QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
DIVISION OF PLANT INDUSTRY BULLETIN No. 308

# AN INVESTIGATION OF PEANUT STORAGE PESTS IN QUEENSLAND

## 2. INSECTICIDAL TREATMENT OF BULK NUT-IN-SHELL PEANUTS IN SILOS

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SUMMARY

**Two trials testing the efficacy of malathion and synergised pyrethrins as protectants for bulk nut-in-shell peanuts stored in silos are described and discussed. A minimum concentration of 41 p.p.m. malathion supplemented by 2-monthly surface treatments of the bulk with malathion and synergised pyrethrins controlled the major pests, *Tribolium castaneum* (Herbst.), *Oryzaephilus mercator* Fauv. and *Cadra cautella* (Walk.). Cost of protection for one year was 2s. per ton. Malathion residues on kernels after 6 months' storage were less than 1 p.p.m. and on shells 9 p.p.m.**

## I. INTRODUCTION

Earlier investigations on control of silo infestations in Queensland, apart from fumigation, concerned the use of paraffin/pyrethrum sprays applied to the top surface of bins at regular intervals, and use of hessian covers over bin tops (Champ 1965). These methods did not come into general use.

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A survey was made in 1961-62 of the pest problems in the silo storage of the Peanut Marketing Board at Kingaroy (Champ 1965). The results indicated that the economic pest species were *Cadra cautella* (Walk.), *Plodia interpunctella* Hübn., *Tribolium castaneum* (Herbst.) and *Oryzaephilus mercator* Fauv.

Synergised pyrethrins and subsequently malathion have been recommended for bulk treatment of nut-in-shell stored in silos in the United States of America (Anon. 1961). Two trials were carried out during the 1961-62 and 1962-63 seasons at the Peanut Marketing Board's storage to test the efficacy of pyrethrins and malathion as protectants under Queensland conditions. Emphasis in the trials was placed on testing of bulk treatment by making surface treatments at rates which would allow some reinfestation pressure without complete breakdown of control.

## II. TRIAL I

### Synergised Pyrethrins and Malathion as Protectants

This exploratory trial was designed to give immediate and positive assessment of the applicability of malathion as a protectant for use in nut-in-shell peanuts. Accordingly malathion was used as a concentration high enough (66 p.p.m.) to ensure a margin over possible commercial application levels.

#### (a) Materials

*Bins*.—Three interspace vertical concrete bins each of 40 tons capacity (Figure 1) were used.

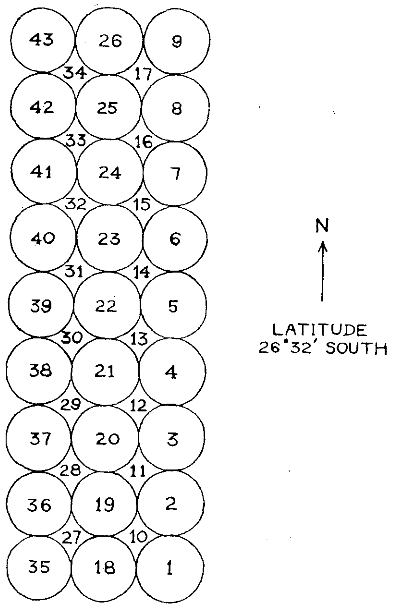


Fig. 1.—Storage bins, Peanut Marketing Board, Kingaroy.
Trial I, bins used: interspace 15, untreated; 16, synergised pyrethrins; 17, malathion. Trial II, bins used: round 25, untreated; 43, 13·8 p.p.m. malathion; 8, 26·2 p.p.m. malathion; 26, 40·8 p.p.m. malathion; 9, 47·8 p.p.m. malathion; 42, 55·2 p.p.m. malathion.

*Peanuts.*—Second grade Virginia Bunch nut-in-shell of 8% average moisture content was used. This was 1961 season crop and had been stacked in the open for 4-5 months in sacks before being cut to bulk for the trials.

*Insecticides.*—The insecticides used were malathion (a premium grade material as an emulsifiable concentrate containing 50% w/v active ingredient); and synergised pyrethrins (an emulsifiable concentrate containing 4% w/v pyrethrins and 64% w/v piperonyl butoxide).

### (b) Methods

Insecticides were applied using a grain sprayer with a "Type WFA 60/8" nozzle, as emulsions in water to the peanut stream on the conveyor belt on the weigher floor of the intake plant. The peanuts at this stage had been through the cleaning cycle which removed all dirt, sticks, stones and broken nuts, and were being weighed before being elevated to the overhead conveyor belt and run into the silos. The application rate for diluted malathion spray (3·6% malathion) was 1 gal to 2⅓ tons of peanuts, giving a concentration of 66 p.p.m. in treated nut-in-shell, and for synergised pyrethrins (0·2% pyrethrins, 3·2% piperonyl butoxide) 1 gal to 3 tons of peanuts, giving concentrations of 3 and 48 p.p.m. respectively. These treatments added 0·15 and 0·19% moisture respectively to the peanuts at the point of treatment. Most of this, however, was lost before the peanuts emptied into the silo.

The surface of the peanut bulk and the roof and exposed inside walls of each bin were sprayed at intervals of 2 months during storage with malathion (0·5%) and synergised pyrethrins (0·04% pyrethrins, 0·64% piperonyl butoxide), using a power spray with twin cone nozzles and a pressure of 50 lb/sq in. Three surface applications were made at 1, 65 and 122 days after the bulk treatment.

Monthly examinations of the top surface of the bulks were made by taking ten 2-lb samples from each bin and making counts of insects that passed a 10-mesh sieve. Bin temperatures 6 ft below the surface of the bulk were recorded.

