currently available)	10 g/L	Apply 1 L of diluted insecticide for every 20 m ² of surface area
	or dichlorvos (500 g/L formulation)	10 mL/L	
	or amorphous silica	Slurry in water - as per label	
	amorphous silica powder	Dust application	
Apply a dust	amorphous silica powder	Dust application	As per label
* 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.			
Refer Table 9 for insecticide Trade names.			

4. Chemical insecticides in stored grains to control insects

Knock-down of Insects in Infested Stored Grains

There are four major methods covered here

1. Knock-down with Dichlorvos alone, applied to grain at while moving (Table 4)
2. Mixing dichlorvos knock-down with protectant insecticides for a single application to grain
3. Fumigating with phosphine (“bombing”) of infested stored grain including safety, application methods, and sealed silos.
4. Fumigating with Vapormate® (this option requires a State-licenced operator, and special application and monitoring equipment approved by BOC Ltd).

Knock-down of live insects with grain-applied insecticides

Application of dichlorvos at the rates specified in **Table 4** can be used to kill insects in grain. Allow three days for all insects to die after treatment, and observe the withholding periods (see below) before sale.

Table 4: Dichlorvos application rates for knockdown of live adult insects in 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 (For Trade names – see Table 9)	Dilution rate ¹	Application rate	Cost ²	Withholding period ³
most species	dichlorvos 1.14 kg/L	5.3 mL	Apply 1 L of diluted insecticide per tonne as grain is augured	12-15c	7 days
	500 g/L	12 mL		30-35c	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	4.4 mL	Apply 1 L of diluted insecticide for every 20m ² of grain surface area	10-15c	7 days
	500 g/L	10 mL		24-30c	7 days

Notes table 4:

ALWAYS CHECK LABELS

For insecticide trade names, see Table 9.

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 2006) for chemicals only are presented as an approximate guide.

3. If grain is infested with lesser grain borers then the 10.5ml rate of dichlorvos is recommended because of resistance in these insects. A withholding period of **28 days** applies to this treatment.

Residual Insecticides (Protectants) for Treating Stored Grains

There are three treatment tables here which cover the following on-farm treatment requirements:

- Treating stored **cereal grain** (except malting barley) Table 5
- Treating stored **feed grains** and/or **seed** Table 6
- Treating stored **malting barley** on-farm Table 7

IMPORTANT NOTES on Protectant Insecticides:

- Protectants (insecticides sprayed directly on to grain at in-loading) **will not always kill adult insects** present at the time of treatment. These treatments are intended to control developing immature insect stages (ie, larvae), rather than existing mature adult stages.
- Methoprene and s-methoprene (IGR[®]), are 'insect growth regulators' - they control only immature stages and **will not kill adult insects**.
- Phosphine or dichlorvos are recommended for use as a knock-down treatment if adult insects are present.
- If protectants are to be added to infested grain then the grain should be treated (fumigated) with phosphine before applying the protectants, **or**, alternatively, dichlorvos (Table 4) can be applied as a direct spray to grain at the same time as the protectants.
- Adhere strictly to label rates so the Maximum Residue Limits (MRL's) are not exceeded when your grain is sold to end-user.

Tables of insecticides approved for treating stored grains

Table 5: Stored cereal grains - 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, sorghum, triticale, wheat. For trade names of these insecticides, see Table 9.

