



FUMIGATING ALMOND STOCKPILES ON-FARM

KEY POINTS

- **Maintain orchard pest management:** Stockpiles with low insect levels will have better fumigation results.
- **Fumigate immediately:** If almonds will be stored on-farm for longer than the total fumigation period fumigate the stockpile as soon as it is formed.
- **Effective fumigation:** An effective fumigation requires a critical concentration of fumigant to be maintained for a specified time required to control all insect life stages.
- **Avoid resistance:** Effective fumigation and rotating fumigants can reduce the chance of resistance build-up.
- **Ensure an airtight seal:** to prevent fumigant loss prepare an impervious ground surface, use good quality tarps with welded seals, and create a continuous attachment to the ground.
- **Consider engaging a fumigation provider:** gas will provide the best results in almonds and requires a licenced operator.
- **Monitor gas concentrations:** Daily readings will show when gas levels drop below the critical concentration.
- **Continuously inspect stockpiles:** Use monitoring traps and daily visual inspections for signs of pest activity and consider refumigating if pest insects are detected.
- **Maintain stock-pad hygiene:** Remove trash and spills from stock-pad areas to prevent reinfesting stockpiles.

INTRODUCTION

Almonds are typically stockpiled on-farm before being sent to a processing plant. Insect pests are likely to have been harvested from the orchard and transported to the stockpile where they continue to feed on the almonds if left untreated. Fumigating stockpiles can assist in preventing insect damage while stored on-farm (Figure 1).

Fumigation must be approached with caution because poor practices will not only waste time and money, but insects can develop resistance to fumigants. If stockpiles are not fumigated correctly on-farm, it could remove the ability to use fumigation to control storage pests in almond processing and warehouse facilities as well. Phosphine resistance has already developed for several storage pests in the grains industry and is a real possibility for the almond industry.

Research has shown it is difficult to keep the concentration of gas for the required time to kill insects at all life stages in almond stockpiles. A contributing factor is the absorption of the fumigant by almond hulls and shells, so not all forms of fumigation are effective. It is advised a third party fumigation expert is engaged to apply and monitor gas concentrations.

This factsheet covers best practice for on-farm fumigation of almonds to control insect pests and avoid resistance. This factsheet and should be read together with the following ABA factsheet:

- Harvesting in adverse weather to maintain quality.



Figure 1. Stockpile under fumigation.

ALMOND PEST LIFECYCLES AND DAMAGE IN ALMONDS

Several insect pests can infest almond stockpiles but not all of them cause damage. The most serious insect pests for almonds are Carpophilus beetle (*Carpophilus truncates*) and Carob moth (*Apomyelois ceratoniae*) which infest stockpiles from orchards or trash around the stock-pad. Rust Red Flour Beetle (*Tribolium castaneum*) is a common storage pest and may also be present in low levels. These insect pests result in kernel damage, downgraded quality, lower grower returns, higher processing costs, loss in sales and ultimately affect the reputation of Australian almonds (Figure 2a, b and c).

Insects can complete their lifecycles and continue to breed in stockpiles. The degree of damage depends on how many insects are initially present in the stockpile, and how long the almonds are stored without treatment. For example, Carpophilus beetle eggs can complete their lifecycle in three weeks indicating how quickly pests can build up in numbers and cause substantial damage.

Figure 2a. Carpophilus beetles tend to consume the meat of the kernel and leave behind the brown skin and fine frass (Photo courtesy Agriculture Victoria).



Figure 2b. Carob moth larvae consume both the skin and the meat of the kernel leaving behind coarse, lumpy frass and webbing (Photo courtesy Agriculture Victoria).



Figure 2c. Rust red flour beetle drill pin holes through the kernel skin producing a fine frass or powder (Photo courtesy Agriculture Victoria).



HOW FUMIGATION WORKS

When almonds are stockpiled, it is likely insect pests are already present and actively feeding on the almond kernels. Fumigation is most effective when pest numbers are low. Therefore, stockpiles that are going to be held on-farm for longer than the total fumigation period should be fumigated, as soon as possible after they are formed as insect numbers will be building up each day until treated.