The trial was finalized in March 1962, as the Peanut Marketing Board had planned an overall fumigation of the silo block with methyl bromide. Top samples were taken as before and the bins turned into adjoining bins. Turning took approximately 4 hr. Samples were taken regularly during run-out by placing

25 in. x 20 in. cardboard sheets on the moving belt before the outlet chute and removing the sheets from the loaded belt after they had passed under the chute. The 25-in. cut of the peanut stream weighed approximately 2 lb and counts were made of insects that passed a 10-mesh sieve.

Grading samples were taken continuously from the bulk during turning. Each hour's sample was bulked and graded separately. Grading data recovered were first grade nut-in-shell percentage of the total sample; second grade nut-in-shell percentage of the total sample; first plus second grade edible kernels; third grade edible kernels; oil kernels; and residue percentages of the reject nut-in-shell. Grading was done by the hand-picking-from-belts method used by the Board to examine farmers' samples at intake—this method itself is a scale-down of the commercial sorting used.

Residue analyses for malathion (Anon. 1960) were carried out on whole and split edible kernels, from rejects from nut-in-shell and on oil kernels.

### (c) Results

A summary of data on bin treatments is given in Table 1. Totals of all pests present in the monthly samples taken from the top surface of the bins are included in Table 2.

**TABLE 1**

TRIAL I, PEANUT STORAGE SILOS, KINGAROY, 1961–62.
SUMMARY OF DATA ON BIN TREATMENTS

| Bin No. | Treatment | Average Moisture Content (%) | Total Weight (lb) | Filling Time (min) | Flow Rate (lb/hr) | Date Treated (1961) |
|---|---|---|---|---|---|---|
| 15 | No treatment .. .. .. | 7·6 | 88,905 | 240 | 22,225 | Sept. 29– Oct. 2 |
| 16 | Synergised pyrethrins (pyrethrins 3 p.p.m., piperonyl butoxide 48 p.p.m.) | 8·7 | 88,810 | 260 | 20,495 | Sept. 27, 28 |
| 17 | Malathion (66 p.p.m.) .. .. | 7·8 | 82,288 | 208 | 23,736 | Sept. 28 |

Comparisons of pest numbers in samples taken during run-out are shown in Figure 2. The nut-in-shell used in the trial was sound, and at run-out was free from moisture accumulation and emptied freely without "hang-ups" on walls.

## TABLE 2

TRIAL I, PEANUT STORAGE SILOS, KINGAROY, 1961–62. NUMBERS OF PESTS IN MONTHLY SAMPLES TAKEN FROM THE TOP SURFACE OF TEST BINS DURING STORAGE, 1961–62

| Bin No. | 15 | | | | | | 16 | | | | | | 17 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bin treatment | No treatment | | | | | | Synergised pyrethrins | | | | | | Malathion | | | | | |
| Date | Oct. 2 | Dec. 6 | Jan. 3 | Feb. 1 | Feb. 27 | Mar. 29 | Oct. 2 | Dec. 6 | Jan. 3 | Feb. 1 | Feb. 27 | Mar. 29 | Oct. 2 | Dec. 6 | Jan. 3 | Feb. 1 | Feb. 27 | Mar. 29 |
| Days after treatment | 0 | 65 | 93 | 122 | 148 | 177 | 0 | 69 | 97 | 126 | 152 | 180 | 0 | 69 | 97 | 126 | 152 | 180 |
| *Tribolium castaneum* (Herbst.)— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | 11 | 202 | 146 | 161 | .. | .. | 7 | 57 | 33 | 88 | .. | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | 6 | 31 | 23 | .. | .. | .. | 9 | 6 | 4 | .. | .. | .. | 1 | .. | .. |
| *Oryzaephilus mercator* Fauv. — | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | 2 | 128 | 681 | 1,891 | .. | .. | .. | 2 | 2 | .. | .. | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | 25 | 386 | 148 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | 1 | .. | .. |
| *Cadra cautella* (Walk.)— | | | | | | | | | | | | | | | | | | |
| Larvae alive | .. | .. | 223 | 29 | 11 | .. | .. | .. | .. | 21 | 13 | 4 | .. | .. | .. | 54 | 8 | 6 |
| Larvae dead | .. | .. | .. | 60 | 1 | 6 | .. | .. | .. | .. | 7 | .. | .. | .. | .. | 120 | 15 | .. |
| *Plodia interpunctella* (Hübn.)— | | | | | | | | | | | | | | | | | | |
| Larvae | .. | .. | .. | 7 | .. | 6 | .. | .. | .. | .. | 1 | 5 | .. | .. | .. | .. | .. | .. |
| *Cryptolestes* spp.— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | 1 | .. | 3 | 10 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Carpophilus dimidiatus* (F.)— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Ahasverus advena* Waltl.— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Sitophilus oryzae* (L.)— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Lasioderma serricorne* (F.)— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Psocoptera*— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | 293 | 2,255 | 731 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Xylocoris flavipes* (Reuter)— | | | | | | | | | | | | | | | | | | |
| Adults + Nymphs | .. | .. | 1 | 2 | 269 | 1,663 | .. | .. | .. | 1 | 2 | .. | .. | .. | .. | 4 | 1 | .. |
| *Microbracon hebetor* (Say)— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | 58 | 58 | 17 | .. | .. | .. | 4 | .. | .. | .. | .. | .. | .. | .. | .. |
| *Microhymenoptera*— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | 13 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Acarina*— | | | | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | 470 | 413 | 110 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | 3 | .. | .. |
| Bin temperature 6 ft below surface (°F) | .. | 75 | .. | 83·5 | 88 | 88·5 | .. | 75 | .. | 81 | 84 | 81·5 | .. | 75 | .. | 81 | 83·5 | 78·5 |