Insecticide ¹ (For Trade names see table 9)	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 -					
Either pirimiphos-methyl (900g/L product)	4.5 mL	30-35 c	4.5 mL	30-35 c	No Withholding period
or chlorpyrifos-methyl (500 g/L product)	10 mL	75-80 c	20 mL	150-160c	No Withholding period, do not apply to rice or malting barley
or fenitrothion (1000g/L product)	6 mL	18-20 c	12 mL	35-40 c	Withholding period 90 days for the high rate
or deltamethrin (eg, 250g/l product) + pip. butoxide	4 mL	15-20c	4 mL	15-20c	No Withholding period (OK for malt barley & sorghum). May not be generally available.
With either					
methoprene (eg, 200 g/L product), or s-methoprene (30 g/L product) or s-methoprene (300g/L product)	5 mL 20 mL 2mL	150-160c	5 mL 20 mL 2mL	150-160c	No Withholding period No Withholding period
Notes on Table 5:					
For insecticide Trade names, see table 9.					
1. Always check dose rates and all other details on product label. The table above is a guide only. Products such as Relden pluS IGR [®] is a single tin formulation mixture containing both chlorphriphos-methyl (500g/L) and S-methoprene (30g/L)					
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.					
3. Costs (cents per tonne in 2006) for chemicals only are presented as an approximate guide. Large pack sizes are cheaper per tonne treated than small packs.					
4. Insecticide residues must not exceed Maximum Residue Limits (MRL). Where application rates exceed MRL you must wait the withholding period to allow residues in the grain to decay to less than the MRL before selling the grain.					
Seedlings of some sorghum varieties are susceptible to toxicity from organophosphorus insecticides such as pirimiphos-methyl, fenitrothion and chlorpyrifos-methyl.					

Table 6: Feed grains and seed- Insecticide application rates for cereal grains for use on farm for seed or animal feed, or for sale for animal feed. Alternatives in **Table 7** 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, sorghum⁵, triticale, wheat.

Insecticide (For Trade names – see table 9)	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 mixture of either pirimiphos-methyl (900g/L product)	4.5 mL	30-35c	4.5 mL	30-35 c	No Withholding period
or chlorpyriphos-methyl (500g/L product)	10 mL	75-80c	20 mL	150-160c	No Withholding period
or fenitrothion	6 mL	18-20c	12 mL	35-40 c	Withholding period 90 days for the high rate
or deltamethrin (250g/L product) + pip. butoxide	4 mL	15-20c	4 mL	15-20c	No Withholding period. May not be generally available.
With carbaryl (check with grain buyer)	10 mL	12 c	16 mL	19 c	Withholding period 90 days for the high rate Do not use carbaryl on malting barley, milling wheat, or grain for bulk handlers

Notes on Table 6:

Trade names of these insecticides are listed in Table 9.

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 2006) 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 you must wait the withholding period to allow residues to decay to less than the MRL before you feed.
4. Seedlings of some sorghum varieties are susceptible to toxicity from organophosphorus insecticides such as pirimiphos-methyl, fenitrothion and chlorpyriphos-methyl.

Table 7: Malting barley on-farm - 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 (for Trade names – see table 9)	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 either fenitrothion	6 mL	18-20 c	12 mL	35-40 c	90 days for high rate
or deltamethrin (250g/l) + pip. butoxide	4 mL	15-20c	4 mL	15-20c	No WHP. May not be generally available. Note – check with maltster before using.
With either					
methoprene (200 g/L product)	5 mL	150-160c	5 mL	150-160c	No WHP
or methoprene (50 g/L product)	20 mL	100-140c	20 mL	100-140c	No WHP
or S-methoprene (30 g/L product)	20 mL	230-240c	20 mL	230-240c	No WHP
Notes on Table 7:					
Trade names of these insecticides are listed in Table 9.					
1. Always check dose rates and all other details on product label. The table above is a guide only. Products such as Relden pluS IGR [®] is a single tin formulation mixture containing both chlorphriphos-methyl (500g/L) and S-methoprene (30g/L)					
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.					
3. Costs (cents per tonne in 2007) for chemicals only are presented as an approximate guide. Large pack sizes are cheaper per tonne treated than small packs.					
4. Insecticide residues must not exceed Maximum Residue Limits (MRL). Where application rates exceed MRL you must wait the withholding period to allow residues in the grain to decay to less than the MRL before selling the grain.					

Applying protectant insecticides

Protectant chemicals will work in all types of storages with no modifications required, but they must be applied evenly to grain to be fully effective. Simple, correctly calibrated application equipment is needed.

- Apply the correct dose – under-dosing will result in reduced protection; over-dosing is wasteful and may cause grain to be rejected by buyers or held for 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. Spray 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 with water 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 (eg., [Dryacide®](http://www.entosol.com.au) at www.entosol.com.au or Absorba-Cide®, or Abrade®, or Permaguard D10®) 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.

