Chlorpyrifos-methyl as a Protectant of Farmers Stock Peanuts[1]

F. H. Arthur*, L. M. Redlinger and R. A. Simonaitis[2]

ABSTRACT

Runner variety farmers stock peanuts were treated with either distilled water, 52 ppm malathion, or chlorpyrifos-methyl (CM) applied at 10, 15, 20 and 25 ppm, held in a metal shed and artificially infested with insect pest species commonly found in stored peanuts. Peanuts were sampled at 2, 4, 6, 9 and 12 months post-treatment. After 6 months ca 22% of loose-shelled kernels (LSK) in malathion-treated peanuts were damaged by insects; after 9 and 12 months damage increased to 36 and 49%. In contrast, LSK damage in peanuts treated with CM exceeded 6% after 9 and 12 months only in the 10 ppm treatment. Damage to kernels from cracked pods in malathion-treated peanuts was 6.9 and 11.2% after 9 and 12 months, respectively, but damaged cracked pod kernels exceeded 2% only in the 10 ppm CM treatment at 12 months. Degradation of CM residues occurred more slowly than malathion residues during the final 6 months of the test.

Key Words: Peanuts, chlorpyrifos-methyl, malathion, loose-shelled kernels *Cadra cautella, Plodia interpunctella, Tribolium castaneum.*

Peanuts are one of the most important crops in the southeastern United States. When harvested in the fall they are transported to large commercial warehouses and are stored for up to 12 months before they are transferred to shelling plants. Almond moths (AM), *Cadra cautella* (Walker), Indianmeal moths (IMM), *Plodia interpunctella* Hubner, and red flour beetles (RFB), *Tribolium castaneum* (Herbst) are major pests of stored peanuts. High populations of these insects can develop in warehouses during warm fall and spring *months* and cause significant economic damage to peanuts by feeding on the kernels. Merchant grain beetles (MGB), *Oryzaephilus mercator* Fauvel, and cigarette beetles (CB), *Lasioderma serricorne* (Fab.), are minor pests of stored peanuts.

Malathion has been used since 1960 to protect stored peanuts from insect damage. In recent years malathion resistance in these pests has increased (1, 5, 15, 16, 17). Synergized pyrethrins, methoprene and *Bacillus thuringiensis* (Dipel (R)) are the only other insecticides labelled for surface application to stored peanuts and they are far more expensive than malathion.

One possible replacement for malathion is chlorpyrifos-methyl (CM), an organophosphate insecticide. Several studies have shown that CM applied at 5-10 ppm will protect stored commodities such as rough rice (4), wheat (2, 3, 8), high moisture wheat (11) and seed corn (6, 7). These low rates of CM were more effective than standard application rates for malathion (4, 6, 7, 8, 11).

LaHue (9) reported that CM applied at 10, 15 and 20 ppm protected Spanish variety peanuts stored for 5 months during spring and summer in Kansas. However, there are no published reports concerning the effectiveness of CM on peanuts stored for 9-12 months under comparatively milder temperatures in the southeast. Objectives of this research were: 1) determine if CM is a more effective protectant of stored peanuts than malathion; 2) determine the application rates necessary for residual control; and 3) determine the degradation rate of CM on inshell peanuts during 12 months of storage.

Materials and Methods

This experiment began in late December 1981 at the USDA Stored-Product Insects Research and Development Laboratory, Savannah, GA. Segregation I runner type 1981 crop farmers stock peanuts delivered to the lab in late November were used in the test.

An experimental unit consisted of 90 kg of peanuts. The insecticide treatments were untreated controls, malathion applied to achieve a theoretical residue of 52 ppm and chlorpyrifos-methyl applied to achieve residues of 10, 15, 20 and 25 ppm. Both insecticides were formulated in 125 mL distilled water, and each treatment was replicated 5 times.

Control peanuts were sprayed with distilled water (125 mL/90 kg) as they fell from a conveying system into a hopper-bottom cart. Peanuts were mixed by transferring them from one cart to another 3 times. Each lot was then divided into 6 corrugated cardboard boxes containing ca. 15 kg each. Peanuts treated with insecticide were handled in the same manner. All boxes were randomly placed in a metal shed (ca. 12.2 m by 3.7 m by 2.8 m) and stored until sampled.

Ten RFB, 10 MGB and 10 CB adults were released into each box. In addition, ca. 100 almond moth and ca. 100 Indianmeal moth eggs were sprinkled onto the surface of the peanuts in each box. Additional beetles were introduced in February (20/box), April and June (10/box). Moth eggs (100 of each species/box) were introduced in February and April. In April and September ca. 1000 adult moths of each species were released into the shed; on 2 and 27 July 250 adult IMM were released. All insects released into the boxes and shed came from susceptible stock cultures maintained at the laboratory.