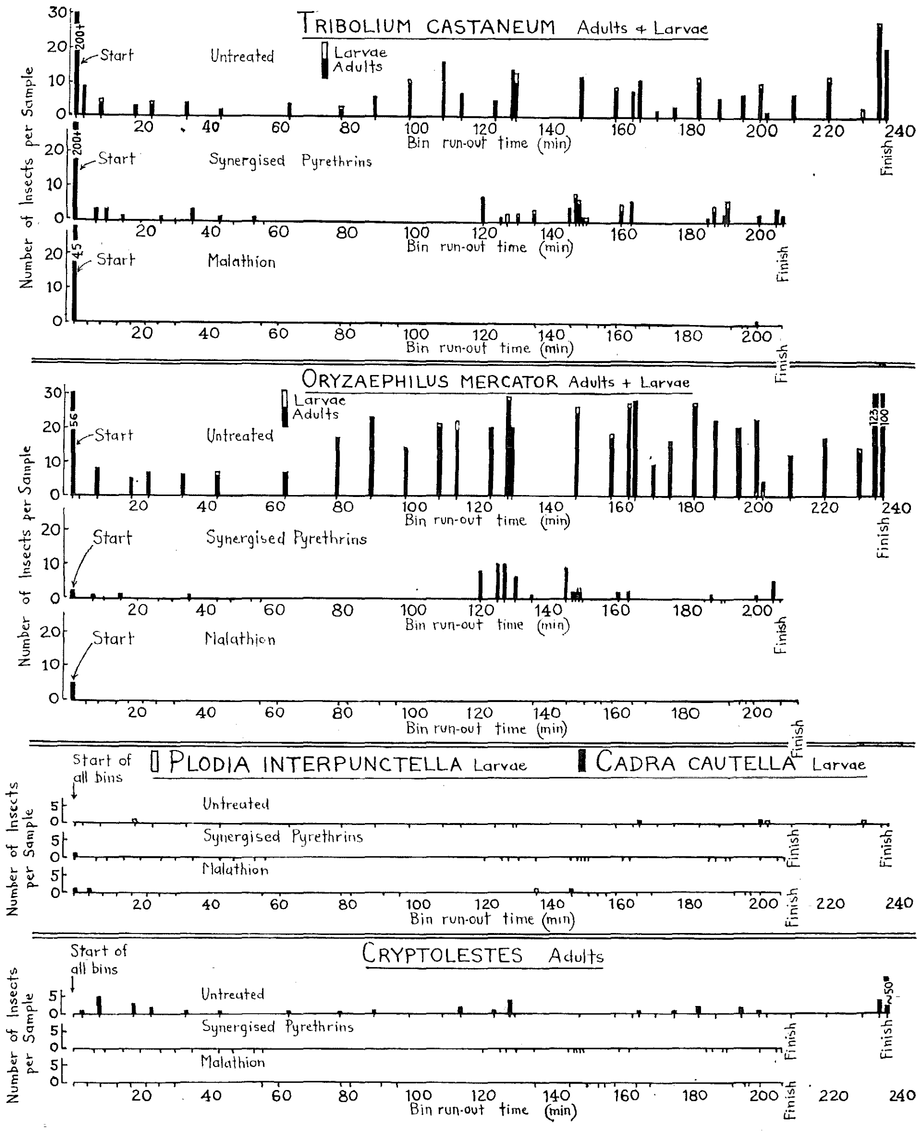


Fig. 2.—Trial I, Peanut storage silos, Kingaroy, 1961-62. Total insect counts from samples taken during run-out of test bins. Times when samples were taken are represented by time markings below the bin run-out time axis.

No significant differences between treatments were found in grading percentages of samples from the various bins; accordingly results have not been presented.

Malathion residues in kernels are given in Table 3. Levels were less than 1 p.p.m., which is below the tolerance set in the United States of America, Canada and the United Kingdom for post-harvest application of malathion to cereals and legumes.

TABLE 3

TRIAL I, PEANUT MARKETING BOARD SILOS, KINGAROY, 1961–62. MALATHION RESIDUES IN KERNELS SIX MONTHS AFTER TREATMENT AS NUT-IN-SHELL

| | |
|---|---|
| Malathion applied (p.p.m.) .. .. .. | 66 |
| Malathion residues (p.p.m.)— | |
| Whole kernels .. .. .. .. | 0 |
| Split kernels .. .. .. .. .. | 0·4 |
| Oil kernels .. .. .. .. .. | 0·9 |

### (d) Comments

The storage time of 6 months was short, but infestation pressure from surrounding storage was high (bin temperatures to 101°F, live insect numbers per 2-lb surface sample to: *T. castaneum* 13,000, *O. mercator* 12,000, *C. cautella* larvae 260 and predator *Xylocoris flavipes* (Reuter) 10,000); and there was evidence of heating in the untreated bin at run-out. Malathion gave good control of all species except *C. cautella* (Table 2, Figure 2); adult moths and webbing, however, were almost absent in the malathion bin though present in quantity in the untreated bin. Synergised pyrethrins gave comparable control of all species except *T. castaneum.*

*Carpophilus dimidiatus* (F.), a fungus feeder that is prevalent in the silos, was absent from most samples because of the sound dry condition of the walls and the test nut-in-shell.

## III. TRIAL II

### Effective Concentration Levels of Malathion as a Protectant

Results from Trial I indicated that malathion exercised a satisfactory level of control over pests in bulk nut-in-shell peanuts at 66 p.p.m. A range of concentrations from 11 to 55 p.p.m. was chosen in Trial II to determine, on a semi-commercial scale, an efficacious concentration for economic control.

### (a) Materials

*Bins.*—Six bins each of 170 tons capacity were used (Figure 1). Bins were cleaned before filling. A light infestation of *C. dimidiatus* was present in debris still caked to the exposed walls of corner bins 9 and 43. All outside bins were subject to moisture accumulation on wall and top surfaces as no aeration facilities were available.

*Peanuts.*—Second grade Virginia Bunch nut-in-shell of 8·6% average moisture content was used. This was 1962 season crop and had been stacked in the open for 4 months in sacks before being cut to bulk for the trials. There was a light infestation of *T. castaneum, O. mercator, C. cautella* and *P. interpunctella* present in samples taken before cleaning. After cleaning, *O. mercator* was readily detectable in samples held and incubated.