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. Always check with the Organic certifying body first. (Refer to NSW DPI Organic farming Agfact "On-Farm Storage of Organic Grain" at www.dpi.nsw.gov.au/agriculture/farm/organic,

Note: These products 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 handling characteristics of grain and slow movement of grain through augers.

Unlike protectant chemical insecticides which are applied to grain as a liquid spray, amorphous silica / diatomaceous earth are applied to grain as a dust. The dust collects on insects and dries them out. A pickle applicator or a special Dryacide® applicator, available from Dryacide Australia through rural supply houses, is the best way to apply such products.

Add amorphous silica powder at the rate specified on the label. If grain is dusty or infested, increasing the application rate will increase its effectiveness. Amorphous silica is not effective on high moisture grain above 12%.

5. Fumigation - Insect control in stored grains with fumigation

The major advantage of fumigation with phosphine (often referred to as "bombing", or "gasing", using eg, Fostoxin, Fumitoxin etc), is that insects can be controlled without moving the grain. See below for dose rates and other critical recommendations.

General information on phosphine fumigation

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 gas. The fumigant must be kept in contact with the insects for **at least 7 days to kill all stages of the insect's life cycle that usually exist in stored grains**. Fumigation in ordinary, unsealed storages will kill some adults but **most eggs, larvae and pupae will survive** to continue the breeding cycle. A silo that is built to be sealed gas-tight is needed to contain sufficient phosphine concentration for long enough to kill all stages of the insects.

Fumigation gives no residual protection to stored grain. In other words, insects will begin breeding, after the phosphine gas concentration has dropped to low levels.

Phosphine fumigant itself leaves minimal residues, and is acceptable to most markets. However, the solid powdery residues left by phosphine generating tablets when they are mixed with the grain are a concern to some markets. It is against label recommendations to mix solid phosphine generating tablets directly into the grain.

Phosphine is effective against insects in most types of grain. But some commodities (for example, oilseeds – linseed, cottonseed) soak up phosphine very quickly, leaving little to kill insects.

Applying phosphine

Most grain growers use phosphine-generating tablets when fumigating. These tablets react with moisture in the air to release phosphine gas. Up to three 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 volumes up to a hundred tonnes.

The problem of tablet residues in the grain can be avoided by putting tablets on trays, suspending trays in the head space or placing trays on the grain surface. An alternative to using tablets is to use phosphine products which are sold as bag chains, belts or blanket formulations. Do not place tablets in heaps on trays – as the tablets on the top smother the tablets underneath preventing full gas release.

Warning: Do not add water to tablets. This causes a dangerous, quick release of gas which is less effective against insect pests.



An ideal simple “tray” for phosphine tablets in a small farm silo. Place tray in silo headspace, suspended or placed on grain surface. Spent tablet residue doesn’t contaminate grain and is easily removed in the tray after fumigant has been vented from silo.

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 dust, so do not carry it in a confined space.

The SIROFLO® system for applying phosphine as a gas

The SIROFLO® application system continually introduces a low concentration of phosphine into a silo from a cylinder for 21 days plus. 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, it has application in specific bulk storage systems. The system using the product named Eco2Fume® is available through [Cytec Australia Holdings](http://www.cytec.com.au/), Baulkham Hills, NSW, Ph: 02 98 466 200, website :www.cytec.com.au/

Dose rate and fumigation times for solid formulations of phosphine

Effective fumigation of grain needs 1.5 tablets per cubic metre of **total storage capacity** (i.e, not the tonnage of grain actually in the storage).

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 below.

Phosphine moves through the whole air space, so apply the same number of tablets whether the storage is full or partly full with grain

Table 8: Phosphine tablets - 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

Notes on Table 8:

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 it contains.

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

Minimum fumigation times 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. See product label for details.

Airing (ventilating) and withholding periods for phosphine

Fumigated grain must be aired before handling to remove toxic gas and to minimise phosphine gas 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 legally transported during this period.