Peanuts were sampled at 0, 2, 4, 6, 9 and 12 months post-treatment. One of the six 15 kg boxes which comprised a replicate was used for each sample date; after the peanuts were sampled they were discarded. A peanut divider was used to obtain a representative sample of 1.8 kg, and a 1 kg sub-sample was taken from this amount. After the number of live insects of each species was recorded the sample was divided into two 500 g lots. One was held for 42 days to allow immatures to emerge. The other 500 g lot was used for damaged kernel counts. All loose-shell kernels (LSK) were examined for damage and kernels in cracked and solid pods in a 200-pod subsample were examined for insect damage.

For residue analysis, a one L sample (ca. 200g) of in-shell peanuts was taken from the 800 g of peanuts not used in the bioassay. All samples were held at O C until analyzed for insecticide residues. Peanuts were prepared for chromatographic analysis by grinding in a Waring Blendor, extracting 40 g in 120 mL pesticide-grade acetone by shaking 3 h on a wrist-action shaker, and filtering the extract. Analysis was performed on a Varian model 3700 gas chromatograph equipped with a flame photometric detector (FPD). Four L were injected into a 2m x 2mm I.D. glass column packed with 2% HI EFF 8AP + 8% OV-101 on 80/100 mesh Gas-Chrom-Q. The temperature of the injection port was 300 C, detector and column oven temperatures were 280 and 230

[1]This paper reports the results of research only. Mention of a pesticide or a commercial or proprietary product does not constitute a recommendation or endorsement by the U. S. Department of Agriculture.

[2]Research Entomologist, Research Entomologist (Retired) and Research Chemist, respectively, Stored-Product Insects Research and Development Laboratory, Agricultural Research Service, U. S. Department of Agriculture, Savannah, Georgia 31403.

C, respectively. Flow rates were: helium, 30 mL/min; air #1, 80 mL/min; air #2, 170 mL/min; and hydrogen, 140 mL/min. Residues were quantified using a Varian CDS 111 recording integrator.

Results were analyzed using the General Linear Models (GLM) procedure of the Statistical Analysis System (14). The 0 month samples were checked for insect damage prior to the experiment; there was none and these samples were eliminated from analysis. Damaged kernels from cracked pods and LSK were recorded and analyzed. Kernels from solid pods were eliminated from analysis since they were not damaged by insects. The number of live insects of each species was recorded on each sample date.

Results

The percentage of insect-damaged LSK in samples taken from untreated and malathion-treated peanuts increased steadily throughout the year (Table 1). Malathion was ineffective by 6 months post-treatment. At 9 months heavy damage had occurred in both control and malathion treatments (35.12 and 35.66%, respectively). Loose-shell kernel damage in these two treatments after 1 year of storage was 45.46 and 49.46%, respectively. In contrast, LSK damage in all 4 CM treatments was much lower during the year. The only samples that exceeded 6% damaged LSK were taken from the 10 ppm CM treatment at 9 and 12 months. In most cases LSK damage in CM-treated peanuts after 12 months of storage was comparable to damage in malathion-treated peanuts after 4 months of storage.

Table 1. Percent (mean ± SE) damaged loose-shell kernels from a 1000 g sample and kernels in cracked pods taken from a 200-pod sample in controls and peanuts treated with malathion or chlorpyrifos-methyl (2-12 months) post treatment.

	MONTHS POST-TREATMENT				
TREATMENT	FEB (2 mo)	APR (4 mo)	JUN (6 mo)	SEPT (9 mo)	DEC (12 mo)
			LSK		
Control	5.52±.85a[1]	10.68±.87a	19.78±2.41a	35.12±6.94a	45.46±3.34a
52 PPM Malathion	4.58±1.68a,b	4.94±2.09b	31.62±2.32a	35.66±5.83a	49.46±2.86a
10 PPM CM	2.86±1.67a,b,c	2.52±1.10b	4.54±1.44b	8.54±4.40b	9.18±3.21b
15 PPM CM	.96±.59c	2.54±1.32b	2.58±1.26b	5.00±3.06b	5.62±1.19b
20 PPM CM	0	1.12±1.12b	2.24±1.38b	.80±.80b	5.38±2.51b
25 PPM CM	1.34±.82b,c	1.12±.68b	1.14±.74b	.96±.60b	4.82±1.24b
			CRACKED POD KERNELS		
Control	1.04±.19a	1.90±.28a	4.28±.79a	8.11±1.58a	11.17±.82a
52 PPM Malathion	.70±.11a,b	1.00±.22b	2.97±.28b	6.91±.85a	11.18±.95a
10 PPM CM	.45±.11b	.77±.13b,c	.54±.06c	1.38±.42b	2.33±.88b
15 PPM CM	.37±.15b	.34±.14c	.32±.13c	.33±.13b	1.03±.43b
20 PPM CM	.35±.14b	.32±..13c	.45±.21c	.44±.11b	.68±.33b
25 PPM CM	.34±.14b	.22±.13c	.36±.15c	.35±.14b	.64±.21b