*Insecticide*.—A premium grade malathion emulsifiable concentrate containing 80% w/v active ingredient was used.

### (b) Methods

The insecticides were applied with a grain sprayer to the peanut stream on the overhead conveyor belt. The spray was applied at the rate of 1 gal to 3 tons of peanuts, that is, 3 gal an hour using a fluid pressure of 22·5 lb/sq in. at 20,000 lb per hr intake,

Five rates of application were planned to give concentrations of 11, 22, 33, 44 and 55 p.p.m. in the test bins. One bin was not treated. Surface sprays of malathion were used at 2-monthly intervals in the filled bins as before at concentrations of 0·5, 1·0, 1·5, 2·0 and 2·5% for the bins treated at 11, 22, 33, 44 and 55 p.p.m. respectively.

Monthly examinations were made at the top surface of the bulk by taking ten 2-lb samples from each bin as before and making counts of insects that passed a 10-mesh sieve. Bin temperatures 6 ft below the surface of the bulk were recorded.

The trial was finalized in March 1963 to determine applicability of the method for use in the 1963 harvest. The bins were turned into adjoining bins and sampled for insect infestation as in the previous trial. No samples were taken for grading but analyses were made of shells and kernels for malathion residues.

### (c) Results

A summary of data on bin treatments is given in Table 4. Totals of all pests present in the monthly samples taken from the top surface of the bins are included in Table 5. Comparisons of pest numbers in samples taken during run-out are shown in Figures 3–5. Malathion residues in kernels and shells are given in Table 6.

TABLE 4

Trial II, Peanut Storage Silos, Kingaroy, 1962–63. Summary of Date on Bin Treatments

| Bin No. | Treatment (p.p.m. Malathion) | | Average Moisture Content (%) | Total Weight (lb) | Filling Time (min) | Flow Rate (lb/hr) | Date Treated, 1962 |
|---|---|---|---|---|---|---|---|
| | Theoretical | Actual | | | | | |
| 25 .. .. | Nil | Nil | 8·77 | 348,877 | 1,198 | 17,473 | Oct. 4 |
| 43 .. .. | 11 | 13·8 | 8·79 | 347,527 | 1,156 | 18,037 | Sept 13 |
| 8 .. .. | 22 | 26·2 | 8·66 | 331,962 | 1,111 | 17,927 | Sept. 19 |
| 26 .. .. | 33 | 40·8 | 8·82 | 324,803 | 1,152 | 16,916 | Sept. 25 |
| 9 .. .. | 44 | 47·8 | 8·41 | 337,794 | 1,084 | 18,697 | Oct. 4 |
| 42 .. .. | 55 | 55·2 | 8·11 | 351,876 | 1,075 | 19,640 | Oct. 12 |

## TABLE 5

Trial II, Peanut Storage Silos, Kingaroy, 1962–63. Number of Insects in Monthly Samples Taken from the Top Surface of Test Bins During Storage, 1962–63

| Bin No. | 25 | | | | | 43 | | | | | 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Malathion concentration (p.p.m.) | Nil | | | | | 13·8 | | | | | 26·2 | | | | |
| Date | Oct. 11 | Nov. 23 | Jan. 8 | Feb. 7 | Mar. 21 | Oct. 11 | Nov. 23 | Jan. 8 | Feb. 7 | Mar. 21 | Oct. 11 | Nov. 23 | Jan. 8 | Feb. 7 | Mar. 21 |
| Days after treatment | 7 | 50 | 96 | 126 | 168 | 28 | 71 | 117 | 147 | 189 | 22 | 65 | 111 | 141 | 183 |
| *Tribolium castaneum* (Herbst.)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | 9 | 31 | 416 | .. | .. | .. | 81 | 1,319 | .. | .. | .. | 2 | 5 |
| Larvae | .. | .. | .. | 17 | 22 | .. | .. | .. | 2 | 39 | .. | .. | .. | .. | .. |
| *Oryzaephilus mercator* Fauv.— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | 1 | 568 | .. | .. | .. | 1 | 6 | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | .. | 24 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Cadra cautella* (Walk.)— | | | | | | | | | | | | | | | |
| Adults* | .. | † | †† | ††† | ††† | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Larvae | .. | 1 | 277 | 99 | 27 | .. | .. | 9 | 124 | 82 | .. | .. | 3 | 101 | 47 |
| *Cryptolestes* spp.— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | 2 | .. | 9 | .. | .. | .. | .. | .. |
| *Carpophilus dimidiatus* (F.)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | 6 | .. | 1 | 5 | 49 | 253 | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | .. | .. | .. | .. | 13 | 16 | 8 | .. | .. | .. | .. | .. |
| *Tenebroides mauritanicus* (L.)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| *Xylocoris flavipes* (Reuter)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | 29 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Microhymenoptera*— | | | | | | | | | | | | | | | |
| Adults | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Bin temperature 6 ft below surface (°F) | 69 | 74 | 76 | 81 | 85 | 74 | 76 | 76 | 79 | 88 | 74 | .. | 79 | 79 | 82 |

* *Cadra cautella* adults per bin: † < 10, †† < 100, ††† < 1000.

