Combination of cooling with a surface application of Dryacide® to control insects

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Abstract

Cooling with ambient air has been regarded in Australia as useful, but insufficient, for complete control of insects under Australian conditions, where wheat is harvested at the beginning of a typically hot summer. However, the conclusion that insect control is 'incomplete' has been recently re-examined.

Key elements of an improved strategy include aiming at an appropriate temperature regime (e.g. by rapid cooling), rather than merely at an appropriate temperature and supplementing weakness in cooling with other control method/s. In the cases reported in this paper, the other control method was an application of the inert dust, Dryacide®, to the top surface of the grain bulk.

In 1992, aeration in a Victorian silo owned by the Grain Elevators Board controlled insects except in the top approximately 10 mm of the grain bulk. A subsequent application of Dryacide® disinfested the grain. In 1993, grain in a horizontal storage and infested with *Sitophilus oryzae* (L.) was dusted with Dryacide® and aerated. No live insects were found in grain probe traps 2 months after the surface application, though dead insects were detected. In 1994 the procedure was used in grain in three stores in Queensland and the wheat outturned to date has met commercial requirements.

The total procedure is straightforward and leaves no chemical residues in food products. It is currently in commercial use. However, careful management is required for success.

Introduction

Grain cooling is widely used to restrict insect damage and maintain quality in stored grain. However, for insect control, cooling is usually regarded as an adjunct to other control methods. This is particularly the case for aeration in uninsulated stores located in warm climates. Previous attempts in Australia to use cooling alone have given good control of insects and grain quality, but failed to meet the standard of no detectable insects (Ghaly 1984; Elder and Ghaly 1984; R.J. Moran, unpublished data, CSIRO Division of Entomology). However, because insects in aerated stores are normally concentrated on the grain surface (Elder and Ghaly 1984), it may be possible to control these insects by the use of a surface application of an insecticidal material. Armitage et al. (1992) used an application of pirimphos-methyl to the grain surface, combined with cooling, to control insects and mites. Conditions for this control were 15% m.c., wet basis) and temperatures of 5–10°C. Although such dry-bulb temperatures are not easily achieved in Australia, comparable wet-bulb temperatures can be obtained on drier grain. This is important because control of grain quality and insects may be better related to wet-bulb than to dry-bulb temperature (Desmarchelier 1990).

In the general application of cooling plus surface treatment, it is probable that any suitable insecticidal material can be used; in this paper we report the use of surface applications of Dryacide®. This was chosen because it leaves no chemical residues in processed foods.

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Materials and Methods

In this paper we report on three trials where cooling has been used in conjunction with a surface application of Dryacide®. The three commercial-scale trials are termed Manangatang, Warmatta and Marsden, referring to stores in, respectively, Victoria, New South Wales and Queensland.

Trial at Manangatang

In this experiment, a 2000 t capacity vertical silo, belonging to the Grain Elevators Board of Victoria and filled with wheat, was aerated with ambient air. The initial insect infestation was below the limit of detection, as no live insects were detected in deliveries straight from harvesting into central storage. The detection method was three probe samples (approximately 1 kg each) per truck load. Insect populations and grain temperatures were monitored throughout the storage period. Insects were monitored using probe traps (Storgard WB Probe II), with 12 traps placed at each of 0.5, 1.0 and 2.0 m depths. Traps were placed in the wheat at 5 intervals throughout the trial, and the numbers of live insects counted after 1 week of trapping. After 9 months of aeration, grain at the surface (top 10 cm) and in the top 50 cm was sampled by hand and sieved. Aeration was controlled by a dry-bulb temperature set-point controller. Air and grain temperatures were montiored using the same computer (Gibbs, these proceedings).

In addition, the grain was sampled for insects during the outloading of the grain to rail wagons.

Trial at Warmatta

This trial was conducted in a horizontal grain store divided into two units (termed unit A and unit B) each of approximate capacity 1750 t. Wheat was received into each storage in an infested condition. Initial infestation levels were measured by manual probing (6–8 probes of 3 kg per unit) and counting the number of live insects per probe. Subsequently, insect populations were monitored from the catch in probe traps (Storgard WB Probe II, 2 per peak per unit), which were left on the surface of the peak for 1 week on 3 occasions throughout the trial. The wheat was also sampled using grain probes. The wheat was treated with Dryacide® 7 weeks after receival by blowing dry Dryacide® (7.5 kg per storage unit) using a

Venturi applicator. In addition, an extra 2 kg was applied to the peak, and mixed with the upper portion of the grain by 'walking it in'. This gave a coverage to a depth of approximately 300 mm, the same as used by Armitage et al. (1992). Grain temperatures were monitored 0.3 m below the surface. The aeration was controlled by a variable dry-bulb temperature set-point controller, which aerated when air temperatures fell below an established value.

In addition, the grain was sampled for insects during the transfer of the grain to the processing facility.