[1] Means followed by the same letter are not significantly different (P <.05, Duncan's [1955] multiple range test).

The percentage of insect-damaged kernels from cracked pods was also greater in samples taken from control and malathion treatments (Table 1). Malathion was effective for 6 months, but after 9 and 12 months insect damage in control and malathion treatments was much higher than in CM treatments. Insect damage was less than 1% except in samples from the 10 ppm treatment after 9 and 12 months and 15 ppm after 12 months.

Almond moths (AM) and Indianmeal moths (IMM) were abundant only in the 6 month sample (Table 2). Mean numbers of AM (primarily larvae) were higher in controls than in malathion and CM treatments. However, the number of IMM in the control and malathion treatments, 37.40 and 27.60, respectively, was much greater than in the CM treatments. Averages for CM treatments ranged from .20 to 1.40.

Table 2. Almond and Indianmeal moths (mean ± SE) detected in 1000 g samples from controls and peanuts treated with malathion or chlorpyrifos-methyl treatment.

	MONTHS POST-TREATMENT				
Treatment	FEB (2 mo)	APR (4 mo)	JUN (6 mo)	SEPT (9 mo)	DEC (12 mo)
			ALMOND MOTH		
Control	0[1]	1.00±.45	17.20±4.42a	0	0
Malathion	.2±.2	1.00±.24	6.60±2.29b	0	0
10 PPM CM	0	.60±.40	1.00±.32b	.80±.20	.40±.24
15 PPM CM	0	.40±.24	.80±.49	.20±.20	0
20 PPM CM	0	0	.40±.24b	.40±.40	.60±.40
25 PPM CM	0	0	0b	0	.40±.40
			INDIANMEAL MOTH		
Control	0	.80±.20	37.40±9.62	0	1.00±.63
Malathion	0	.40±.24	27.60±6.02a	.20±.20	0
10 PPM CM	0	.40±.24	1.40±.40b	.80±.49	.80±.37
15 PPM CM	0	.20±.20	1.20±.37b	0	0
20 PPM CM	0	0	1.00±.32b	.40±.24	.60±.40
25 PPM CM	0	0	.20±.20	0	.40±.40

[1] Means followed by the same letter are not significantly different (P <.05, Duncan's [1955] multiple range test).

Data for the beetles are summarized in Table 3. Red flour beetles were detected in samples from control and malathion treatments at 4 months post-treatment, but large populations were not detected until 9 months. Mean numbers in the control and malathion samples (35.60 and 22.40) at 9 months and at 12 months (59.20 and 38.40) were much greater than in the CM treatments. The 25 ppm CM treatment was especially effective; only 1 live adult was detected in the samples at 12 months. Samples taken from the controls at 9 and 12 months contained a high population of MGB but few were detected in either malathion or CM treatments. Cigarette beetle populations were apparently unable to establish on the peanuts.

Residue analysis of in-shell peanuts indicated that the dosages applied were similar to the desired concentrations (Fig. 1). Chlorpyrifos-methyl residues declined gradually during storage whereas malathion declined more rapidly. After 12 months the malathion residue was 4.22 ppm, or 7% of the original concentration of 58.9 ppm malathion. In contrast, the CM residues were 1.9 (17%), 2.9 (19%), 2.9 (19%), 2.9 (16%), and 7.3 (33%) ppm, from original concentrations of 10.2, 15.9, 18.4 and 22.2 ppm, respectively.

Discussion

Results show that CM can protect farmers stock peanuts from insect damage during storage. Chlorpyrifos-methyl was superior to the standard malathion treatment; effective rates were 20-50% lower than the labelled rate for malathion. As mentioned previously, similar results were reported for field tests with CM as

Table 3. Red flour, merchant grain and cigarette beetles (mean ± SE) detected in 1000 g samples from controls and peanuts treated with malathion or chlorpyrifos-methyl (2-12 months post treatment.

