An assessment of Damfin to control an established infestation of saw-toothed grain beetle in malting barley

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Abstract

Damfin (methacrifos) emulsifiable concentrate, diluted in water, was applied to malting barley infested with *Oryzaephilus surinamensis*. Two methods of application were used: a conventional hydraulic spray nozzle and a dribble bar. Both were equally effective in terms of biological activity and the dose achieved on the grain, but the dribble bar resulted in reduced buildup of dust close to the site of application. A single application of Damfin at an intended dose of 4.75 mg/kg controlled the infestation within 24 hours and prevented reinfestation for the 3-month duration of the trial. Bioassay and chemical analysis of samples of the treated grain showed that good persistence was obtained during this period.

Introduction

Infestations in stored grain cannot be tolerated, as pests will damage grain and the contamination that they cause is unacceptable to the end users. There are a number of effective strategies to prevent insects which can be applied at the start of the storage period. However, when grain becomes infested during storage, particularly if it has already reached the premises of an end user, the options for control are limited.

Grain can often be fumigated in situ but this process may require the closing of the store for up to 14 days in temperate conditions. It is also an expensive process that can be carried out only by an approved contractor. Another option is to treat the grain with a contact pesticide. However, there are few data detailing the speed of action of pesticides used in this way and also some concern over the level of residues created in grain, particularly when it is treated shortly before use. Obviously, a pesticide with a rapid action and which also decayed rapidly, would facilitate such a control option.

The organophosphorous pesticide, methacrifos, is very effective against a wide range of stored-product insects and mites, and has a relatively short residual life (Renfer et al. 1979; Tigar and Pinniger 1989). Some field evaluations of this product have been carried out to assess its effectiveness in giving rapid disinfestation of grain and are reported in this paper.

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Materials and Methods

Layout of the site

The trials were done in the grain store attached to a traditional malting in East Anglia in the United Kingdom during November 1990. The main granary serving the malting consisted of a brick barn housing a series of metal grain bins and the attendant conveying, cleaning and drying equipment. The metal bins were arranged in 6 rows of 7 (Fig. 1) and had capacities of about 40, 50 or 60 tonnes (Fig. 2). The bins had conical bottoms and emptied into a chute leading to a bottom conveyer. Grain was moved around the store by means of a series of belt conveyers and bucket elevators.

There was a general infestation of *Oryzaephilus surinamensis* in the building, and the barley in a number of bins was heavily infested. The manager of the maltings considered that four bins were the most heavily infested (Bins 1, 2, 8 and 9; see Fig. 1) and these were chosen for this trial. However, much of the rest of the grain in the store was also infested and the insects were well dispersed throughout the fabric of the building.

Method of treatment

An emulsifiable concentrate of methacrifos (95% a.i.), diluted in water to 0.66% a.i., was applied to the grain as it was transferred between bins (see Fig. 1) using the standard conveying equipment. As there were large numbers of live insects in the barley, the pesticide was applied to the grain immediately after it left the bin and flowed down the discharge chute. This increased the chance of dosing any insects that might have escaped during conveying but also added to the risk that pesticide would be lost during conveying. After treatment, the grain passed along a belt conveyer, up an elevator and then along another conveyer, before being discharged into an empty bin. The total length of this conveying system was about 25 m.

The diluted methacrifos was applied to the grain at the rate of 750 mL/tonne. Two methods of treatment were used: a commercial grain sprayer with a conventional, hollow cone nozzle; and a dribble bar consisting of a hollow tube with a series of 1 mm holes. The rate of application was monitored in both cases with a flow meter and adjusted with a needle value. Two bins of grain were treated by each method of application. With both methods, the intended rate of application was 4.75 mg of methacrifos per kg of grain.