Total fumigation time for phosphine

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, 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. Always refer to the label.

Safety with phosphine

Phosphine is very toxic to people and farm animals. Health workers specify an air concentration of 0.3 ppm as acceptable in work areas. Gas detector tubes are one method of monitoring workplace concentrations. Two Australian firms selling phosphine detectors can be contacted at the [Canary Company](http://www.thecanaryco.com) at www.thecanaryco.com and [Airmet](http://www.airmet.com.au) at www.airmet.com.au. There may be other companies in this field also. Note that most gas detection / monitoring equipment requires regular checking and calibration to verify accuracy and reliability. So potential buyers should be aware of the cost of this checking and service availability.

Guidelines for staying safe when using phosphine:

- DO NOT 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. Fines apply.
- 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 50cm deep.
- Phosphine corrodes electrical wiring in vehicles and buildings.

Refer also to GRDC Advice Notes “[Keep Phosphine Safe](http://www.grdc.com.au/director/events/factsheets)” at www.grdc.com.au/director/events/factsheets, and “[Sealed Silos](http://www.grdc.com.au/director/events/factsheets)” at www.grdc.com.au/director/events/factsheets.

Improving effectiveness of fumigation with phosphine

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. Sealed silos usually cost about 7 - 12% more than the same capacity unsealed silo. Sealed silos need to pass a standard 3 minute half life pressure test to ensure they are capable of retaining the required gas concentrations for sufficient exposure time.

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 during the fumigation or conducting a pressure test prior to fumigation shows you whether the fumigation enclosure is sufficiently gas-tight.

Phosphine concentrations and times required:

- A minimum of 300ppm phosphine for 7 days
- or a minimum 200ppm phosphine for 10 days

You can measure phosphine concentration with a hand pump and gas detector tube. Several companies sell suitable gas detection gear and prices vary.

Shortcuts for using phosphine for quick treatment of grains

A common question asked about quick cleanup of pests of stored grain is, ‘*What can I do to kill the weevils in the grain that I’ve got to deliver today?*’.

There isn’t a quick, easy answer to the immediate problem. The long-term answer is to plan your storage so that the problem doesn’t arise. See treatment times for phosphine and dichlorvos above.

Dichlorvos sprayed on to grain or phosphine fumigation, are the only approved insecticidal “knockdown” treatments (details of use are given above). Some of the residual protectant treatments, such as Reldan + methoprene, or Actellic + methoprene (Table 4 or 5 above), do not have problems with withholding periods or MRLs. However chemical companies will not guarantee that these chemicals will kill adult beetles, even over three days. Methoprene alone has almost no effect against adult insects.

Plan on checking grain (by sieving samples looking for insects) one month and again at one fortnight prior to sale to allow time for treatment if live insects are found. Have at least one gas-tight storage as a “hospital bin” for fumigation of infested grain or, have a calibrated sprayer and an empty storage into which cereal grain can be treated with dichlorvos.

Fumigating stored grain with Vapormate Fumigant® (ethyl formate)

Vapormate Fumigant® (166.7 g/kg ethyl formate) has recently been approved by the Australian Pesticides and Veterinary Medicines Authority and released on to the Australian market by BOC, as a post-harvest fumigant for the control *adult stages* of certain insect pests in stored cereal grains, oilseeds, grain storage premises and equipment (and certain horticultural produce). Vapormate Fumigant® is supplied as a liquified

gas under pressure and is to be applied in sealed, gas-tight chambers. Visit [BOC Gases](http://www.boc.gases.com/products_and_services/) website at www.boc.gases.com/products_and_services/ for full information.

This fumigant is to be used only by **licensed fumigators** who hold appropriate State/Territory license, and are trained in the proper use of required detection devices. *It is not to be applied to farm grain silos as a general use recommendation, by unauthorised, untrained operators.*

Vapormate Fumigant® is approved for control of adult stages only of Rice weevil, Lesser Grain Borer, Rust Red Flour Beetle and Psocids. Application rate in stored grains is 420g/m³. Required exposure period is 24 hours. For treating grain storage premises and equipment, application rate is 420g/m³ and exposure time is 6 hours.

