The use of a managed bulk of grain for the evaluation of PC, pitfall beaker, insect probe and WBII probe traps for trapping *Sitophilus granarius, Oryzaephilus surinamensis* and *Cryptolestes ferrugineus*

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Abstract

A 100 tonne flat-store of wheat has been used to evaluate PC (surface and buried), pitfall beaker, insect probe and to a lesser extent WBII probe traps for trapping *Sitophilus granarius, Oryzaephilus surinamensis* and *Cryptolestes ferrugineus*. Each of three trials evaluated the traps against one species over an eight-week period. *S. granarius, O. surinamensis* and *C. ferrugineus* were seeded into the bulk at 1.0, 0.3 and 0.75 per kg, respectively. The WBII traps were evaluated against *O. surinamensis* (for the last two weeks of the trial) and *C. ferrugineus* only. 'Tinytalk' temperature data recorders were used to record ambient temperatures, those at the grain surface at 5 cm depth and for trials with *O. surinamensis* and *C. ferrugineus* temperatures on and within traps. The temperature and trap records showed the trials to be conducted close to the movement threshold for each species. The traps throughout the eight-week trial periods trapped only 0.3% *S. granarius*, 2.75% *O. surinamensis* and 0.9% *C. ferrugineus* from those released. The surface PC and pitfall beaker traps were the most effective for trapping *S. granarius*, both PC traps for *O. surinamensis* and the WBII trap for trapping *C. ferrugineus*. The surface PC trap showed a close correlation of trap catch with the PC buried trap for all three species. Both of these traps also correlated well with maximum temperatures recorded on the surface of the grain during each week of the *O. surinamensis* trial. The three trials showed the importance of considering temperature in trapping programs and further demonstrate the importance of trap type and position with regard to trapping different grain beetle pests.

Introduction

The use of traps for the detection of insect pests in large bulks of grain has been shown to be far better than the use of sampling techniques (Cogan and Wakefield 1987). The initial evaluation of detection methods for beetle pests in grain was undertaken by the authors in flat (floor) stores in both farm and commercial stores. Commercial stores were found to be more uniform in storage practices and provided a more reliable experimental site. As the intended end use of the grain was more predictable, experiments could be planned with some reliability.

Commercial storekeepers in the U.K. have implemented trapping as a means for the detection of beetle pests. Cogan and Wakefield (1987) recommended the use of two traps—one placed upon the surface and one buried—in order to detect all the storage beetle species found in U.K. grain stores. However, those storekeepers that use traps tend to use one type either designed for surface trapping or one for detecting insects located beneath the grain surface (Prickett and Muggleton 1991). For this reason the PC trap was developed (Cogan et al. 1990), one trap performing both functions.

Following the success of the introduction of traps into commercial stores, storekeepers now have some experience of traps and interpreting trap catch. Interpretation varies from store to store but the awareness of traps has led many storekeepers to implement remedial measures when any trap shows insect presence. This usually takes the form of localised surface treatments with insecticide. Evaluation of traps in such stores has thus become extremely difficult.

For this reason our approach has been to set up a representative grain store for the evaluation of traps, including the PC trap. The major grain pests of the U.K., *Sitophilus granarius, Oryzaephilus surinamensis* and *Cryptolestes ferrugineus*, have been used to evaluate PC, pitfall beaker (Cogan and Wakefield 1987), insect probe (Burkholder 1984) and to a lesser extent, the WBII (Burkholder 1988) traps.

Traps are most useful and provide the earliest warning of damage if they trap at low infestation levels. Considerable warning is also obtained if traps are able to trap at low temperatures prior to the grain heating to the breeding temperatures of the beetle pests. Insect movement for storage beetles is considered to start above 5°C (Field 1992) and breeding above 12°C (Howe 1965). Commercial stores in the U.K. often maintain their grain below 12°C for much of the year. For the trials reported here, the grain was maintained at a temperature sufficiently low for each species so as to provide information on low temperature trapping.

Method

The site housing the experiment was a shed approximately 90 × 60 m with a 15 m height to the roof girders.