Impact of fumigation on lifecycle stage

It is likely that all lifecycle stages including eggs, larvae, pupae and adult stages, will be present in the stockpile for a number of different insect pests. Different stages of the insect lifecycle are more or less susceptible to fumigation. Eggs and pupae generally take the longest to kill as the fumigant needs to penetrate the hard shell of the egg or pupae casing. Eggs and pupae have a lower metabolism, slowing the uptake of the fumigant. The weather can also influence the metabolic rate of insects and therefore influence fumigation duration. Some species may be more tolerant to the fumigant than others and therefore need longer fumigation time to make sure all pests are eliminated.

Target of control

An effective fumigation will aim to control and eliminate approximately 99.9% of all lifecycle stages for all insect pests.

Critical concentration

To achieve the control target of 99.9% a critical concentration in parts per million (ppm) must be met and maintained for several days as recommended for each fumigant.

Temperature can influence the required exposure, aeration, withholding and total fumigation time. For example, all forms of phosphine require a critical concentration of 300ppm for seven (7) days when temperatures are above 25°C, and a critical concentration of 200ppm for 10 days when temperatures are between 15-25°C. Phosphine should not be applied below temperatures of 15°C. Check the label recommendations for each fumigant.

There are several factors that influence fumigant concentrations and movement through almond stockpiles including: absorption of the fumigant by almond hull and shells, application type, wind and temperature, and the number of escape pathways where gas can be lost (refer to creating an airtight seal).



Total fumigation period

The Total Fumigation Period (TFP) is the sum of the minimum exposure period, plus the time needed to ventilate the fumigant, plus a withholding period of two days after ventilation is completed.

All three components are needed to be observed for effective fumigation otherwise a shortened exposure period will not reach the control target of 99.9% and resistance may develop, a reduced ventilation period poses a serious risk of poisoning staff and bystanders, and a reduced withholding period poses risks for human consumption or stock feed.

For example, the total fumigation period for phosphine is between 10 and 18 days (depending on storage conditions) including the minimum exposure period, ventilation time and withholding period. Check the label recommendations for each fumigant.

Avoiding resistance

If the critical concentration is not reached or maintained for the specified time, it will mean those insects that have managed to survive will produce more resistant offspring. Eventually more resistant insect populations will mean that fumigation is no longer effective and will remove fumigation as an effective pest control option across the almond industry.

Phosphine resistance has already been observed in the grains industry for several storage pests and all efforts should be made to avoid resistance to fumigants in almonds by meeting recommended concentration levels for the specified time period, monitoring fumigant concentrations daily and rotating between different fumigant products.

ALMOND FUMIGANTS

There are very few fumigation compounds that are registered for use in almonds. The two main compounds registered for use in almonds are sulfuryl fluoride (SF) typically applied as a gas and phosphine which comes in three forms: blankets, tablets, and gas.

Gas

Gas fumigation using phosphine or SF is currently the most effective option for on-farm fumigation of almonds as gas concentrations can be monitored.

SF gas and phosphine gas are applied in the same way by injecting in and pushing through the stockpile to allow for an even distribution of the fumigant.

A registered and licensed fumigation provider is required to undertake both SF and phosphine gas fumigations. There are several service providers in Australia (see below). Growers wanting to undertake gas fumigation themselves must first complete the required training and meet licence requirements.

Blankets and tablets

While Phosphine blankets and tablets are registered for use and are readily accessible there are concerns about maintaining the required concentrations uniformly through the stockpile. Tablets and blankets release gas when exposed to air. Tablets are recommended to be evenly distributed along the stockpile, on trays separated from the crop in a way that allows free circulation of gas underneath the gas proof sheeting or tarp.

If using blankets and tablets it is important to monitor concentration levels and be ready to change approach if concentration levels are not reached or able to be maintained.

WHAT TO CONSIDER WHEN FUMIGATING ON-FARM

Timing of treatment

If it will be necessary to move the stockpile before the total fumigation period has expired, then fumigation should NOT be carried out. Movement of treated nuts is contrary to label instruction and there are risks of exposing staff and the public to harmful levels of fumigant.

Start fumigation as soon as possible

When it is known that stockpiles will need to remain on-farm for more than 18 days fumigation should commence as soon as the almond stockpile is formed (Figure 3). This will ensure pest numbers are at their lowest point and therefore will achieve the best result possible as the insect pests will be eliminated before they damage the crop further.