6. Controlled atmospheres - Insect control in stored grains storage using 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 produce a gas mixture toxic to insects. 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 CA's 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.

For further information on controlled atmosphere fumigation, contact the commercial suppliers of appropriate gas and equipment, [BOC Gases Australia Ltd](http://www.boc.gases.com/products_and_services/), Ph on 13 12 62, or BOC's website at www.boc.gases.com/products_and_services/

Contact Organic certifying bodies for specific requirements for organic grains. You can also get basic information on this subject by visiting [NSW Department of Primary Industries](http://www.agric.nsw.gov.au) website at www.agric.nsw.gov.au.

7. Aeration for cooling – to control insects in stored grains

Temperature effects on grain insects

Numbers of common grain pests can increase by 20-25 times a month at typical grain harvest temperatures of 30°C and grain moisture content of 14% for wheat (equivalent to 73% relative humidity (RH)).

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 20°C for most species or below 15°C for rice weevil.

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 well-managed 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 (see **Table 9** for product names) into the top 30cm of grain at the rate of 1kg/tonne of grain. The amorphous silica is diluted when out-loading to levels that are acceptable to buyers. Painting a silo white can reduce surface grain temperature by 4-5°C.

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

For more detailed information on aeration, refer also to:

- DPI&F Note Grain Storage - “Aeration Cooling & Drying”
- GRDC Grains Research Update Advice “[Aeration in On-Farm Storage – What’s Possible](http://www.grdc.com.au/director/events/factsheets)” at www.grdc.com.au/director/events/factsheets.
- GRDC Grains Research Update Advice “[How Aeration Works](http://www.grdc.com.au/director/events/factsheets)” at www.grdc.com.au/director/events/factsheets.

PLEASE NOTE: DPI&F WEBPAGES ARE CURRENTLY UNDER REDEVELOPMENT. PLEASE SEARCH the DPI&F’s Field crops website at www.dpi.qld.gov.au/fieldcrops for the latest information from July 2007.

8. Insect identification – stored grain insect pests

Effective insect management in stored grains requires at least a basic ability to identify the insect species present. This is especially important where insecticide resistance is suspected as the cause of control failures.

See DPI&F Notes for a basic guide to identifying the common insect pests in grain storages:

- Identification of Insect Pests
- Psocid Pests and booklice”
- Bruchids in mungbeans and other pulse crops”
- Mite Pests”.

PLEASE NOTE: DPI&F WEBPAGES ARE CURRENTLY UNDER REDEVELOPMENT. PLEASE SEARCH the DPI&F’s Field crops website at www.dpi.qld.gov.au/fieldcrops for latest information from July 2007.

9. Resistance and failure of insect control treatments in stored grains

Managing resistance to protectants

Resistance of grain insects to protectants has become a major problem in Australia. Mixtures of different protectants have become necessary to effectively manage the range of different insect species normally occurring in stored grains. The recommended and approved insecticides for treating stored grains are fully covered in Tables 2-8 above.

For the latest information on insecticide resistance see DPI&F Note “[Grain Storage - Resistance to Phosphine Fumigant and Protectant Insecticides](http://www.dpi.qld.gov.au/fieldcrops)” at www.dpi.qld.gov.au/fieldcrops

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

- Saw-toothed grain beetle is resistant to fenitrothion, chlorpyrifos-methyl and pirimiphos-methyl.
- Lesser grain borer is resistant to dichlorvos, fenitrothion, chlorpyrifos-methyl and pirimiphos-methyl, resistance to methoprene is now also common. For further information on identification of the common insects of stored grains, see DPI&F’s Note “[Grain Storage – Identification of Insect Pests](http://www.dpi.qld.gov.au/fieldcrops)” at www.dpi.qld.gov.au/fieldcrops.

PLEASE NOTE: DPI&F WEBPAGES ARE CURRENTLY UNDER REDEVELOPMENT. PLEASE SEARCH DPPI&F’s Field Crops website www.dpi.qld.gov.au/fieldcrops for the latest information from July 2007.