The grain walling consisted of 1.5 × 1.75 m wide panels bolted to supports to form a barrier 3 m in height. The back wall of the store was built to a width of 7.8 m and the two sides projected forwards 11.2 m (see Fig. 1a). There was no wall at the front.

A central aeration duct approximately 0.45 m diam connected to an aeration fan was positioned at the rear of the store and extended through to within 1 m of the front of the grain slope. The duct was sealed at the front end.

One-hundred tons of pesticide-free feed wheat were added to the store so that for a distance of 5 m from the back of the store the grain was level and at a depth of 2 m. This area represented 59% of the grain volume and 41% of the exposed surface area. For the rest of the bulk (7.8 × 6.5 m) the grain sloped down to the floor at the front (Fig.1b).

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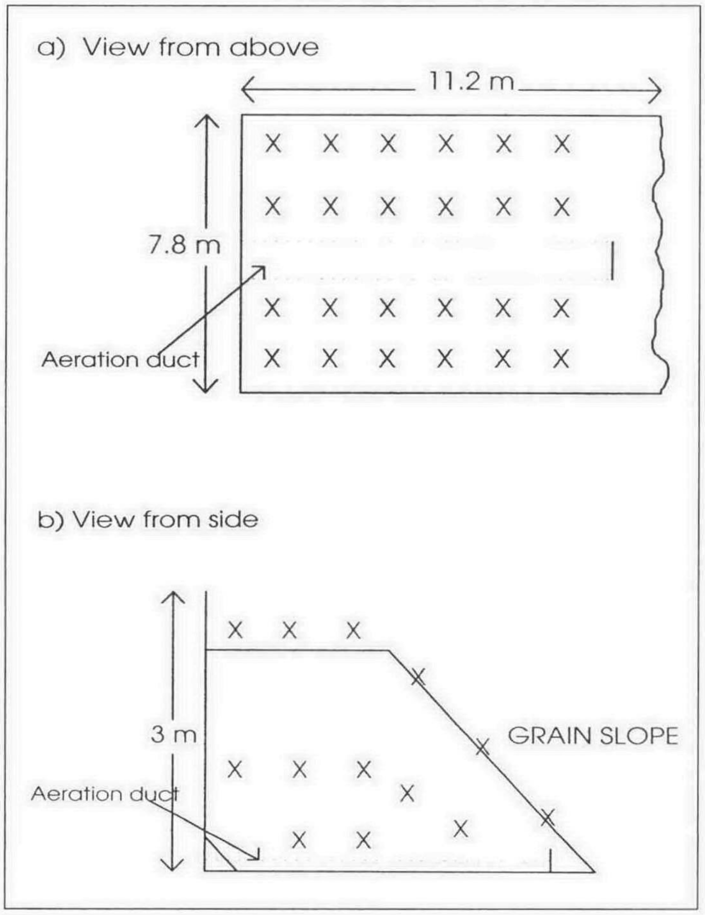

Fig. 1. Plan of 100 t floor store. X = trapping position.

Duckboards were placed centrally from the front to the rear of the store. A second path of duckboards was placed across the back of the store approximately 1 m from the rear grain walling.

One week after delivery of the grain for the first trial, a 1 kW electric fan heater was connected to the intake of the aeration fan. After one week the heater was increased to 2 kW. After a further week excessive condensation made it necessary to stop heating the grain.

For the second trial it was not necessary to heat the grain, but for the final trial heating using 2 kW was undertaken throughout the period.

Addition of insects

A vacuum sampler attached to a 2 cm diameter tube was used to remove a core of grain down to the bottom of the bulk. Adult insects were added to the grain bulk by pouring into the tube in batches of 500 to prescribed depths within the grain. After pouring in the insects at the lowest depth, 2 m, the tube was then removed to 1m depth before pouring in the next batch of insects. This was repeated at 0.5 m and 0.25 m. The distribution of batches was made so that they were added at regular intervals in a grid pattern across the bulk. The number of batches necessarily varied with the depth of the grain and number of insects of each species.

