FIELD TRIALS ON ETHYL FORMATE FOR ON-FARM STORAGE FUMIGATION

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Introduction

After 2005, methyl bromide will be phased out leaving phosphine as the only registered fumigant available for farm use in Australia. Fumigation with phosphine requires a long (>5 days) exposure in sealed bins at temperatures above 15°C. The majority of existing farm bins are unsealed and therefore unsuitable for effective fumigation as concentrations cannot be maintained for the time required for total insect control. The over-reliance on phosphine in unsealed bins in Australia has resulted in 1) a higher frequency of resistance, 2) dangerous practices, and 3) grain delivered to grain depots containing live insects and unreacted aluminum phosphide residues. There is an urgent requirement for the development of a multifunctional grain treatment for on farm use which should be inexpensive and easy to handle and administer.

For the past few years, the CSIRO Stored Grain Research Laboratory (SGRL) has been re-evaluating ethyl formate as an alternative fumigant for grain stored in unsealed farm bins. Ethyl formate has a long history of use as a fumigant for stored products and is currently registered as a fumigant for dried fruit in Australia. It is a colourless liquid with a low boiling point (54.1°C) and a pleasant aromatic odour. It occurs naturally in soil, the ocean, vegetation and a range of food products, including vegetables, fruit, grain, beer and animal products such as milk and cheese.

On-Farm Storage Trials

Recently, SGRL has conducted several successful trials with ethyl formate on wheat (Harden, NSW), sorghum (milo) (Warwick, QLD) and split faba beans (Two Wells, SA) in unsealed farm bins (Table 1). The liquid ethyl formate was applied as a pulsed, or double dose, to the top of the grain through a PVC probe (ϕ 4cm $\times$ 1.2m). This method of application was chosen to: maintain ethyl formate concentrations below the flamability level; reduce vapourisation and maintain an effective concentration of ethyl formate for >10 hours; and avoid liquid ethyl formate accumulating at the bottom of the bin.

Table 1. Details of farm bins trialed with ethyl formate on three commodities

Commodities	**Bin**	**Wheat**	**Faba bean splits**	**Sorghum**
Bin capacity/ Amount of grain	1	125t/125t	75t/75t	145t/140t
	2	125t/125t	75t/75t	140t/135t
Moisture content (wb)		11.1%	11.8%	15.2%
Grain temperature	1,2	32°C, 32°C	27°C, 27°C	20°C, 10°C
Dose of ethyl formate		85g/t × 2	85g/t × 2	85g/t × 2

Bioassays were conducted by placing mixed aged insects in metal insect cages (2.5 cm × 3 cm o.d.) containing a standard laboratory culture medium for that species. These were inserted into the grain bulk at least 0.5 m from the walls and at a depth of 1-4 m. The bioassay samples were retrieved at the end of the fumigation period. The live and dead adult insects were counted, removed and the remaining mixed aged cultures incubated at 25°C and 55-60% r.h. Subsequent emerging adult insects were counted weekly for a period of 6 weeks, and live and dead adults removed at each count.

During application, exposure and aeration, the in-bin gas samples from each sampling point (11 sampling lines were located at 3 levels+bottom+headspace) were withdrawn at timed intervals using an electric pump (2 L/min). Fumigant concentrations were determined on-site using a PHOTOVAC 10S Portable Air Analyser GC, equipped with PID. After fumigation, the grain samples were collected from different depths (0.5, 2 and 3 m) in the bin for analysis of ethyl formate residues.

Results

With wheat, the concentration of ethyl formate was maintained at effective levels for about 2 days, all insects at all stages were killed rapidly (Tables 2, 3), and after another 3-5 days, the residues were reduced to natural levels (Table 3) without aeration. Faba beans sorbed ethyl formate strongly and the residues persisted longer, but full control was achieved. Control was high but not not 100% in the sorghum trials. Residues in the sorghum at 10ºC persisted significantly longer than at 20ºC. During application and fumigation, the levels of ethyl formate in the working environmental did not exceed the worker safety level of 100 ppm (TLV).

Table 2. Control (%) by ethyl formate in farm bins containing different commodities

	Bin	*Sitophilus oryzae*	*Rhyzopertha dominica*	*Tribolium castaneum*	*Callosobruchus phaseoli*
Wheat	1	100	100	100	-
	2	100	100	100	-
Faba bean	1	100	100	100	100
	2	100	100	100	100
Sorghum	1	84(38-100)	99(97-100)	100	-
	2	96(84-100)	100	100	-

Table 3. Mean intra-bin ethyl formate concentrations and residues in grain

	Bin	First reading g/m^3	Day 2 reading g/m^3	Last reading g/m^3	Residue mg/kg
Wheat	1	82	48.4	8.8	3.32
	2	80	43.6	23.5	3.12
Faba bean	1	76	9.9	3.6	34.6
	2	67	10.7	3.4	41.4
Sorghum	1	57.7	6.6	3.8	7.02
	2	58.9	5.8	1.6	36.0

Conclusions

Field trials have shown that ethyl formate has good potential as a fumigant in unsealed farm bins. Unlike phosphine, which takes days to kill insects, ethyl formate kills rapidly. Residues can be reduced to natural levels without aeration. It also has the added advantage of degrading to non-poisonous and naturally-occurring products (formic acid and ethanol).