Treatment	FEB (2 mo)	APR (4 mo)	JUN (6 mo)	SEPT (9 mo)	DEC (12 mo)
		MONTHS POST-TREATMENT			
		RED FLOUR BEETLE			
Control	0[1]	2.40±.40a	6.20±1.02a	35.60±7.32a	59.20±11.21a
52 PPM Malathion	.20±.20	.80±.53b	2.00±.55b	22.40±3.69b	38.40±3.75b
10 PPM CM	0	.80±.37b	1.00±.45b,c	2.00±.77c	2.40±.67c
15 PPM CM	0	.40±.24b	.20±.20c	2.20±1.25c	3.00±1.26c
20 PPM CM	0	0b	0c	.80±.58c	2.20±.97c
25 PPM CM	0	0b	0c	0c	.20±.20c
		MERCHANT GRAIN BEETLE			
Control	0	.80±.20	1.80±.37a	29.00±7.41a	21.20±6.86a
52 PPM Malathion	0	.20±.20	0b	0b	.20±.20b
10 PPM CM	0	.40±.24	.40±.24b	.20±.20b	.60±.24b
15 PPM CM	0	0	0b	0b	.80±.20b
20 PPM CM	0	0	0b	.40±.24b	.20±.20b
25 PPM CM	0	0	0b	0b	0b
		CIGARETTE BEETLE			
Control	0	1.00±.32	1.00±.77	5.40±1.40a	2.60±.74a
52 PPM Malathion	0	0	0	0b	0
10 PPM CM	0	.20±.20	.40±.24	.40±.24b	.20±.20b
15 PPM CM	0	0	.60±.24	.20±.20b	0b
20 PPM CM	0	.40±.25	0	0b	0b
25 PPM CM	0	0	0	0b	0b

[1] Means followed by the same letter are not significantly different (P <.05, Duncan's [1955] multiple range test).

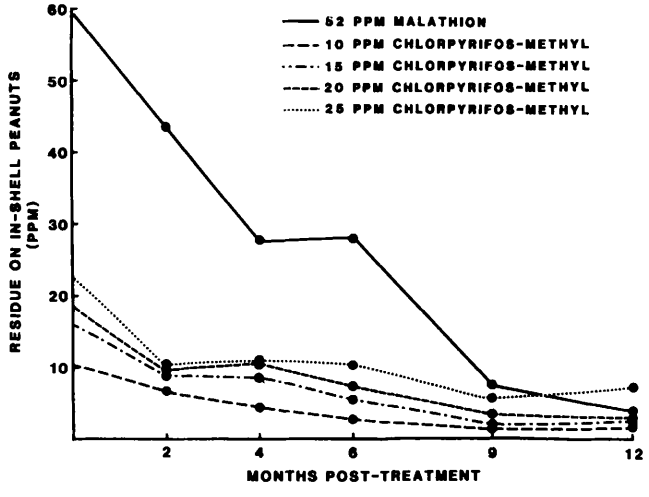

Fig. 1. Malathion and chlorpyrifos-methyl residues on in-shell peanuts sampled after 0, 2, 4, 6, 9 and 12 months of storage.

a protectant of other stored commodities.

Chlorpyrifos-methyl was particularly effective in reducing damage to LSK, which are more vulnerable to attack than in-shell kernels. Loose-shelled kernels will be heavily damaged if insects are not controlled (9, 12, 13). Insect pests cannot usually penetrate a solid pod to feed on the kernels. They gain access to the kernels either via a split and/or crack in the pod or from damage to the pods which results in the removal of kernels from the shell. The solid peanut pod is an effective barrier, and management practices which reduce damage to the pods during harvesting, handling and storage should be encouraged.

Almond moths and Indianmeal moths were detected in abundance only in samples taken 6 months post-treatment (June). High summer temperatures may have eliminated the moths and prevented population development from new releases of adults after this time. However, RFB populations were apparently unaffected. LeCato (10) showed RFB to be a dominant species that reduced the numbers of other species when reared on corn. High RFB populations therefore may have limited moth and cigarette beetle population development. Merchant grain beetles were present in untreated peanuts during the final 6 months of the test and were apparently unaffected by high temperature and the presence of RFB.

Degradation of chlorpyrifos-methyl on inshell peanuts occurs gradually during storage. An initial application of 25 ppm controlled RFB and MGB. However, since AM and IMM were not present during the latter months of storage, the degree of control toward these species is unknown. Either a high initial application rate or surface applications during storage may be necessary.