First trial

A total of 100 batches of 500 *S. granarius* (a laboratory insecticide-susceptible population, in culture for more than 20 years) were added to provide a density of 0.5/kg.

After eight weeks, and very few insects recorded in the traps, a further 50000 *S. granarius* were added to make a total of 100000 beetles in the grain, i.e. 1.0/kg.

Second trial

O. surinamensis (a laboratory insecticide-susceptible population, in culture for six years) were added at 0.3/kg. A total of 60 batches of 500 insects were put into the grain (30000 or 0.3/kg).

Third trial

A total of 75000 (0.75/kg) *C. ferrugineus* (a standard insecticide susceptible laboratory population, in culture for more than 10 years) were added.

Disinfestation between trials

After the first trial the grain was fumigated using methyl bromide. The 100 t of feed wheat was then turned. This was achieved by removing the grain from the store using a tractor fitted with a 1 t bucket and once the store was empty returning the grain back as for the first trial. For the final trial the wheat was disinfested using carbon dioxide from burner gas. The wheat was turned and returned to the store as for the second trial.

Monitoring the bulk

Samples of the wheat were taken after delivery and analysed for insecticide contamination. No insecticides were detected.

At each visit, spot temperatures were recorded using a portable temperature probe. Twelve locations across the bulk were recorded at each visit, taking readings at approximately 5 cm and at 1.5 m depths. Ambient temperature within the shed was also recorded.

'Tinytalk' temperature data recorders were used to record at two-hour intervals the temperature of the grain in the surface layer at approximately 5 cm depth. The 'Tinytalks' were sited approximately 1 m from the rear wall, one in the middle and one on either side of the bulk. Additional 'Tinytalks' were added during the second and third trials so that two trapping positions were monitored, one at the back of the bulk and one in the middle of the bulk. 'Tinytalks' were placed at 5 cm depth in the grain, on the PC trap top on the grain surface at the centre and within a pitfall beaker located at the back of the bulk.

For analysis, only the maximum temperatures recorded each week by the 'Tinytalks' were considered, as trap capture is largely dependent upon temperatures that allow insect activity. Temperatures within the bulk throughout the trials were not sufficiently low for a long enough period to cause insect mortality.

Trap location

Traps were positioned at 24 locations (Fig. 1). At each location there were two PC traps; one with its lid placed upon the surface (PC) and one with its lid approximately 5 cm below the grain surface (PC buried). Also at each location a pitfall beaker trap and an insect probe trap were inserted into the grain. Traps were initially positioned 1 m apart, one at each cardinal point. At each position the traps were assigned randomly but keeping the PC and PC buried traps opposite each other. Where depth permitted (Fig. 1), insect probe traps were also inserted to depths of 1 m (20 locations) and 2 m (four locations). These insect probe traps were buried near to the centre of each trapping location.

At each weekly visit the traps were examined and the catches recorded. The traps were then rotated to occupy the cardinal position 90 degrees either clockwise (even numbered trap positions) or anti-clockwise (odd numbered positions).

For the last two weeks of the second trial and throughout the final trial WBII traps were included. WBII traps were placed randomly between the traps on every other trap location and moved as described above.

Each trial lasted 10 weeks from the initial addition of the insects. Traps were placed in position one week after addition of the insects, thus providing eight weeks of trap catch results. Only 11 *S. granarius* were trapped in the first part (0.5/kg) of the first trial and therefore trap catches were recorded for a further eight weeks after introduction of the second batch of insects. Results for the second part only (1.0/kg) are considered in this paper.

One week after introduction of each batch of 50000 *S. granarius*, and inclusion of *O. surinamensis*, gravity spear samples were taken at 2 m (where possible), 1 m and 0.5 m. On these occasions, 1 kg samples were obtained and sieved at 12 locations, roughly corresponding with the temperature recording positions. Spear samples were not taken for *C. ferrugineus*.