**TABLE 5** (continued)

Trial II, Peanut Storage Silos, Kingaroy, 1962–63. Numbers of Pests in Monthly Samples Taken from the Top Surface of Test Bins During Storage, 1962–63

| Bin No. | 26 | | | | | 9 | | | | | 42 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Malathion concentration (p.p.m.) | 40·8 | | | | | 47·8 | | | | | 55·2 | | | | |
| Date | Oct. 11 | Nov. 23 | Jan. 8 | Feb. 7 | Mar. 21 | Oct. 11 | Nov. 23 | Jan. 8 | Feb. 7 | Mar. 21 | Oct. 11 | Nov. 23 | Jan. 8 | Feb. 7 | Mar. 21 |
| Days after treatment | 16 | 59 | 105 | 135 | 177 | 7 | 50 | 96 | 126 | 168 | 2 | 45 | 91 | 121 | 163 |
| *Tribolium castaneum* (Herbst.) — | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | 29 | .. | .. | .. | .. | 3 | .. | .. | .. | .. | 107 |
| Larvae | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Oryzaephilus mercator* Fauv.— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Cadra cautella* (Walk.)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Larvae | .. | .. | 9 | 36 | 22 | .. | .. | .. | 14‡ | 8 | .. | .. | .. | 12‡ | 45 |
| *Cryptolestes* spp.— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Carpophilus dimidiatus* (F.)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3 | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | .. | .. | .. | .. | .. | .. | 3 | .. | .. | .. | .. | .. |
| *Tenebroides mauritanicus* (L.)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Larvae | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Xylocoris flavipes* (Reuter)— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *Microhymenoptera*— | | | | | | | | | | | | | | | |
| Adults | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Bin temperature 6 ft below surface (°F) | 77 | 74 | 74 | 76 | 77 | 75 | 76 | 76 | 76 | 78 | 80 | 77 | 77 | 78 | 79 |

‡ In cone samples only.

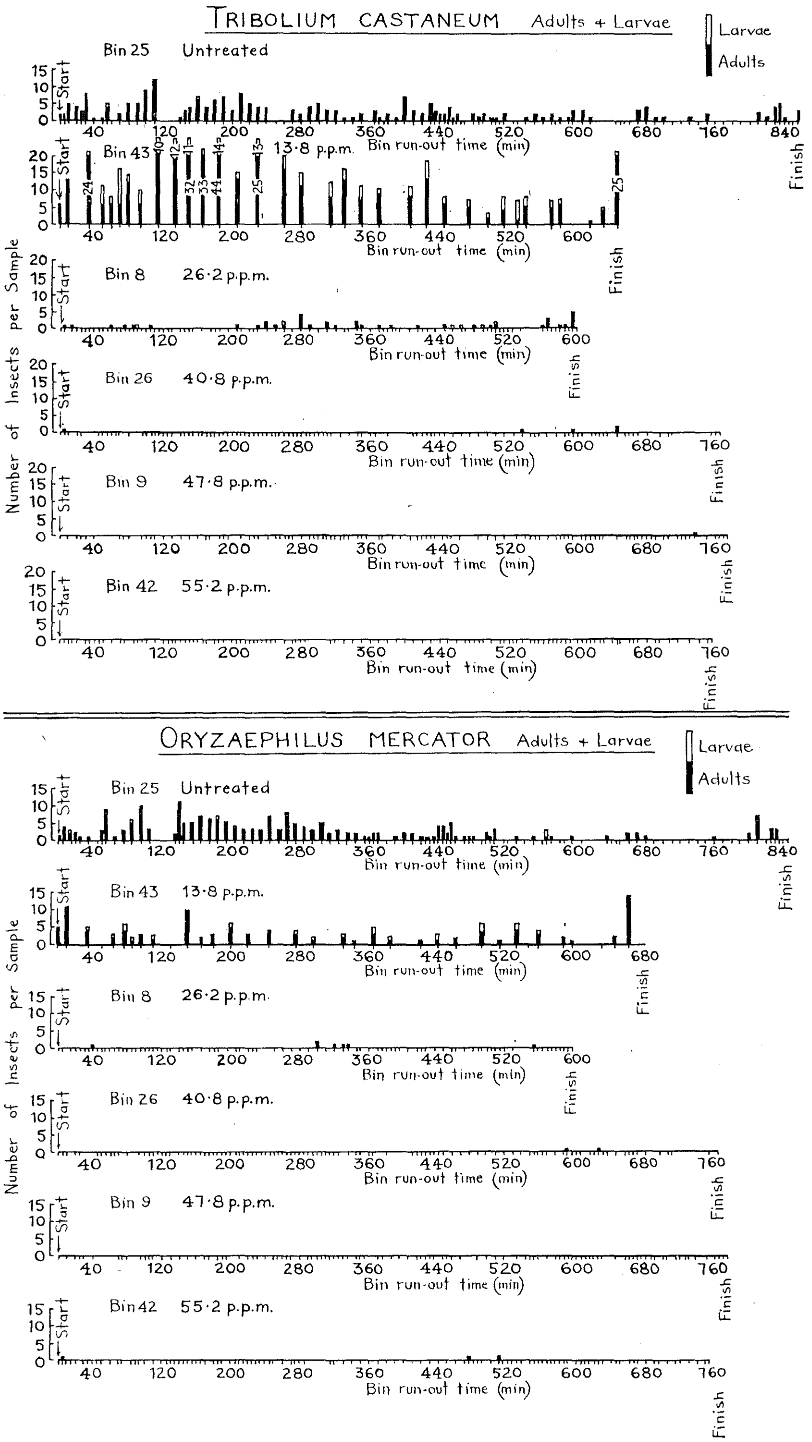


Fig. 3.—Trial II, Peanut storage silos, Kingaroy, 1962-63. Total counts of adults and larvae of *Tribolium castaneum* (Herbst.) and *Oryzaephilus mercator* Fauv. from samples taken during the run-out of test bins. Times when samples were taken are represented by time markings below the bin run-out time axis.