Figure 3. Stockpile that has been correctly sealed ready for fumigation.

Ensure an airtight seal

Escaping gas can result in poor fumigation results and can increase the total fumigation time and cost. Ways to create an airtight bunker and minimise chemical losses include:

- 1) Use an impermeable stockpad surface (e.g. concrete) as soil absorbs fumigant
- 2) Source high quality tarps free of rips, tears or holes to cover the stockpile
- 3) Tarps welded together with heat will hold better than those joined using tape.
- 4) Reduce the number of joins in tarps will reduce the potential for leakage.
- 5) Secure tarps to the ground with a band of sand, tyres or water snakes to provide a continuous seal around the base of the stockpile (Figure 4).



Figure 4. Soil can be used to secure the tarp to the ground and prevent fumigant loss.

Ideally the best solution to avoid gas loss to the environment for fumigation would be to fumigate in sealed silo or shed or silo with aeration to manage gas circulation within the silo. Research is currently being done in this area.

Work health and safety

Check the label recommendations for work health and safety for each fumigant. The label will also describe the required personal protective equipment (PPE) to be worn when applying the fumigant or monitoring gas levels and/or insect activity. At a minimum, full body overalls, glasses, gloves and a full-face respirator coupled with a dust and gas cartridge should be worn. Observe measures implemented by fumigation providers to protect the safety of workers and the environment.

Setting exclusion zones

Before fumigating an almond stockpile, an exclusion zone must be established. Australian regulation states that an exclusion zone of at least 3m when fumigating outdoors and 6m when fumigating indoors is required. Signs need to be clearly displayed around the almond stockpile to indicate that fumigation is being undertaken (Figure 5).



Figure 5. Exclusion zone sign indicating an ongoing fumigation.

Maintaining stock-pad hygiene

Discarded almond material left on or near storage areas, may harbour insect pests and provide an opportunity for re-infestation of stockpiles. Stock-pads and surrounds should be kept clean and free of trash and almond debris at all times.

Calculating stockpile volume

Stockpile volumes are useful to know when calculating fumigant application rates. Once the top of the stockpiles are smoothed or evened out they take the shape of a long trapezoid. To calculate the volume of a trapezoid the following formula can be used:



Stockpile Volume (m^3) = $(B_1 + B_2) / 2 \times H \times L$

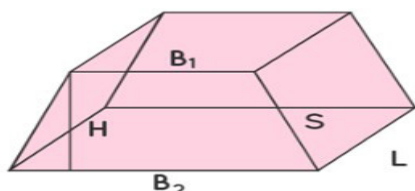
Where: B_1 is the width across the top of the pile.

B_2 is the width across the bottom of the pile.

H is the height of the pile.

L is the length of the pile.

With all measurements recorded in metres.



MONITORING ALMOND STOCKPILES

Successful fumigation can be determined by monitoring stockpiles for critical gas concentrations and insect activity.

Gas monitoring devices

Phosphine monitoring devices can be used to track changes in gas concentrations at various depths, locations and sites in the almond stockpile during and after fumigation. Several devices are available and the price generally reflects the devices functionality (see below).

Monitoring insect levels

After fumigation visual inspections should be undertaken frequently to monitor for insect levels especially after extended storage periods. Insect traps can be installed in and around stockpiles to help detect insect activity. Standard methods to trap insect pests include:

- Pitfall trap, perforated tube, placed in the stockpile where insects crawl in and are collected.
- Pheromone traps target flying insects placed near the base of the stockpile.

If pests are detected, and prolonged storage is imminent, fumigants may need to be reapplied.

FUMIGATION SERVICE PROVIDERS AND SUPPLIES

Fumigation:

- [Genera Biosecurity \(Australian Fumigation\)](#)
- [Fumax](#)

Tarps:

- [Bartlett Industrial Textile Product Manufacturing](#)
- [Polytex](#)
- [Fleximake](#)

Concentration monitoring devices & Personal Protective Equipment (PPE):

- [Draegar Australia](#)
- [Gastech Australia](#)
- [Air-Met Scientific](#)
- [Canary Co.](#)

FURTHER INFORMATION

[Insect management using fumigation in almond stockpiles](#)

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