A total of 32 bait bags (Pinniger 1975) were positioned at 1.5 m intervals at approximately 2 m from the outside edge of the grain walling. These were checked at weekly intervals for escapes from the experiment. A further metre outside the bait bags, 1 m-wide band of chlorpyrifos-methyl emulsifiable concentrate was sprayed at field dose to prevent any insects that had escaped from leaving the building.

Trap types were compared using Mann-Whitney ranking and trap capture relationships with temperature and trap types (and positions) were investigated.

Results

The wheat was delivered at a moisture content of 15.5%. For the second and third trials the moisture content of the bulk of the grain was approximately 16%, with the surface ranging between 16 and 19%.

Wheat was delivered for the first trial at a temperature of approximately 8°C. Heating raised the grain temperature to a 10.5°C mean (range 6.8–13.0°C) at the surface and 10.8°C (9.2–12.3°C) at 1.5 m in the bulk, before addition of the first batch of insects. By the time the second batch of insects was added the temperature had fallen to 3°C at the surface (range 2.9–3.4°C) and 6.4°C at 1.5 m (4.6–7.7°C).

For the second trial the initial grain temperature averaged 13.7°C (range 13.2–14.0°C) on the surface and 15.1°C (13.5–16.1°C) at a depth of 1.5 m in the bulk, at the time of the addition of the insects.

For the final trial the average temperatures at the surface were 9.3°C (range 7.8–12.3°C) and at 1.5 m, 12.9°C (10.7–16.5°C), at the time of the addition of the insects.

Results of the trap catches for each trap type along with the number of traps that were positive, i.e. the number of traps which recorded insects present, are presented in Tables 1–5.

For all three trials a high correlation was found between the trap catches for the PC and PC buried trap with $r = 0.75$ for *S. granarius*, $r = 0.95$ for *O. surinamensis* and $r = 0.90$ for *C. ferrugineus*.

First trial (*S. granarius*)

Maximum spot temperatures for the surface (5 cm depth) rose from 3.4°C at the time of the addition of the second batch of insects, to 9.0°C two weeks later. For the rest of the trial, maximum spot temperatures remained between 6.1°C and 9.8°C. Maximum spot temperatures at 1.5 m, rose from 7.7°C to 8.1°C then remained between 5.9°C and 8.3°C for the rest of the trial.

Table 1. Number of *S. granarius* recorded in traps over an eight-week trial period from 100000 released into a 100 t grain bulk.

	P.C traps			Insect probe traps		
Week	Pitfall	Surface	Buried	Surface	1 m	2 m
1	11	12	15	3	0	0
2	44	63	17	0	1	0
3	15	15	1	0	0	0
4	13	3	0	0	0	0
5	10	14	0	0	0	0
6	10	11	5	0	0	0
7	9	7	2	0	0	0
8	4	3	0	1	0	0
Total	116	128	40	4	1	0

The 'Tinytalk' surface maximum temperature readings for the second period (1.0/kg) are presented in Figure 2. Surface temperatures remained below 9.5°C for the first five weeks of the trial, rising to 12°C for the final three weeks.

All trap types, except for the 2 m insect probe traps, trapped *S. granarius* but only two were trapped in the 1 m probes (Table 1). A total of 300 *S. granarius* (0.3%) were trapped from the 100000 released into the grain.

During the trial, the greatest number trapped in one week was 125 (43% of those trapped). This occurred during the second week (Table 1).

Comparing the effectiveness of the traps with regard to their ability to detect *S. granarius*, the PC and pitfall beaker were significantly better ($p < 0.05$), i.e. more per trap and more positive traps, than the PC buried and the insect probe traps (Tables 4 and 5).

No *S. granarius* were found in the bait bags and only one was found in the gravity spear samples.

Second trial (*O. surinamensis*)

Surface spot readings fell from a mean of 13.1°C (range 12.5–13.1°C) in the second week to 7.0°C (6.1–7.6°C) at the end of the trial. During the fourth week only, the temperature rose to give a mean of 13.9°C (13.5–14.6°C).

Spot temperatures at 1.5m were at their maximum on the second week with a mean of 15.4°C (range 14.8–15.7°C). The mean fell gradually throughout the trial to 12.7°C (10.4–13.8°C) at the end of the trial.

