EFFECTIVENESS OF MAGNESITE AS A PROTECTANT OF FARM-STORED OATS

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Summary

The effectiveness of finely divided magnesite (magnesium carbonate) as a protectant of stockfeed oats on-farm was assessed in laboratory bioassays, small bulk simulations and normal silo storage. Oats of moisture content 10% or 12% were dusted with magnesite at 1-10g/kg and challenged with adults of seven grain insect species. Rates of between 1.0 and 6.3g/kg of magnesite on oats of 10% moisture content were required for 90% adult mortality after 21 days exposure. The order of decreasing susceptibility and the approximate rate required to limit progeny to less than the number of parents was *Sitophilus granarius, Oryzaephilus surinamensis, Cryptolestes ferrugineus, S. oryzae*, 2g/kg> *Rhyzopertha dominica, Tribolium confusum* 5g/kg > *T. castaneum* 10g/kg. At 12% moisture, only *C. ferrugineus* and *O. surinamensis* progeny were controlled effectively (5g/kg). In small bulks of treated oats at 13% moisture, *S. oryzae* developed larger infestations than *T. castaneum, R. dominica* and *O. surinamensis*, and natural infestations of psocids also developed in these treatments. In silo trials the dominant species in most infestations was *T. castaneum*, but other species were also detected, including psocids. The protection period varied from less than three months to at least two years, and was longest where oats were stored at moisture contents lower than 10%.

Keywords: Magnesite, protectant, stored oats, infestation, insecticide, storage insects, farm silos

INTRODUCTION

Cereal grains such as oats are often retained on-farm in Australia as drought-reserve stockfeed. The grain may be stored for periods of 1-5 years in unsealed storage structures with little protection against attack by grain insects. Chemical grain protectants are not suitable for long-term storage because of residue decay, and label effectiveness claims are limited to 9 months control. Effective fumigation would be impractical in the type of storage commonly used and would provide only short-term salvage of grain. Insect infestations could result in significant damage to the grain as well as cross-infestation of high quality marketable grain stored nearby.

Many desiccant dust treatments with abrasive or sorptive properties were assessed for protection of grain during war-time storage (Parkin 1944; Fitzgerald 1944). Magnesite (magnesium carbonate) was considered to be the most effective product of several mineral dusts tested in trials where bagged wheat was challenged by *Sitophilus oryzae,* rice weevil, over a 12-month period (Gay *et al.* 1947). By current standards only limited protection was achieved, and the effectiveness varied between and within natural deposits. However it was considered acceptable at the time despite natural infestation by *Rhyzopertha dominica*, lesser grain borer, since untreated wheat was completely destroyed when stored in the same conditions. Finely-ground magnesite had at one time been recommended as a treatment for stock feed grain using a rate equivalent to 10 g/kg (Nicholson 1959). This rate resulted in extremely dusty conditions during application, and adversely affected the grain flow and the performance of augers. A rate of 5 kg/t was adopted as a compromise between reasonable effectiveness and ease of handling.

Magnesite has since been used with varying degrees of effectiveness to manage insect infestations in oats retained for on-farm use in parts of southern NSW. Treated grain was suitable for direct feeding to stock but was difficult to handle. Magnesite was also found to be moderately effective in laboratory trials against *S. oryzae* on organic rice (Milvain 1992), but little other recent objective data on insect control were available. This paper reports laboratory and silo-based assessments of the level of protection given by magnesite-dusted oats against a range of grain insects, and the practical limitations of this product.

MATERIALS AND METHODS

Insects

Seven species of grain insect common to NSW were reared at 26°C and 60% rh. The whole grain feeders *Rhyzopertha dominica* (Fabricius), lesser grain borer, *Sitophilus oryzae* (Linnaeus), rice weevil, and *S.*

granarius (Linnaeus), granary weevil, were reared in wheat conditioned to 12% moisture content. *Tribolium castaneum* (Herbst), rust-red flour beetle, *T. confusum* Jacquelin du Val, confused flour beetle, *Oryzaephilus surinamensis* (Linnaeus), sawtoothed grain beetle, and *Cryptolestes ferrugineus* (Stephens), flat grain beetle, were reared in a medium of rolled oats, kibbled wheat and yeast (8:8:1). Standard insecticide-susceptible reference strains were used where possible, except for representative field strains of *R. dominica* (fenitrothion-resistant) and *T. castaneum* (malathion-resistant). Adult progeny were used in laboratory assays after developing for 8 - 12 weeks.