Technical reasons prevented the rate at which the barley was moved between bins from being measured. Therefore, the estimate of 10–12 tonnes/hour provided by the store foreman was used and the applicator was set accordingly. The start and finish times for each treatment were noted and, as a good

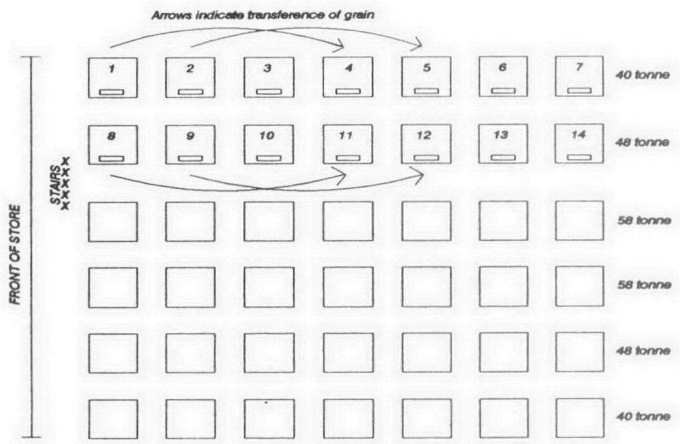

Fig. 1. Plan of the grainstore showing position of bins.

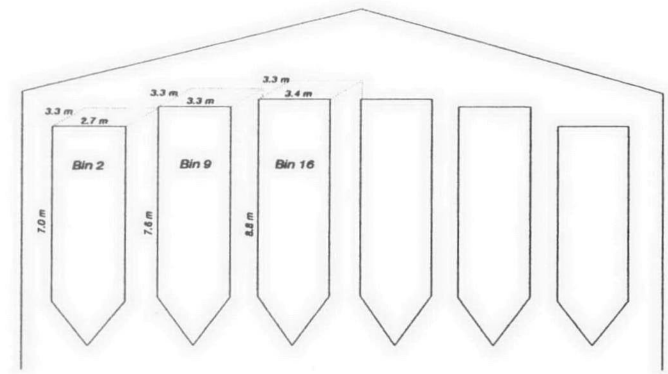

Fig. 2. Approximate dimensions of bins in store.

estimate of the amount of grain in each bin could be made, the conveying rate was calculated retrospectively. As data accumulated during the treatments, some adjustments were made so that the output of the applicator corresponded more closely to the grain flow rate. The amount of diluted spray used during each treatment was recorded, thus allowing the theoretical dosage rate to be calculated.

Assessment of grain quality at time of treatment

During each treatment, 500 g-samples of grain were collected at 15-minute intervals from the chute immediately ahead of the point at which the pesticide was applied. Between 7 and 16 samples were collected, depending on the rate of grain flow and the quantity of grain in the bin. Each sample was sieved over a 2 mm mesh and the number of adult insects in the sievings were recorded. No distinction was made between live and dead insects. The moisture content and temperature of the sieved grain was determined with a capacitance moisture meter (Sinar Agritec G3).

Assessment of grain quality after treatment

During each treatment, a series of samples were collected at 15- minute intervals from the discharge spout, where the treated grain was tipped into the new bin. At intervals of approximately 1 hour, samples were also collected from the discharge point of the bottom conveyer, approximately 3–6 metres after the treatment point. These samples were analysed for pesticide residues.

One day and then 1, 2, 5, 8 and 13 weeks after the grain had been treated, a 3-metre-long, core sample was removed from the centre of each treated bin using a vacuum sampler. Three 500 g aliquots were removed from these samples, sieved over a 2 mm mesh and the sievings examined for insects. At the 1 week and subsequent sample intervals, the remainder of the core sample was taken to the laboratory for biological and chemical assessment. The temperature of the grain at a depth of 1 metre in the centre of each bin was recorded with a thermistor probe on each occasion that samples were collected.

When the 1-week samples were collected, two insect probe traps were inserted into the surface layers of each bin. These were examined for insects at each subsequent sampling.

Determination of pesticide residues

Two methods were used to extract methacrifos from the samples of barley taken for residue determinations. Samples collected during treatment were extracted on-the-spot by the following procedure.

The sample was mixed and then two lots of 25 g were weighed into conical flasks.

50 mL of acetone was added to each flask. 1 mL of a standard malathion spike solution was also added to some samples to provide an analytical check.

The flasks were swirled and allowed to stand for 30 minutes

A 5 mL sample vial was then filled to capacity with the solution from each flask and the vials capped with screw caps.

The vials were kept at about 5°C until the solution was analysed by gas–liquid chromatography.

Samples collected one or more weeks after treatment were taken to the laboratory and extracted using the method specified by Ciba-Geigy for the determination of methacrifos in cereal grains. All the extracts from both methods were analysed by gas–liquid chromatography.