'Tinytalk' temperatures recorded on the PC trap-top fell from a maximum of 16.9°C during week two to 8.4°C by week six, continuing with this temperature as a maximum until the end of the trial. In the surface layer (5 cm depth) the maximum temperature fell from 15.2°C in week one to 7.8°C by week seven (Fig. 2).

A total of 990 *O. surinamensis* (2.75%) were trapped from the 30000 released into the grain (Table 2). The greatest number trapped in one week was 268 (27% of those trapped), during the first week of trapping. Numbers trapped decreased except for week six and for the final week (Table 2).

All trap types trapped *O. surinamensis* (Table 2). Although only three were recorded in the 2 m insect probe traps, 138 were recorded from the 1 m insect probe traps, with 49 of these recorded during the last week.

Comparing the effectiveness of the traps with regard to their ability to detect *O. surinamensis*, i.e. positive traps (Table 5),

Table 2. Number of *O. surinamensis* recorded in traps over an eight-week trial period from 30000 released into a 100 t grain bulk.

		PC trap		WB11		Insect probe traps	
Week	Pitfall	Surface	Buried		Surface	1 m	2 m
1	13	92	91	-	42	29	1
2	4	59	91	-	20	17	1
3	1	45	66	-	4	1	0
4	7	29	62	-	7	9	1
5	2	16	30	-	3	9	0
6	4	20	24	-	8	14	0
7	5	10	17	12	4	10	0
8	4	22	26	8	1	49	0
Total	40	293	407	20	89	138	3

Table 3. Number of *C. ferrugineus* recorded in traps over an eight-week trial period from 75000 released into a 100 t grain bulk.

		PC traps		WB11		Insect probe traps	
Week	Pitfall	Surface	Buried		Surface	1 m	2 m
1	2	13	7	16	6	32	3
2	0	0	3	66	12	4	1
3	40	1	3	22	16	30	8
4	1	1	2	19	12	12	4
5	0	0	1	16	11	4	2
6	12	6	8	15	5	2	11
7	4	6	6	3	4	16	0
8	8	37	78	21	30	21	8
Total	67	64	108	178	96	121	37

Table 4. Number per trap during the eight-week trapping periods. [a]Extrapolated from two weeks' data.

		PC trap		WB11		Insect probe traps	
	Pitfall	Surface	Buried		Surface	1 m	2 m
S. granarius	5.0	5.4	1.7	-	0.2	0.1	0
O. surinamensis	1.7	12.2	17.0	7.3[a]	3.7	6.9	0.8
C. ferrugineus	2.8	2.7	4.5	16.2	4.0	6.1	9.3

[a]Extrapolated from two weeks' data.

Table 5. Number of traps recording insects (positive traps) per trapping position during the eight-week trapping period. * Extrapolated from two weeks' data.

		PC traps		WB11		Insect probe traps	
	Pitfall	Surface	Buried		Surface	1 m	2 m
S. granarius	2.4	2.1	0.6	-	0.1	0.1	0
O. surinamensis	1.5	3.8	4.9	4.0*	2.1	2.4	0.8
C. ferrugineus	0.8	0.8	1.1	2.8	2.0	1.9	2.5

both surface and buried PC traps proved significantly better ($p < 0.05$) than the probes and the pitfall beaker. The PC buried traps proved significantly better ($p < 0.05$) than the 1 and 2 m insect probe traps.

There was a high correlation between the trap catches for PC and pitfall beaker traps ($r = 0.97$) and to a lesser extent with PC buried and surface insect probe traps ($r = 0.77$). Maximum temperatures recorded by the 'Tinytalk' temperature data recorders on the trap-top correlated closely (both $r > 0.8$) with PC and PC buried trap catch.

Only three *O. surinamensis* were found in the bait bags and none were found in the gravity spear samples.