Laboratory grain assays

Bulks of oats, variety Cooba, were conditioned to target moisture contents of 10%, 12% or 13% (w/w) by addition of water in a rotating mixer followed by equilibration for several days. Grain moisture was monitored before and during the trials by a portable moisture meter, (Pfeuffer HOH from Graintec, Toowoomba Qld) which was calibrated against oat flour samples oven-dried to constant weight at 130°C.

In the first trial, a range of magnesite treatments was evaluated on oats conditioned to 10% and 12% moisture content (w/w). Oats (50 g) were placed into glass bottles and magnesite was individually weighed into each bottle at rates of 1, 2, 5 and 10 g/kg. Bottles were secured with an open lid over filter paper and were tumbled by hand in a consistent action to ensure the grain was uniformly treated. Fifty insects of each species were added to individual bottles. Each combination of moisture content, insect species and magnesite rate, including untreated controls, was replicated three times. Infested bottles were stored in controlled environment rooms or chambers at 26°C and either 45% rh or 58% rh for oviposition. These equilibrium relative humidities corresponded to 10% and 12% moisture content respectively. Parents were removed after three weeks to be assessed for mortality, and the grain was returned to the constant environment. After a further 5 - 10 weeks, depending on species and conditions, adult progeny in each treatment bottle were counted and assessed for mortality. Effectiveness was measured as LC90 of parent insects using a maximum likelihood probit program after Finney (1971), and also as the minimum rate of magnesite required to limit progeny to less than the number of parents in all replicates.

In a second trial, magnesite at the 5 g/kg rate was bio-assayed at 13% moisture content to simulate poor storage conditions. Duplicate samples of treated grain (200 g) were infested separately with 50 adults of *R. dominica, S. oryzae, T. castaneum* or *O. surinamensis,* and total adults present after 16 weeks storage at 26°C and 65% rh were counted.

Small bulk storage

Bulks (50 kg) of oats at approximately 12% moisture content were dusted with magnesite (2.5 g/kg or 5 g/kg) in a mixer and tumbled into portable 120 L storage bins ("Sulo" bins). For comparison, a further bulk was treated with Dryacide® at label rate of 1 g/kg. Dryacide® is a sorptive dust insecticide that is registered for admixture to farm-stored feed grain to prevent insect infestation. Each bulk was infested with approximately 1000 insects of *S. oryzae, R. dominica, T. castaneum* and *O. surinamensis,* and was placed under shelter at Glenorie NSW for approximately 5 months during summer and autumn. The storage period simulated worst-case conditions of storage in a warm, humid, near-coastal environment. Lids were left partly open and a perforated conduit was driven into each bulk to allow moisture equilibration. At the conclusion of the trial the effectiveness of control was estimated from the number of live insects sieved from each complete bulk over an inclined screen mesh (White 1983).

Farm silo storage

Seven bulks totalling 365 t were dusted with magnesite on inland properties of farmers who were familiar with the product. The average of the treatment rates chosen by farmers was 3.1 g/kg (range 1.2-4.9 g/kg). Magnesite was applied by the method normally used on the farm and the rate was estimated from the amount used and tonnage treated. Dust was applied in one of three ways; usually by even admixture at the auger loading point; or by "sandwich" treatment applying heavy dusting to first and last loads only; or by layered treatment. The last method was achieved by adding magnesite to the grain surface on each delivery truck. Most dust then became entrained in the first portion of the load during tipping, with the effect that heavily dusted grain entered the silo before grain with little or no magnesite. Several truckloads were needed for filling of silos, leading to layers of treated grain in the silo. Insect infestation during storage was monitored at the bulk surface using probe traps, and infestation in the main bulk was estimated using an inclined sieve (White 1983) on 50 kg samples taken at out-loading.

RESULTS

Laboratory grain assays

Magnesite at 2 g/kg or less gave high mortality of adults (LC90) of *S. oryzae, S. granarius, O. surinamensis* and *C. ferrugineus* in oats at 10% moisture (Table 1), and limited the number of progeny to less than the number of parents. Rates of 5 or 10 g/kg were needed for a similar level of control of adults and progeny of *R. dominica, T. confusum* and especially *T. castaneum*. In grain at 12% moisture only *C. ferrugineus* and *O. surinamensis* progeny were controlled effectively by 5 g/kg. All other species tested were not controlled adequately in moist grain, even at 10 g/kg. Mean F1 progeny of all species exceeded 100 in untreated oats in all cases except *C. ferrugineus* at 10% moisture content. At 13% moisture, the number of mixed generation progeny of *S. oryzae* (14.1 per parent) that developed in oats treated with 5 g/kg magnesite far exceeded *T. castaneum* (4.2), *R. dominica* (3.3) and *O. surinamensis* (2.2).