Commercial usage at Marsden

Wheat was received in a lightly infested condition into three vertical silos of 1000 t capacity. The grain was lightly infested in that most probe samples were free of live insects but some contained 1 live insect, to give an average density of <1 live insect per trap. The upper layers of wheat were treated by mixing 15 kg of Dryacide® with the last 40 t of wheat loaded into the bin. In addition, the surface of each bins was treated with Dryacide® (7 kg per silo) applied by Venturi applicator. The wheat was quickly cooled (14 days of continuous operation per grain storage unit) using refrigerated aeration.

Results

Trial at Manangatang

The wheat in this storage was very dry, with moisture contents from samples being in the range 9–10% (w/w, wet basis). Grain temperatures and insect population densities are summarised in Table 1. Grain temperatures in the bulk fell from 28.2°C in the first week after receival, to 18.2°C 3 months later, to 16.3°C after 5 months, at which time aeration was stopped. Maximum daily temperatures at the grain surface remained above 18.5°C for 5 months (Table 1), presumably due to the steel roof.

The number of insects per trap per week was low throughout the trial, and the majority of insects were found in the centre traps, particually at the surface. For example, in 4 samplings with 33 traps, other than the centre traps, live insects were detected in only 3 of a possible 132 traps (Table 1). Insects detected were *Rhyzopertha dominica* (F.) in one trap, and *Tribolium castaneum* (Herbst) in 2 traps. In contrast, the trap at the surface of the peak always detected live insects before the surface application of Dryacide® (Table 1). Insects detected were *R. dominica* and *T. castaneum.* One or both of the traps 1 and 2 m below the surface of the peak usually contained live insects, except after application of Dryacide®. Immediately before application of Dryacide®, grain was manually sampled. The top 1 cm of the grain was found to contain 5 live *R. dominica* in 20 kg, as well as 3 dead *R. dominica*, 12 dead *T. castaneum*, 1 dead *Oryzaephilus surinamensis* (L.) and 1 dead lathradiid (species unspecified). The top 50 cm of the peak contained one live *R. dominica* in a 3 kg sample, but no progeny developed on incubation. Other grain samples did not contain live insects.

After surface application of Dryacide®, traps were reinserted 1 day later and no live insects were detected 6 days later, when the traps were removed immediately before outloading. The grain on outloading passed the industry test for no live insects, as ascertained by the standard sampling procedures.

Table 1. Grain temperatures and trap catches at Manangatang

Date	Depth (m)	Grain temperature (°C)	Insects/centre traps[a]			Insects/outer traps[a]		
			R.d.	T.c.	Other	R.d.	T.c.	Other
			Per week					
1/1	0.1[b]	34.9	c	c	c	c	c	c
1/1	1	-	c	c	c	c	c	c
1/1	2	28.2	c	c	c	c	c	c
3/3	0.1[b]	24.1	6	12	0	0.09	0	0
3/3	1	-	0	0	0	0	0	0
3/3	2	23.2	1	0	0	0	0	0
30/3	0.1[b]	24.0	10	8	0	0	0	0
30/3	1	-	0	0	0	0	0	0
30/3	2	18.2	1	0	0	0	0	0
6/5[c]	0.1[b]	18.5	1	25	0	0	0.64	0
6/5	1	-	0	4	0	0	0.09	0
6/5	2	16.3	0	10	0	0	0	0
13/8	0.01	-	0.3/kg[d]	0/kg[d]	0/kg[d]	o/kg[d]	0/kg[d]	0/kg[d]
13/8	0–0.3	-	0.3/kg[d]	0/kg[d]	0/kg[d]	0/kg[d]	0/kg[d]	0/kg[d]
19/8	0.1	-	0[e]	0[e]	0[e]	0[e]	0[e]	0[e]
19/8	1	-	0[e]	0[e]	0[e]	0[e]	0[e]	0[e]
19/8	2	-	0[e]	0[e]	0[e]	0[e]	0[e]	0[e]

[a]R.d, *R.dominica*; T.c., *T.castaneum*; other, any other species.
[b]maximum daily surface temperature.
[c]no insects were detected by sieving of samples during receival in the 3 weeks before this date (1/1).
[d]samples by manual probe and sieve, not by trap.
[e]after Dryacide® application on 13/8.

Trial at Warmatta

Grain temperatures and insect population densities are summarised in Table 2.

In each unit, grain temperatures declined within 1 month from approximately 25–30°C to 18-19°C, and after a further month to approximately 13°C (Table 2). The temperature fall at Warmatta was faster than at Manangatang because aeration was started at Warmatta at a cooler time of the year (in autumn rather than in summer).

In each storage unit, insect populations were initially high, e.g. 20–30 per manual probe sample of approximately 1 L. Before the application of Dryacide®, but after the start of aeration, catch numbers were 6–10 per trap per week (Table 2). After application of Dryacide®, no live insects were detected in probe traps near the surface, and from random sampling in the bulk of storage unit A using manual probes. A similar situation applied in storage unit B, with the exception that a localised insect infestation was detected by random sampling using manual probes. This infestation contained 20–30 insects per sample (approximately 1 L).

No insects were detected during outloading of unit A. Unit B is still in storage. The electricity usage averaged 1.8 kWh/t.

Table 2. Grain temperature, insect number per sieve and trap catches at Warmatta, before and after Dryacide® application on 6/5.