Third trial (*C. ferrugineus*)

The ambient temperature throughout the *C. ferrugineus* trial was between 3.4°C and 8.1°C. Spot temperatures fluctuated widely at the beginning of the trial with the surface mean 12.3°C (range 9.3–13.6°C) and 1.5 m mean 16.5°C (range 10.3–25.6°C).

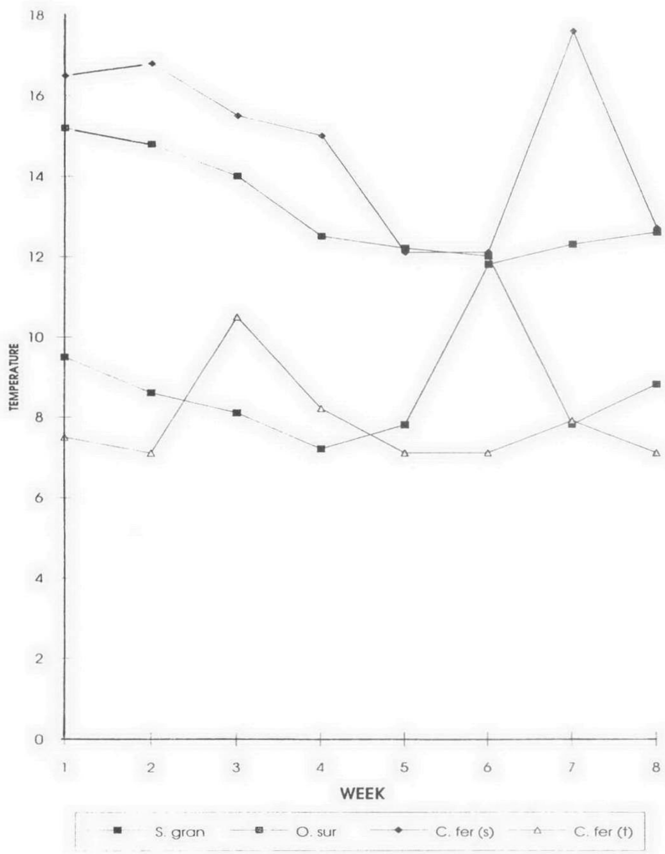

Fig. 2. Weekly maximum temperatures at surface layer, s—surface, t—trap top.

Temperatures were lower by week two, with the surface mean at 9.1°C (6.1–14.6°C) and 1.5 m mean 10.7°C (7.4–13.6°C).

Temperatures were more consistent on the surface of the bulk for the rest of the trial, at approximately 8°C. However, the 1.5 m spot temperature means fluctuated from a 15.3°C (week 3) to 9.5 °C (week 5) and to 12.8°C by the end of the trial.

The 'Tinytalk' temperature recorder buried 5 cm into the surface layer at the back of the bulk showed a gradual drift in maximum temperature from 16.8°C in the second week to 12°C by week five, then up to 17.6°C in the penultimate week (Fig. 2). A similar pattern was observed in the centre surface layer trap but the 'Tinytalk' positioned upon the trap top recorded between 5°C and 9°C lower each week compared with those in the surface layer. Temperatures on the trap top were between 7.1°C and 8.2°C except for the third week when it was 10.5°C (Fig. 2). At the front of the bulk, on the sloping grain, temperatures fell from 8°C (maximum) to 6°C over the same period and then rose to 8°C in the last week.

The 'Tinytalk' placed in the pitfall beaker trap in the surface layer fluctuated wildly from 15°C in the second week to 7°C by week five and then back to 14°C by the final week.

Condensation and damping were evident on the surface of the bulk after five weeks of the trial.

A total of 671 *C. ferrugineus* (0.89%) were trapped from the 75000 released. In the final week 203 (30% of the 671) were trapped, the highest weekly catch. None were trapped in the traps positioned at the front of the grain slope.

All trap types trapped *C. ferrugineus*. Thirty-seven (6% of trap captures) were recorded in the 2 m insect probe traps and only 131 (20%) were recorded in the surface traps (PC and pitfall beaker combined). Over 70% of the total PC buried trap catch was recorded during the last week (Table 1).