Small bulk storage

Magnesite-treated oats that were stored in small bulks above 12% moisture developed larger infestations of *S. oryzae* than other species (Table 2), and natural infestations of psocids also developed in these treatments. By comparison, grain treated with Dryacide® remained clear of live infestations despite a similar challenge. Grains from the surface of the bulks treated with magnesite sustained damage caused by insect feeding activity.

Farm silo storage

The effectiveness of magnesite on oats stored on-farm varied from poor to excellent, depending on the initial moisture content of the grain and the method of application (Table 3). Bulk S was the driest of the seven bulks under test, and gave effective long-term protection despite the magnesite rate being low. All other bulks developed infestations, and five were fumigated with phosphine as a precaution or as a salvage measure. The dominant species in most infestations was *T. castaneum* but several other species were also detected, including psocids (Table 4). The infestation of *O. surinamensis* at site B, where only the first and last loads had been treated, probably developed in the untreated middle portion of the bulk. The infestation of *Cryptolestes* spp in bulk N was localised to a small amount of wind-rowed oats at higher moisture content than the main bulk.

Surface infestations of *T. castaneum* were particularly heavy in bulks G and H from the same property, where oats had been harvested early with numerous green heads and other admixture seeds. *T. castaneum* also developed large numbers at site R where the magnesite had been layered, and consequently the surface was virtually unprotected.

DISCUSSION

In dry oats of 10% moisture content, *Tribolium* spp. were least susceptible to magnesite and would be expected to dominate any infestation that might develop. The current silo trials generally confirmed this prediction, with *T. castaneum* being detected to

Table 1. Minimum rate of magnesite (g/kg) required for limitation of infestation by seven species of grain insect on treated oats in laboratory assays.

Species		Magnesite rate required (g/kg)			
	Control level:	LC90 parents[a]		F1 progeny less than parent no.	
	Moisture content:	10%	12%	10%	12%
S. oryzae		2.0 (2.3-1.8)	2.7 (3.2-2.4)	2	>10
S. granarius		1.0 (1.4-0.7)	3.5 (4.2-2.9)	1	>10
R. dominica		3.9 (5.2-3.0)	>10	5	>10
T. castaneum		6.3 (7.3-5.4)	>10	10	>10
T. confusum		4.6 (5.4-4.0)	>10	5	>10
O. surinamensis		1.5 (1.9-1.2)	8.7 (13.5-5.6)	1	5
C. ferrugineus		1.8 (2.2-1.6)	10.7 (14.7-7.8)	1	1

a 95% fiducial limits in brackets

Table 2. Infestation recovered from treated oats (50 kg) after challenge with mixed populations of grain insects at a near-coastal site.

Species	Live adult progeny after 5 months storage on-farm		
	Magnesite 2.5 g/kg	Magnesite 5.0 g/kg	Dryacide® 1.0 g/kg
S. oryzae[a]	11,700	3,450	0
R. dominica[a]	90	0	0
T. castaneum[a]	150	420	0
O. surinamensis[a]	200	0	0
psocids[b]	many	moderate	none seen
Moisture content (n=6)	12.6±0.2	12.1±0.3	12.3±0.3
Damaged grains (n=500)	8%	6%	0.2%

a initial infestation of approximately 1000 adults of each species
b natural psocid infestation

Table 3. Summary of inland on-farm silo trials of magnesite-treated oats.

Site	oats	Moisture content (%)[a]	Magnesite	Method	Storage (months)	Farmer assessment
S	25t	9.2	2.7 kg/t	admixed	24	very satisfactory
N	28t	9.8 (11.8)	4.0 kg/t	admixed	6	acceptable
R	24t	10.7 (12.6)	4.9 kg/t	layered	9	qualified acceptance
B	48t	12.3 (13.4)	4.0 kg/t	sandwich	6	qualified acceptance
E	44t	10.5	1.2 kg/t	admixed	3	acceptable for short-term
G	90t	11.8 (17.1)	2.5 kg/t	admixed	6	unsatisfactory
H	16t	11.5	2.5 kg/t	admixed	4½	unsatisfactory

a moisture content at intake; figures in brackets measured at the surface after storage

some extent in every infested bulk, sometimes in enormous numbers. Nair (1957) also found *T. castaneum* to be less susceptible than other species when adults were immersed directly in dust, and he concluded that the smooth surface of this species shed the dust more readily than other species.

In moist oats of 12% moisture content, progeny of both *Sitophilus* species were poorly controlled although adults were the most susceptible of the species tested. This appears to be related to the behaviour of *Sitophilus* adults, which oviposit directly into the dusted grains, thereby protecting the progeny from the effects of magnesite during development. *S. oryzae* developed large infestations in treated bulks stored in a near-coastal environment, but not in any of the inland silos despite being detected in several bulks. The highest incidence of *S. oryzae* (30/trap) was found after six weeks monitoring at the first sampling in bulk N, but the infestation declined to low numbers following surface fumigation.