At present there are few insecticides available for insect control in peanut warehouses. Malathion has been extensively used as a surface spray but it no longer adequately protects peanuts from damage. Automatic dichlorvos aerosol systems in the headspaces of warehouses control adult moths but do not entirely prevent oviposition and larval development on the surfaces. Peanuts in storage are usually fumigated at least once with phosphine, but in many cases warehouses are either unsuitable for fumigation or are not properly sealed. With multiple fumigations becoming common, rapid development of resistance may result from this increased reliance on phosphine as a primary means of insect control. Additional protectants such as chlorpyrifos-methyl would greatly improve insect pest control operations in peanut warehouses.

Acknowledgment

The authors wish to thank J. E. Baker, J. H. Brower, J. W. Press, J. S. Smith, Jr. and H. Womack for reviewing earlier drafts of this manuscript. We would also like to thank J. E. O'Bryan and R. S. Cail for technical assistance.

Literature Cited

1. Arthur, F. H., J. L. Zettler, and W. R. Halliday. 1988. Insecticide resistance among populations of almond moth and Indianmeal moth (Lepidoptera: Pyralidae) in stored peanuts. J. Econ. Entomol. (In Press).
2. Bengston, M. L., L. M. Cooper and F. J. Grant-Taylor. 1975. A comparison of bioresmethrin, chlorpyrifos-methyl and pirimiphos-methyl as grain protectants against malathion-resistant insects in wheat. Queensl. Agric. Anim. Sci. 32(1):51-78.
3. Bengston, J. L., M. Connel, R. A. H. Davies, J. M. Desmarchelier, W. B. Elder, R. J. Hart, M. P. Phillips, E. G. Ridley, B. E. Ripp, J. T. Snelson and R. Sticka. 1980. Chlorpyrifos-methyl plus bioresmethrin; methacrifos; pirimiphos-methyl plus bioresmethrin: and synergised bioresmethrin as grain protectants for wheat. Pestic. Sci. 11:61-76.
4. Cogburn, R. R., D. L. Calderwood, B. D. Webb and M. A. Marchetti. 1983. Protecting rough rice stored in metal farm biinsect attack. J. Econ. Entomol. 76:1377-1383.

5. Halliday, W. R., F. H. Arthur, and J. L. Zettler. 1988. Resistance status of the red flour beetle (Coleoptera: Tenebrionidae) infesting stored peanuts in the Southeastern United States. J. Econ. Entomol. (In Press).
6. LaHue, D. W. 1976. Grain protectants for seed corn. J. Econ. Entomol. 69:652-654.
7. LaHue, D. W. 1977. Grain protectants for seed corn: Field test. J. Econ. Entomol. 70:720-722.
8. LaHue, D. W. 1977. Chlorpyrifos-methyl: Doses that protect hard winter wheat against attack by stored-grain insects. J. Econ. Entomol. 70:734-736.
9. LaHue, D. W. 1979. Pirimiphos-methyl and chlorpyrifos-methyl as controls of indigenous infestations in farmers stock peanuts. J. Econ. Entomol. 72:621-624.
10. LeCato, G. G. 1975. Interactions among four species of stored-product insects in corn: a multifactorial study. Ann. Entomol. Soc. Am. 68:677-679.
11. Quinlan, J. K., G. D. White, J. L. Wilson, L. I. Davidson and L. H. Hendricks. 1979. Effectiveness of chlorpyrifos-methyl and malathion as protectants for high-moisture stored wheat. J. Econ. Entomol. 72:90-93.
12. Redlinger, L. M. 1976. Pirimiphos-methyl as a protectant for farmers stock peanuts. J. Econ. Entomol. 69:377-379.
13. Redlinger, L. M. and R. A. Simonaitis. 1977. Field tests with pirimiphos-methyl as a protectant for farmers stock peanuts. Peanut Sci. 4:27-31.
14. SAS Institute, Inc. 1985. SAS Users' Guide's Statistics, Version 5 Edition. SAS Institute, Inc., Cary, NC. 956 pp.
15. Zettler, J. L. 1982. Insecticide resistance in selected stored product insects infesting peanuts in the southeastern United States. J. Econ. Entomol. 75:359-362.
16. Zettler, J. L. 1974. Malathion resistance in *Tribolium castaneum* collected from stored peanuts. J. Econ. Entomol. 67:339-340.
17. Zettler, J. L., L. L. McDonald, L. M. Redlinger and R. D. Jones. 1973. *Plodia interpunctella* and *Cadra cautella* resistance in strains to malathion and synergised pyrethrins. J. Econ. Entomol. 66: 1049-1050.

Accepted March 5, 1988