Comparing the effectiveness of the traps with regard to their ability to detect *C. ferrugineus* (Tables 4 and 5), the WBII trap was significantly ($p < 0.05$) better than the PC, pitfall beaker or PC buried.

The 1 m insect probe trap catch showed a high correlation with the ambient and also the surface spot temperatures (both $r > 0.83$).

No *C. ferrugineus* were found in the bait bags surrounding the bulk.

Discussion

The store was set up to represent a typical 100 t farm store. The layout appears to be representative of the U.K., but no farm store would be monitored so heavily.

The ability to heat the grain using fan heaters connected to the aeration fan had some success but condensation in the first trial became a problem so the heating had to be abandoned. Condensation and damping of the grain also became a problem after five weeks in the final trial.

Temperatures achieved throughout the trials were sufficiently low as to provide information on low temperature trapping.

The lack of insects found in the spear samples is unsurprising, with only 12 kg of samples taken and a density of 0.5 and 0.3/kg for *S. granarius* and *O. surinamensis*, respectively. This lack of recovery of the two species further demonstrates how unwise it is to rely on spear samples for detecting insects. The insects had not left the grain bulk during the trials or they would have been detected by the bait bags. It must be assumed that the insects were therefore in the bulk but not detected except as determined by the trap catches. The percentage trap catches for *O. surinamensis* (2.75%) and *C. ferrugineus* (0.9%) were lower than those recovered (8.6 and 2.9 %, respectively) in the bin trial by Wilkin et al. (1990). For *S. granarius* the recovery was the same at 0.3%. It must be noted that the initial temperature of the grain in the Wilkin et al. trial was far higher than the trials presented here and that the more mobile species (*O. surinamensis* and *C. ferrugineus*) would be expected to find their way to the traps more readily than the less mobile *S. granarius*.

Although *S. granarius* is the most cold hardy storage beetle in the U.K. (Howe 1965) it is unlikely that it moves much below 9°C. Wilkin et al. (1990) trapping the same laboratory strain of *S. granarius* used in these trials, found that pitfall beaker trap catch ceased at temperatures below 6.5°C and only occasionally were *S. granarius* trapped below 12°C. In the experiment reported here, some of the *S. granarius* found in the pitfall beaker traps may have fallen in involuntarily through movement of the grain, but those in the PC surface traps must have been trapped and therefore indicate insect movement throughout the eight weeks of the trial.

The low temperatures recorded by both the 'Tinytalk' temperature recorders and the spot readings for the period when the *S. granarius* were present at 1.0/kg do not explain the relatively high numbers trapped. It is important to note that it is the maximum temperatures, as seen in the 'Tinytalk' records, which should be considered when viewing the possibility of movement. The Tinytalk readings were at two-hour intervals and therefore reflect far more accurately the temperature changes in the trials than do the weekly spot readings.

For the whole of the first trial, spot surface temperatures remained below 10°C and at 1.5 m below 8°C. The 'Tinytalk' recordings agree with the surface spot recordings and show the surface layer maximum temperature at 9.5°C on the first week but after that date not above 8°C until week six. By this time most of the *S. granarius* that were trapped in the trial had been trapped.

The *S. granarius* were a laboratory population and as such might be considered to be less likely to move at low temperatures than field populations. The trap catches and temperature data show that *S. granarius* are able to move and be trapped at temperatures below 10 °C , particularly on the grain surface. An explanation for their movement might lie in the position of the 'Tinytalk' recorders, which for the first trial were buried 5 cm below the grain surface. Temperatures may have fluctuated more widely closer to the grain/air interface as occurred in the other trials and may have reached such temperatures as to allow movement.

As was expected from both laboratory and field trials (Cogan and Wakefield 1985, 1987), the insect probe traps performed poorly against *S. granarius*. A total of just five insects were recorded during the trial.

Although more *S. granarius* were trapped by the PC surface traps (Table 4), the pitfall beaker trap recorded more positive trap catches (Table 5). Surprisingly, the PC buried traps trapped 12% of all the *S. granarius* trapped.