O. surinamensis and *C. ferrugineus* were the most susceptible species based on potential for progeny development, and low rates of magnesite would therefore be expected to limit infestations of these species effectively in treated oats. *O. surinamensis* is a common pest of farm-stored oats and sometimes is the only species detected. It is highly resistant to fenitrothion in eastern Australia, and some strains are also highly resistant to all organophosphates

Table 4. Infestations detected in inland on-farm silo bulks of magnesite-treated oats.

Site	Species	Surface infestation (mean insects/trap) months in storage				Insects at out-load	Comment
		1.5	3.0	4.5	6.0		
S	*T. castaneum*	n/a	n/a	n/a	n/a	0/50 kg	trial observed at 24 months only
	others	n/a	n/a	n/a	n/a	0/50 kg	
N	*T. castaneum*	0.5	3.0	3.5	0.0	0/50 kg	fumigation at 1.5 months
	others	49	24	11	1.0	4/50 kg	*S. oryzae*, *Cryptolestes* sp, *R. dominica*
R	*T. castaneum*	n/a	18	450	100	0/50 kg	layered treatment – unprotected surface
	others	n/a	0.5	2.0	1.0	0/50 kg	*O. surinamensis*
B	*T. castaneum*	38	0.5	0.0	0.5	4/50 kg	fumigation at 1.5 months
	others	48	4.0	9.0	2.5	17/50 kg	*O. surinamensis* > *R. dominica* and *S. oryzae*
E	*T. castaneum*	1.0	11	n/a	n/a	n/a	fumigated at beginning of storage
	others	1.0	0.0	n/a	n/a	n/a	*S. oryzae*, psocids
G	*T. castaneum*	n/a	51	210	>500	93/50 kg	salvage fumigation and treatments applied
	others	n/a	190	3.0	40	0/50 kg	*Typhaea stercorea*, *O. surinamensis*, psocids
H	*T. castaneum*	n/a	2.0	230	n/a	25/50 kg	fumigation at 1.5 months
	others	n/a	1.0	3.0	n/a	0/50 kg	*R. dominica*, psocids

n/a trapping not available, or grain already removed

registered for use (Wallbank 1996). Magnesite may therefore provide an appropriate alternative control measure at sites where this species has a history of recurring.

The criterion for effectiveness of fewer F1 progeny than parents, should result in infestations being limited to low levels in short to medium-term storage. This is likely to be acceptable where grain is to be used for stockfeed on-farm, but not for grain to be sold. Where infestations were not completely eliminated, the surviving parents may continue to produce progeny beyond the period of observation in the laboratory experiments, and limit effectiveness for long-term storage. Effectiveness would also decrease in localised areas of the grain mass where moisture was absorbed from ambient air or increased as a result of insect activity. In some cases in the silo trials, a surface infestation developed and accelerated but the main bulk remained relatively clear of infestation.

The main factor influencing the effectiveness of magnesite was the moisture content of the oats, although the treatment rates may also have been relevant since they were lower than recommended from the laboratory trials. Bulk S was stored safely for two years with a rate of 2.7 g/kg, indicating that magnesite has good potential for protecting stockfeed oats for extended periods when the grain moisture is very low (9.2%). Storage periods up to six years were reported by Greening (1974), but the conditions for achieving this period of protection were not described.

Farmers in this trial generally assessed magnesite as giving acceptable control subject to some qualification about the length of safe storage, but most also opted for superficial fumigations within two months of commencement of storage. One farmer assessed magnesite as unsatisfactory for his purpose but agreed that the condition of the grain was unsuitable for long-term storage. In this case moisture increased to over 17% at the central peak and was only partly salvaged by fumigation and dichlorvos treatment. The intention had been to store for at least two years, but the early failure of the magnesite forced the grain to be utilised prematurely.

Magnesite is allowed as an addition to feed grain but it is not used in the wider commercial stockfeed industry, nor is it registered as a grain protectant. In addition the scenario of using magnesite on-farm for protecting drought-reserve oats for several years appears to be feasible only with dry grain. The amount of magnesite currently sold per annum would treat no more than 10,000 tonnes of grain if all were to be used for grain protection. Its cost of approximately $1.50 per tonne when applied at an application rate of 5 g/kg compares with up to six times that amount for label rate (1 g/kg) applications of registered grain protectant dusts such as Dryacide®. The cost-benefit of using magnesite for on-farm purposes would need to be considered carefully because of the limitations imposed by moisture content and the difficulty of handling treated grain.

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