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. However, don't jump to the conclusion that every control failure is caused by resistance. Often the reason for control failure can be a problem with the dose rate or application technique.

If you suspect insecticide resistance

If you suspect resistance is causing control failures, you can have your insect specimens tested for resistance. Please send live specimens in grain to:

Food Protection Team,
DPI&F (Entomology)
80 Meiers Road,
Indooroopilly, Qld., 4068.
(Phone: (07)38969433 or (07)38969807).

NB: Please include your full contact details and details of previous grain treatments.

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.
- Use amorphous silica powder instead of chemical insecticides for treating silo surfaces and storage areas after cleanup as 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.

10. Commercial Preparations of Insecticides and Fumigants Approved for Farm-Stored Grains in Queensland

Table 9: Commercial preparations of insecticides and fumigants. Product registrations, trade names and availability are all subject to change. This information was extracted February, 2007 from Infopest – a database of pesticides approved in Australia. (Phone 07 3239 3967 to inquire about Infopest subscription), or Email [Infopest](mailto:infopest@dpi.qld.gov.au) at <mailto:infopest@dpi.qld.gov.au>

Active constituent	Concentr'n of active	Commercial preparation (® - full trade name)	Distributor / Supplier
Amorphous silica (see notes g,s)	900g/kg	Dryacide Grain Protectant®	Entosol, NSW
	900g/kg	Absorba-Cide Sorptive Dust Insecticide®	Growchoice, NSW
	450g/L	Abrade Abrasive Barrier Insecticide®	Growchoice, NSW
	1000g/kg	Permaguard D-10 Insecticide®	Mara Seeds, NSW
Azamethiphos	500g/L	Alfacron 500 Residual Insect Spray® (currently unavailable).	N/A
Carbaryl (see note g)	500g/L	Carbaryl 500 Flowable®	David Gray & Co, WA
Chlorpyrifos-methyl	500g/L	Diplomat Grain Protectant®	Imtrade Aust P/L, WA
		Reldan Grain Protector®	Dow Agrosiences
	500g/L (+ 30g/L methoprene)	Reldan pluS IGR Grain Protector®	
Deltamethrin	250g/L	Delta 250 Insecticide®	Allfire Ent., WA
Dichlorvos (see notes g,s)	500g/L	Dichlorvos 500 Insecticide	Barmac Ind., Qld.
		Dichlorvos 500EC Insecticide®	Imtrade Aust., WA
		D.D.V.P. 500 Insecticide®	David Gray & Co., WA
	1140g/L	Dichlorvos 1140 Insecticide®	Nufarm Aust. Ltd, Vic
	Pressurised gas 50g/kg	Insectigas-D® (for use by licenced &/or authorised personnel only, not normal farm use)	BOC Gases, NSW
Ethyl formate (see notes s, f)	166.7g/kg	Vapormate Fumigant® (for use by BOC - authorised and State licenced applicators only)	
		Fenitrothion (see note g)	1 kg/L