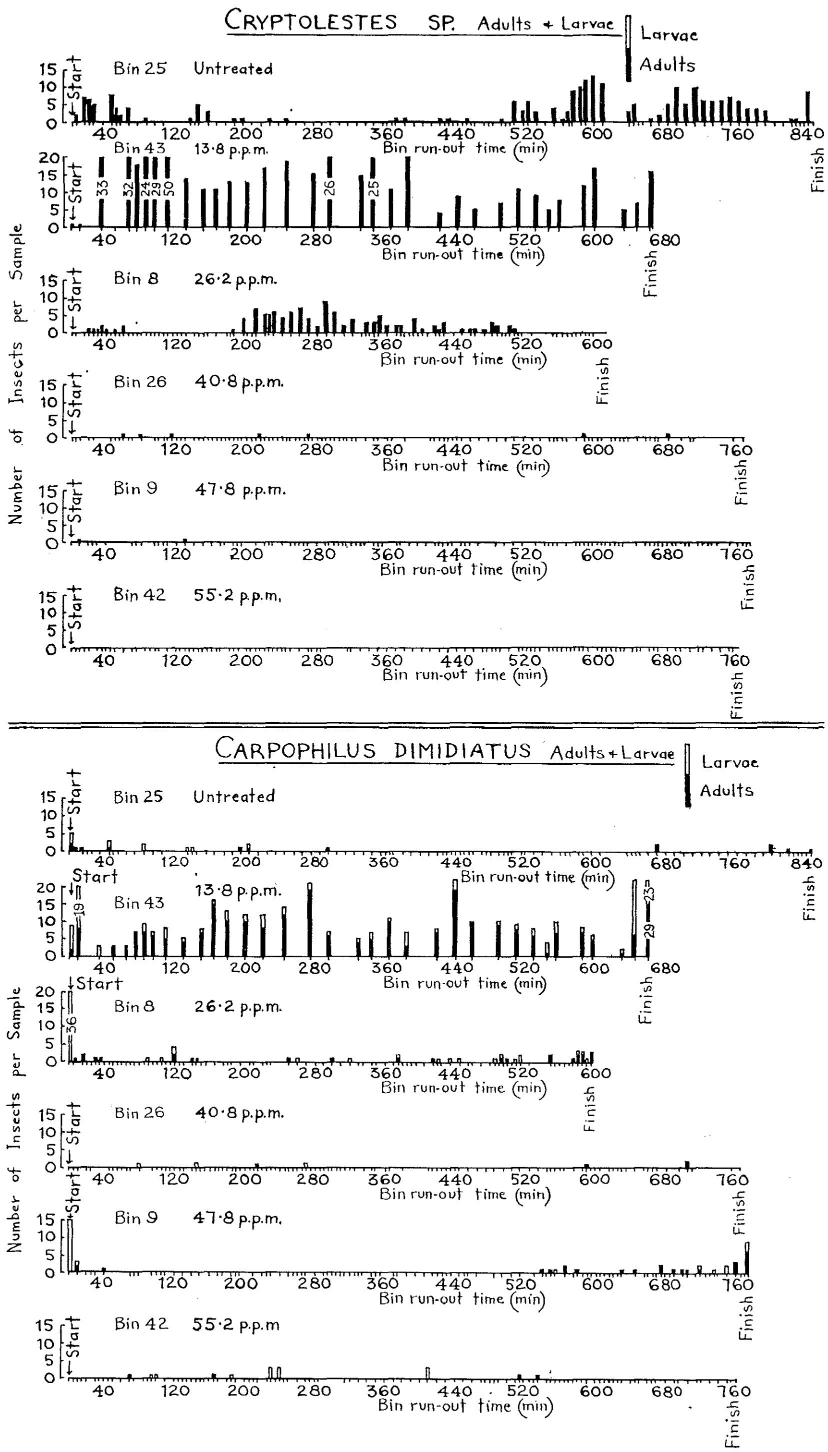


Fig. 4.—Trial II, Peanut storage silos, Kingaroy, 1962-63. Total counts of adults and larvae of *Cryptolestes* spp. and *Carpophilus dimidiatus* (F.) from samples taken during the run-out of test bins. Times when samples were taken are represented by time markings below the bin run-out time axis.

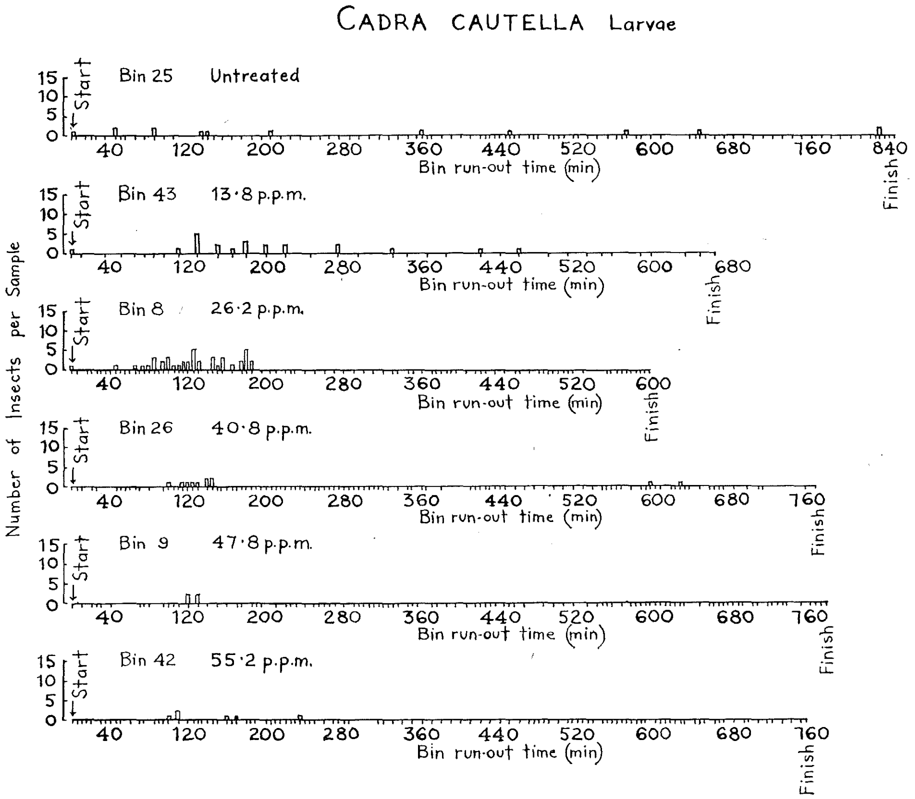


Fig. 5.—Trial II, Peanut storage silos, Kingaroy, 1962-63. Total counts of larvae of *Cadra cautella* (Walk.) from samples taken during the run-out of test bins. Times when samples were taken are represented by time markings below the bin run-out time axis.