Unit	Date	Temperature at 0.3 m (°C)	Insects per sample unit
A	17/3	30	20–30/ 3 kg sieve
	6/5[a]	18	6–10/ trap/ week
	25/5	12	–
	21/7	13	0/trap/week
	2/8	13	0/ trap/week
B	17/3	25	20–30/3 kg sieve
	16/4	19	–
	6/5[a]	18	6–10/ trap/ week
	25/5	12	–
	21/7	12	0/ trap/week
	2/8	12	0/ trap/week
	2/9	13	–

[a]Dryacide® application on 6/5.

Commercial usage at Marsden

The wheat stored at Marsden is in good condition and, although low numbers of insects can be detected in the bulk, insects have not been detected in the grain outloaded to date, using the current industry inspection procedures.

Some effects have been noted on grain characteristics at Marsden. These include an increase in the angle of repose of the wheat at the top of the bin, and a slight decrease in the apparent bulk density of the wheat at the top of the bin which was treated with Dryacide®.

Discussion

In previous Australian work on cooling (R.J. Moran, unpublished data, CSIRO Division of Entomology), aeration proved useful but was unable to meet the industry standard of no detectable insects, as assessed by a standard sampling protocol. Several attempts have been made to overcome the weakness of aeration under Australian conditions where wheat and barley are harvested in spring to early summer, and subsequently stored under hot ambient conditions. These attempts include use of insulated storages and refrigerated air (Sutherland et al. 1970; Elder and Ghaly 1984). While no major damage from insects was experienced, refrigeration presented four principal difficulties. First, insulation is expensive and not durable (e.g. cockatoos tear it off stores). Second, energy consumption is high, e.g. 18 kWh/t (Sutherland et al. 1970) or 25 kWh/t storage capacity (Elder and Ghaly 1984). Third, grain near the surface remained infested, as also occurs with ambient air aeration. Fourth, the large amount of aeration resulted in increase in moisture content, especially near the air inlets, with localised loss of quality (Ghaly 1984); such moisture increase may also occur with aeration if not properly controlled.

It was therefore especially pleasing to observe good insect control in our trials, which used a relatively low degree of cooling and an adjunct, Dryacide®, which leaves no chemical residues in processed products. The method of aeration plus surface application is an attractive alternative to refrigerated aeration in insulated storages.

In some ways, results from the trials reported in this paper were better than expected. For example, the number of insects at Manangatang before application of Dryacide® was lower than expected, and probably below the limit of detection on outloading. The aridity of the grain and the initially low number of insects certainly contributed to these results, but are not a complete explanation, as Australian grain invariably becomes infested if left for 9 months without insect control. Likewise, the rapid disinfestation observed at Warmatta was greater than expected. At least part of the explanation lies with insect behaviour: insects are driven to the surface by aeration. There is clearly a need to understand such insect behaviour, in order to utilise aeration more efficiently in insect control.

The detection of insects in part of storage unit B at Warmatta, however, indicates possible problems with the procedure. The infestation detected was thought to be due to inadequate duct design, which has subsequently been corrected. However, it may also have been due to a poor surface application of Dryacide® as the method of application was being developed as the trial was in progress.

The overall strategy in these trials was very similar to that of Armitage et al. (1992). However, the moisture content of the British grain, 15%, was much higher than that of the Australian grains, 9–11%. This required lower temperatures of 5–10°C on the wetter grain, as against 13–20°C on the drier grain. However, the range of wet-bulb temperatures achieved in each trial was comparable. For example, 10°C, 15% moisture content and 17°C, 10% moisture content have the same wet-bulb temperature of 8.5°C. It is also probably true that initial infestation levels were higher in the British grain than in our trials, and the lower moisture content of the Australian grain resulted in the absence of mites.

Nonetheless, the work reported in this paper and that of Armitage et al. 1992 cover a wide spectrum of grain conditions under which surface application of an insecticide plus aeration gave a high degree of insect control.

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References

Armitage, D.M., Wilkin, D.R., Fleming, D.A. and Cogan, P.A. 1992. Integrated pest control strategies for stored grain—surface pesticide treatments of aerated commercial and farm storages to control insects and mites. Slough, U.K., Home Grown Cereal Authority, 84p.

Desmarchelier, J.M. 1990. A new look at aeration. In: Fleurat-Lessard, F. and Ducom, P., ed., Proceedings of the 5th International Working Conference on Stored products protection, Bordeaux, France, 1173–1181.

Elder, W.B. and Ghaly, T.F. 1984. Insect population dynamics at the surface of refrigerated bulk bins of up to 15,000 tonnes. In: Proceedings of the 3rd International Working Conference on Stored product Entomology, Manhattan, Kansas, USA, 78–98.

Ghaly, T.F. 1984. Aeration trial of farm-stored wheat for the control of insect infestation and grain quality loss. Journal of Stored Products Research, 20, 125–131.

Sutherland, J.W., Pescod, D. and Griffiths, H.J. 1970. Refrigeration of bulk stored wheat. Australian Air-Conditioning and Heating, 24, 30–45.