Methoprene (see note g) S-methoprene (see note g, s)	50 g/L	IGR Grain Protectant Aqueous Grain-Star 50 IGR Grain Protectant®	Webcot <u>or</u> Farmoz - as above
	200 g/L	IGR 200 Grain Protectant Aqueous® Grain-Star 200 IGR Grain Protectant®	Webcot <u>or</u> Farmoz - as above
	300 g/L	Rizacon S IGR Grain Protector®	Dow Agrosciences, <u>or</u> Wellmark Int'nl Aust, NSW
	30 g/L	Reldan+IGR Grain Protector® IGR Grain Protectant® Grain Protection Pack®	Dow Ag-sciences Rentokil Initial Webcot
Phosphine (see note f)	Tablets release 1g phosphine	Quickphos Fumigation Tablets®	UPL, NSW
		X-phos Fumigant®	Webcot
		Celphide Fumigation Tablets®	Excel Ind., NSW
		Pestex Fumigation Tablets®	Farmoz, NSW
		Fumaphos Fumigation Tablets®	National Fumigants, WA
		Fumitoxin Coated Fumigation Tablets® Fumitoxin Coated Insecticide Tablets®	Newfarm, Vic
		Gastion Phosphine Fumigation Tablets®	Rentokil Initial
		Sanphos Fumigation Tablets®	Jedcourt P/L, Qld.
	Bag chain, belt release 110 g phosphine	Quickphos Phosphine Fumigation Bag Chain®	UPL, NSW
		Gastion Phosphine Fumigation Belt®	Rentokil Initial
Blanket releases 1.1 kg phosphine	Gastion Phosphine Fumigation Belt®		
	Quickphos Fumigation Blanket® Celphide Fumigation Blanket® Fumaphos Fumigation Blanket®	UPL, Excel Ind., National Fumigants	
Pirimiphos-methyl (see notes g, s)	900g/L	Actellic 900 SF Solvent Free Insecticide® Webtellic 900 Solvent Free Insecticide®	Syngenta Crop Prot, NSW Webcot
	22.8g/L	Conserve Grain Protector® – NOT expected on market in Australia until 2007- 08.	Dow AgroSciences
Notes on Table 9: g - approved grain additives: - s - approved treatment for storages and handling equipment; f – approved fumigant.			

11. Further information

Department of Primary Industries and Fisheries (Queensland), The following **DPI&F**Notes are currently available at

“Grain Storage - Identification of Insects”

“Grain Storage - Bruchids in Pulses”

“Grain Storage - Mites”

“Grain Storage - Psocids – booklice”

“Grain Storage - Insect Resistance to Phosphine and Protectant Insecticides”

“Grain Storage - Aeration for Cooling and Drying”

Further information on grain quality including detailed colour photos is available in ‘*GRAIN QUALITY Winter grain Crops: The Ute Guide*’ by M. Wurst, S. Parker and K. Panagiotopoulos, available from Queensland DPI&F Information Centres. You can also order any DPI&F publications by contacting the DPI&F, Ph: 13 25 23 (interstate callers phone 07 3404 6999, or by calling the Toowoomba Client Service Centre on 07 4688 1415, or [email: mailto:callweb@dpi.qld.gov.au](mailto:callweb@dpi.qld.gov.au)

Contact one of the **National Grain Storage Extension Team**

Qld	Peter Hughes	07 4688 1200
Qld	Philip Burrill	07 4660 3620
Vic.	Peter Botta	03 5761 1647
SA	Peter Fulwood	08 8568 6422
WA	Chris Newman	08 9366 2309
NSW	John Cameron	02 9482 4930

See [DPI&F website](http://www.dpi.qld.gov.au) at www.dpi.qld.gov.au

Phone DPI&F from 8.00am to 6.00pm Monday to Friday (telephone 13 25 23 for the cost of a local call within Queensland; interstate callers 07 3404 6999) or email .

Grains Research and Development Corporation, GRDC Advice Notes:

“[Sealed silos save - keep Phosphine Safe](http://www.grdc.com.au/director/events/factsheets)” at www.grdc.com.au/director/events/factsheets

“[Aeration - How Aeration Works](http://www.grdc.com.au/director/events/factsheets)” at www.grdc.com.au/director/events/factsheets

“[Aeration - What’s Possible?](http://www.grdc.com.au/director/events/factsheets)” at www.grdc.com.au/director/events/factsheets

NSW DPI:

“[On-Farm Storage of Organic Grain](http://www.dpi.nsw.gov.au/agriculture/farm/organic)”, NSW Ag., Agfacts at www.dpi.nsw.gov.au/agriculture/farm/organic

Western Australia Department of Agriculture website at www.agric.wa.gov.au:

“[Sealed Silos make \\$ense](#)”

“[Grain Storage: Maintaining Grain Quality](#)”

“[Grain handling and storage for pulses](#)”

“[Grain Storage: Design and Installation](#)”

http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/FCP/STOR/FN064_2003.pdf

CSIRO Stored Grains Research Laboratory website at www.sqri/CSIRO.au:

[Storage hints](#)