Bioassay assessments

Samples of treated barley from each treated bin were bioassayed by exposing adult insects from three strains of adult insects to the barley. The three species, *O. surinamensis*, *Tribolium castaneum* and *Sitophilus granarius*, were all known to have resistance to OP pesticides, as defined by the FAO discriminating dose test. However, checks against methacrifos using an admixture test have indicated that only low levels of resistance to this compound (×1 to ×1.6 at the LD_{99}) were present. Twenty-five adult insects were exposed on 50 g lots of grain in wide-necked glass jars for 7 days at 25°C and 70% r.h. The insects were then removed from the grain and categorised as live, knocked down or dead. Three replicates were set up for each sample/species combination and controls were set up on untreated barley.

Results

Application of the pesticide

All four bins were treated without problems. The easy access to the application site made this an ideal location from the operations point of view. The only difficulty related to the inability to obtain an accurate estimate of the rate of grain flow during the treatments. The flow rate for each bin was set by means of a gate in the bin outlet chute so some variations between bins were inevitable. However, the tonnage of grain in each bin was known with reasonable accuracy so that, by noting the start and finish times, the actual conveying rate could be calculated for each bin of grain. This, together with a record of the amount of diluted pesticide used, allowed the theoretical dose to be calculated. The grain flow rate and calculated dose for each bin are given in Table 1.

There was little opportunity to observe the differences between the conventional nozzle and dribble bar as the conveying system was largely enclosed. However, in the immediate vicinity of the point of application, there was a greater build-up of dust stuck to the walls of the conveyer with the conventional nozzle. This may indicate that spray was being lost in the form of drift.

Condition of grain

The mean numbers of insects found in the samples collected during treatment and the grain temperature and moisture content are given in Table 2. No moisture data are available for Bin 1 because of equipment failure but it is very likely that the moisture content of the grain in this bin was similar to that found in the other three bins. All insects found in the samples were *O. surinamensis*.

The samples of grain removed from the bins 24 hours after treatment contained no live *O. surinamensis*. No live insects were found in any of the samples subsequently removed from the treated grain, nor were any insects found in the probe traps.

After treatment, the temperature of the grain at the centre of the treated bins was in the range 10–14°C. Exceptionally, the temperature in one bin (Bin 12) rose to about 17°C during the 2 weeks after treatment, but then fell to about 14°C for the remainder of the trial.

Pesticide residues

The mean, maximum and minimum level of residues, together with the standard deviations for the samples collected during the treatment of each bin are given in Table 3. The mean dose for all bins is below both the intended dose of 4.75 mg/kg and the calculated dose for each bin based on the amount of pesticide used. However, the treatments are consistent, apart from Bin 1, where the conveying rate was well above the predicted level. There is a large difference between the maximum and minimum values, showing that variations occur between small, individual batches of grain, probably caused by fluctuation in the conveying rate. An analysis of the variation between replicate, analytical samples confirmed that neither the extraction nor the analytical techniques were responsible for the variation.

The results from the small number of samples collected from the bottom conveyer, close to the point of application, gave mean values of Bin 1: 0.9 mg/kg; Bin 2: 0.2 mg/kg; Bin 8: 6.0 mg/kg; Bin 9: 4.4 mg/kg. The variation between samples was also much greater, suggesting that the lack of mixing of the treated grain was causing sampling problems.

The levels of residues determined in samples collected after treatment are given in Table 4.

Laboratory bioassay

The results of the laboratory bioassays are given in Table 4. There was no mortality of control insects of any species throughout the trial.

Discussion

The structure of the store and the wide distribution of the insects in both the grain and on the fabric of the building, limited the options for control. For example, continuous access to the store was required, so fumigation would not have been possible. The level of infestation detected during the treatments was high and must have constituted a serious

Table 1. The amount of grain treated, conveying rate and calculated dose of pesticide for each of the treated bins.

Bin[a]	Tonnes	Nozzle	Conveying rate (t/hour)	Pesticide used (litres)	Calculated dose (mg/kg)
1	38	Spray	16.8	20	3.3
2	40	Dribble bar	14.2	28.5	4.5
8	50	Dribble bar	14.2	44	5.6
9	48	Spray	12.8	38	4.8

[a]Bin numbers indicate origins of grain.

Table 2. The level of infestation, moisture content and temperature of the grain, as determined by the examination of samples collected during treatment.