The PC trap catch was possibly aided by the low temperatures as the *S. granarius* would have supposedly been less able to 'dangle' i.e. hang by just two legs into the trap hole as described in Wakefield and Cogan (1993) and then withdraw from the trap hole to avoid capture. This may help explain the lack of correlation between increase in temperature and trap catch reported for *Rhyzopertha dominica*, *Tribolium castaneum* and *S. oryzae* (Fargo et al. 1989). Traps do not catch all insects encountering the trap. Some may 'dangle' in the trap hole then withdraw. Trap catch falls with temperature decrease due to fewer insect / trap encounters over a period of time. As temperatures fall, a point is reached where trap catch will increase due to the inability of the insects to escape from an encounter with the trap hole, resulting in a greater success rate for the trap.

For the *O. surinamensis* trial, temperatures were higher than in the first trial. Throughout the trial weekly maximum temperatures fell at the surface from 17°C at the start down to less than 9°C at the end. These temperatures correlated well with the catch found in the PC surface and buried traps. This relationship between temperature and trap catch should greatly assist with the calibration of the PC traps when relating *O. surinamensis* infestation with trap catch.

The surface trap catches, i.e. in PC and pitfall beaker, also correlated well, although the PC trap (surface and buried) proved to be the most effective trap type used for*O. surinamensis* detection.

The high number recorded in the 1 m insect probe traps during the last week may well reflect migration of this species down into the bulk as temperatures at the surface lowered during the final two weeks.

The temperatures in the *C. ferrugineus* trial showed the greatest fluctuations but at the surface layer the temperature remained above 12°C throughout the period. This was above the temperature at which traps caught this species in the trials conducted by Wilkin et al. (1990). Temperatures on the surface traps as determined by the 'Tinytalk' recorder on the PC trap top showed the importance of recording at the trap/air interface. The surface layer was found to be between 5°C and 9°C above this trap top temperature where maximum temperatures were 7.1°C for four weeks and only rose above 10°C during one week. This rise to 10°C coincided with the largest trap catch for the pitfall beaker traps with 60% of their total caught in the one week.

The high trap capture in the last week of the *C. ferrugineus* trial is harder to explain but may have been due to the sudden 5°C increase in maximum temperatures during the penultimate week. The lowering by 5°C in the final week may have resulted in many beetles migrating into the bulk of the grain, having moved to the surface when the temperature was more favourable during the preceding week. This is supported by the trap catch of the PC buried and surface insect probe traps both of which had their largest catch in the final week. A difficulty with this hypothesis is that the PC trap on the grain surface also recorded its largest catch during the final week when the temperature at the trap was at a maximum of 7.1°C.

Cuperus et al. (1990) considered that aggregation of species such as *C. ferrugineus* makes trap catch sensitive to trap placement. Watters (1969) and Loschiavo (1983) found*C. ferrugineus* movement to be affected by moisture and temperature. Trap catch also increases significantly as grain temperature increases (Loschiavo and Smith 1986; Fargo et al. 1989). This trial considered temperature alone but we only found a correlation between catch in the probe traps at 1 m depth with ambient and spot surface temperatures. The correlation with ambient may have been due to the influence of the aeration fan for much of the trial; the temperature of the heated air being largely determined by the temperature of the ambient air drawn into the fan.

The number of insects trapped may in future be of importance for accurately determining the population size within the grain bulk. However, as traps currently catch a small percentage of those present, as found in this trial, the number of positive traps is probably of more importance. Positive traps indicate those traps which consistently catch the pest species and therefore give a measure of trap sensitivity. In this trial the difference between the results for trap catch numbers and positive trap numbers was small for *S. granarius* but for the other two species, the differences between the traps was noticeably less when positive traps were considered.

The questions raised by these trials indicate that closer examination of data from such trials is necessary. Temperature recorder data needs to be directly related to individual trap catch. This is particularly relevant if traps are to be calibrated to relate infestation or risk of infestation with trap catch For this relationship to be explored it would appear necessary to increase the density of insects used in such trials in order to provide sufficient trapping data for analysis.

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