## TABLE 6

TRIAL II, PEANUT STORAGE SILOS, KINGAROY, 1962-63. MALATHION RESIDUES (P.P.M.) IN SHELLS AND KERNELS SIX MONTHS AFTER TREATMENT AS NUT-IN-SHELL

| Malathion Applied (p.p.m.) | Shells | | Kernels |
|---|---|---|---|
| | Samples Taken in Sequence over Whole Run-out Period | Average | |
| 13·8 | 2, <2, 2·2, <2, <2, 2·9, <2 | <2 | <1 |
| 26·2 | 8·1, 9, 9, 9·2, 3·2, 3·8, 10·0, 3·3, 8·4, 4·8 | 6·9 | <1 |
| 40·8 | 8, 9, 11, 7·5, 8·8, 10·5, 10, 9·4, 8·4, 8·4, 7·6, 7·4, 9 | 9·1 | <1 |
| 47·8 | 14, 14, 11·5, 14, 11·5, 15 | 13·3 | <1 |
| 55·2 | 16, 17, 12·5, 13·5, 14·5 | 14·7 | <1 |

### (d) Comments

Though the entire silo block had been fumigated with methyl bromide in the previous March, heavy infestations had built up in all other bins in use in the block. The important pests present in the test bins were *T. castaneum, O. mercator, C. cautella* and *C. dimidiatus*. The distribution and abundance of these will be discussed separately as an appendix.

In summary, the minimum concentration of malathion that was necessary to give adequate control of these pests was 41 p.p.m. This approximates to the United States Department of Agriculture recommendation of 44 p.p.m. (Anon. 1961).

At 41 p.p.m., residues after 6 months' storage were $<$ 1 p.p.m. in kernels and 9 p.p.m. in shells. Shells were previously dumped or used as mulch but have become popular recently as roughage in stock feeding. On a weight basis, shells would not exceed 25% of any feed mixture and residues would be reduced to safe levels accordingly. Residues should thus be of no consequence.

## IV. DISCUSSION

Malathion did not prevent reinfestation of bulk surfaces at the time of population peaks in surrounding untreated bins (trials I and II). Accordingly, because of the well-known efficacy of pyrethrins for control of *C. cautella* and *P. interpunctella,* a surface spray of 2·5% malathion and 0·05% pyrethrins/ 0·5% per cent piperonyl butoxide was chosen for commercial use. At 1963 prices of malathion 80% w/v concentrate (£5 14*s* 6*d* per gal) and synergised pyrethrins (5% pyrethrins, 50% piperonyl butoxide) (£28 10s per gal), material costs for bulk treatment at 44 p.p.m. are 1*s* 5*d* per ton and material costs for a total of 6 surface sprays are 4½*d* per ton per year. No additional labour costs for bulk treatment would be involved with the sprayers installed along the overhead conveying system, where an operator is in attendance in case of blockages. Assuming 2 men would treat 5 round bins (20 ft diameter, of 170 tons) per hour with surface sprays, labour costs for the maximum 6 treatments would be 1⅓*d* per ton at a wage rate of £15 per week. This would reduce to less than 1*d* per ton over the whole crop, allowing for disposal to markets. A maximum figure of 1*d* per ton over 20,000 tons would cover depreciation and part replacement of the spray equipment. The total figure for protectant use would approximate 2*s* per ton. Considering residual effectiveness, this figure compares favourably with the present cost (2*s* 6*d* to 3*s* per ton) of methyl bromide fumigation, which gives no subsequent protection.

In 1963 the whole intake to Board storage at Kingaroy was treated with malathion at 44 p.p.m., applying the spray as in trial II to the peanut stream on the overhead conveyor belts. Observations and sampling indicated virtually complete control of the major pest species until January 1964, when light *C. cautella* infestations were found in some bins. A primary cause of this was storage of untreated nuts on the bin-top floor; these nuts were heavily infested with *C. cautella*. No serious infestations were recorded, and as such storage of untreated material has been discontinued, a higher level of control can be expected from overall treatment of the silo block (this was, in fact, achieved with the 1964 crop). Infestations of *C. dimidiatus* were present in many bins but numbers were not high. These infestations again were associated with residues on walls of bins and areas where localized moisture accumulation occurred. Aeration should be the answer to this problem and such a facility would improve greatly the persistence of malathion.

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## REFERENCES

ANON. (1960).—The determination of malathion residues in cereals and oilseeds. *Analyst* 85:915-21.

ANON. (1961).—Insect prevention and control in farmers stock peanuts. *U.S. Dep. Agric.* AMS-453.

CHAMP, B. R. (1965).—An investigation of peanut storage pests in Queensland. 1. Introduction, species and pest status. *Qd J. Agric. Anim. Sci.* 22:227-40.

LEFKOVITCH, L. P. (1963).—The biology of *Cryptolestes pusilloides* (Steel and Howe) (*Coleoptera, Cucujidae*), a pest of stored cereals in the Southern Hemisphere. *Bull. Ent. Res.* 54:649-56.

SURTEES, G. (1963).—Laboratory studies on dispersion behaviour of adult beetles in grain. III. *Tribolium castaneum* (Hbst.) (*Coleoptera, Tenebrionidae*) and *Cryptolestes ferrugineus* (Steph.) (*Coleoptera, Cucujidae*). *Bull. Ent. Res.* 54:285-96.

## APPENDIX

### Observations on the Distribution and Abundance of *Carpophilus dimidiatus* F., *Tribolium castaneum* Herbst.), *Oryzaephilus mercator* Fauv., *Cryptolestes* species and *Cadra cautella* (Walk.) in Silo-stored Nut-in-Shell Peanuts Treated with Malathion

The sequence of pest build-up in silo storage at Kingaroy, Queensland, has been discussed previously (Champ 1965). The following observations on pest distribution and abundance were made during assessment of the efficacy of malathion in trial II reported in the text of this paper.