Bin[a]	Insects/500 g			Moisture content (%)			Temperature (°C)		
	mean	max.	min.	mean	max.	min.	mean	max.	min.
1	30	105	2		No data		10.9	13.2	8.6
2	31	213	5	12.9	13.3	12.7	12.0	15.6	6.4
8	40	334	2	12.9	13.3	12.5	10.8	14.3	6.1
9	6	20	2	13.1	13.5	12.7	13.9	17.1	8.4

[a]Bin numbers indicate origins of grain.

Table 3. The level of methacrifos residues found in samples of barley collected during treatment.

Bin	Nozzle	Methacrifos residues (mg/kg)			
		mean	max.	min.	S.D.
1	Spray	2.3	2.8	1.9	0.26
2	Dribble bar	3.7	4.2	2.8	0.39
8	Spray	3.8	4.9	1.1	0.79
9	Dribble bar	3.8	4.6	3.2	0.35

problem. There are no data on the damage caused to malting barley by *O. surinamensis*, but there must have been a risk of the insects attacking the germ of the barley grains and reducing its viability. In these circumstances, turning and treating with a pesticide was one of the few options and certainly the most cost-effective one.

The application of methacrifos to the grain gave rapid and effective control of the infestation. The relatively cool grain (<15°C) would not have been conducive to rapid action but no live insects could be found in the grain 24 hours after treatment. Moving infested grain often stimulates insect activity but no migration of insects from the conveying systems or treated bins was noted, suggesting that the treatment produced a rapid knockdown.

The widespread distribution of insects on the structure of the building, and the presence of other bins of infested grain, meant that there was a high probability that the grain would become re-infested if the pesticide failed to give a period of protection after treatment. However, the absence of any live insects in either grain samples or the probe traps indicated that the application of methacrifos protected the grain from re-infestation for the three-month period of observation. Post-treatment protection arising from admixture treatments is related to the dose applied and its subsequent persistence. Analysis of samples collected during the treatment showed that between about 50 and 80% of the intended dose of 4.75 mg/kg could be recovered from the grain, which must be regarded as a satisfactory result for a field treatment. Subsequent monitoring of the residues showed only a modest decline over the three-month period and these findings explain the lack of reinfestation despite the proximity of insects. The temperature of the grain remained below a maximum of 17°C and mostly below 14°C after treatment and this must have reduced the rate of breakdown of the methacrifos compared with the results obtained by other workers (Bengston et al. 1980). The low moisture content of the grain may also have reduced the rate at which the residues decayed.

The laboratory bioassays confirmed the effectiveness of the treatment. Complete control of all insects was obtained in every case except for one sample taken three months after treatment, where only 96% of the *T. castaneum* were killed.

Variations in the rates of grain flow were almost certainly responsible for variations in the dose achieved by each treatment. Unfortunately, these variations were large enough to mask any difference between the efficacy of the two methods of application. However, the results obtained with the dribble bar, in terms of dose achieved and the standard deviation, were as good as those from the conventional spray nozzle. The

Table 4. The results of chemical and biological assessment of samples of treated grain removed at intervals after treatment. Bioassays were carried out with adults of resistant strains of *Tribolium castaneum*, *Sitophilus granarius* and *Oryzaephilus surinamensis*.

Bin[a]	Weeks after treatment	Residues (mg/kg)	Mortality after 7 days (%)		
			OS	SG	TC
4	1	2.6	100	100	100
5		4.0	100	100	100
11		3.2	100	100	100
12		3.7	100	100	100
4	2	2.7	100	100	100
5		4.0	100	100	100
11		3.5	100	100	100
12		4.0	100	100	100
4	5	1.9	100	100	100
5		3.1	100	100	100
11		3.4	100	100	100
12		2.8	100	100	100
4	8	2.1	100	100	100
5		3.3	100	100	100
11		3.1	100	100	100
12		2.9	100	100	100
4	13	2.9	100	100	100
5		3.5	100	100	100
11		3.1	100	100	100
12		2.9	100	100	96

[a]Bin numbers indicate holding bin for treated grain.

dribble bar does have advantages for practical applications, such as the reduced risk of blockage because the orifice size is much larger than that in a hydraulic nozzle. Further development of this method of applying pesticides to grain would seem to be warranted.

Acknowledgments

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