No specific examination was made of the run-out behaviour of bins. General observations, however, indicated that a normal funnelling sequence was followed. The core emptied first, being replaced by fall-in from the walls; the top surface layer appeared about 120 min after run-out started and portions of it were present in the outflow for approximately 60-80 min. Thus, from start to approximately 120 min the core of the bin from bottom to top appeared progressively, followed after 200 min by the outer layers from top to bottom.

The patterns formed by the occurrence of the various insect species in the run-out samples indicated their distribution in the different bins. Population densities were correlated with top surface treatments as well as bulk treatment and the effectiveness of both was reflected in these patterns.

Populations were highest in bins 25 (control) and 43 (13·8 p.p.m.). Bin 25 had no exposed walls and there was no noticeable moisture redistribution; the temperatures recorded (Table 5) were a true indication of the trends within the whole bulk. Bin 43 had two-thirds of its wall surface exposed with a north-west aspect, the aspect most conducive to temperature fluctuations, heating and mould growth; the temperatures recorded from the middle of this bin at 6 ft (Table 5) were lower than those on the north-west side and top surface of the bin.

Control was satisfactory in bins treated at 41 p.p.m. and above. Run-out samples from these bins indicated light infestations of *Carpophilus dimidiatus* F. This had been evident throughout storage by the presence of considerable numbers of larvae, mostly dead, in samples taken from the bottom of the bins and from a continuous emigration through cracks in outlet chute fittings. The occurrence of *C. dimidiatus* followed the degree of exposure of bin walls to diurnal temperature variation and consequent moisture accumulation (Figures 1 and 4, bin 43). Further evidence of this moisture gradient and consequent decline in *C. dimidiatus* numbers along this gradient is shown in Figure 4, where core samples contained fewer insects than peripheral samples. Probably, breeding *C. dimidiatus* was exposed to low levels only of malathion in treated bins because of unfavourable conditions for malathion stability; fully grown larvae and adults leaving the habitat would have been exposed to the higher concentrations that occurred generally through the bins. Control of *C. dimidiatus,* however, does not primarily concern insecticides; prevention of local moisture build-up and mould growth are necessary; for example, by protection of walls from violent temperature fluctuations, and by aeration.

*Tribolium castaneum* (Herbst.) breeds with difficulty at 80°F and temperature considerations alone cannot account for the higher and actively breeding population in bin 43 compared with the almost non-breeding population of bin 25 (Figure 3). The malathion had no apparent effect on numbers in bin 43, which were highest in the top surface layers (from 120 to 200 min) and progressively decreased down the bin. The core pattern corresponded with that of the outer layers and breeding was apparent throughout the bin. Bin 8 (26·2 p.p.m., 1·0% top spray) had a reduced population and *T. castaneum* was almost absent from the surface layers (Figure 3, 120–200 min; Table 5); these effects were attributable to the malathion treatment. Again core and outer layer patterns corresponded and breeding was apparent in all areas of occurrence. Five live adults were found at run-out in bin 26 (40·8 p.p.m.) and one in bin 9 (47·8 p.p.m.); these were located in the bottom 20 ft of the bin (Figure 3). Some *T. castaneum* was found in top surface layer samples from these bins and in bin 42 (55·2 p.p.m.), which was clear of *T. castaneum* at run-out. These were located in the peaks of the bulks and may have represented immigrants from surrounding bins, as bin manhole covers were left open during the trial. Control was effective at 40·8 p.p.m. and above.

*Oryzaephilus mercator* Fauv. was present in numbers in bins 25 and 43 only (Figure 3, Table 5). Numbers were comparable but again the population in bin 43 was breeding more actively. As with *T. castaneum*, infestation was present in the core and the periphery of the bin but showed a progressive decrease from the top surface down the bin. Control was effective at 26·2 p.p.m. and above.

*Cryptolestes* species were active in bins 25, 43 and 8 (Figure 4). Limited determinations of species were made; *C. pusilloides* (Steel and Howe) appeared to be the species implicated. As with *T. castaneum* and *O. mercator,* bin 43 had a higher population than bin 25. Lefkovitch (1963) associated *C. pusilloides* with warm and high humidity conditions (optimum 30°C, 90% R.H.), which appears a factor in the present distribution. The infestation in bin 25 was confined to the lower half of the bin, and as would be expected with an internal bin, was not localized horizontally. The lower part of this bin was filled with nut-in-shell at a slightly higher moisture content than the top half (average 0·5% difference) and did contain some loads as high as 10–10·5%. The highest infestation was recorded in bin 43. Here, numbers in samples were highest in the core, depressed in the top surface layer (see Table 5 also) and slightly higher in the outer portions. The higher core figures indicated the moisture gradient from the outer walls across the bin discussed earlier. It appeared that the distributions of *Cryptolestes* (probably *pusilloides*) and *C. dimidiatus* overlap. Bin 8 had core figures lower than those from the periphery, which again indicated a moisture gradient from the outside wall, with, in this instance, *Cryptolestes* numbers decreasing across the bin from this wall. *Cryptolestes* were absent from the surface layers of bin 8; the malathion surface treatment may have been a factor in this. It appears though that this species was absent from surface layers at low population densities (up to 10 insects per sample) (cf. *ferrugineus* (Steph.), Surtees 1963) but appeared in these layers as populations increased. Control was effective at 40·8 p.p.m. and above.

*Cadra cautella* (Walk.) was the only phycitid present. The larval population at run-out was confined to the core of the bin. Seasonal occurrence of *C. cautella* has been discussed previously (Champ 1965), and as is evident from Table 5, surface populations were down to low numbers which were reflected throughout the bulk (Figure 6). Malathion exercised some control but deficiencies were apparent, particularly with top surface sprays.

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