Comparison of Pneumatic and Manual Probe Sampling of Kansas Farm-stored Grain Sorghum

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ABSTRACT Six circular metal farm bins containing grain sorghum were sampled in northeastern Kansas with a pneumatic grain sampler. The grain mass ranged in volume from 109.6 to 429.6 m^3. A stratified random sampling method was used. Samples were analyzed in the laboratory for species and numbers of live insects, percentages of fungal-invaded kernels, and percent moisture content. *Cryptolestes ferrugineus* (Stephens) was the only insect species collected in all six bins. High numbers of *C. turcicus* (Grouvelle) were collected, while few *C. pusillus* (Schönherr) were found. In five of six bins, more live insects were found at or near the floor; in four, moisture content was greater on the floor. In comparisons with a manual gravity-fill probe, equal numbers of insects and broken grain were collected. Regression analysis was used to propose practical sampling schemes in which manual probes were used to sample upper areas of the grain mass.

A VARIETY of devices and methods have been used to sample stored-product insects. Water traps, consisting of opened water-filled jars, have been used for surface collection of arthropods (Watters and Cox 1957). Bait traps have been used to determine insect distributions, ranges, and density levels, and have contained food or food mixtures (Strong 1970, Bains et al. 1976). Volatile attractants such as decaying wheat (Loschiavo and Atkinson 1967) or sex pheromones (Barak and Burkholder 1976) have also been used as baits in traps. Gravity-fill triers, probes, and spears have been used to sample insects generally in the upper areas of the grain mass (Winburn 1940, Osmun 1954, Barak and Harein 1981), although creative and time-consuming manual sampling devices have reached ca. 25 m (Anderson and Martin 1943). Power generated sampling devices have increased the vertical sampling universe by being able to sample greater depths with greater ease (Burges 1960).

Recent government policies have encouraged storage of surplus grain on farms. Recent surveys (unpublished data) in Kansas have indicated that many farmers not only fail to use good grain storage practices, but are often not aware of problems when they occur. This lack of awareness is often attributable to improper inspection. Common grain depths are 5–6 m and may be more than 10 m. A standard manual grain sampling probe usually cannot be forced deeper than 3–4 m, depending upon type and condition of the grain. Thus, grain in the lower part of the bin is not sampled for insect infestation, grain moisture content, or other factors affecting grain quality.

The objectives of this study were to use a pneumatic grain sampler to detect insect infestations in all parts of farm grain bins and develop a practical sampling procedure. To study the practical aspects of the sampling plan, manual probe samples were concurrently taken, with the hypothesis that both sampling tools would yield similar results.

Materials and Methods

During 1980, six circular metal grain bins were intensively sampled in northeastern Kansas using the stratified random sampling technique. The grain masses ranged from 109.6 to 429.6 m^3, and the grain sorghum was of different harvest years (Table 1). The bins were selected on the basis of availability and insect species detected in them during an earlier grain sorghum survey (unpublished data). The grain surface was horizontally stratified with three concentric circles; then the surface was further divided by two lines (diameters) through the center and perpendicular to each other. These lines divided the areas between the concentric circles, which were located so that the central circle and all the areas between the circles were equal. The location of a probing in each area was determined by randomly selecting an angle and a radial distance from the bin center (Fig. 1).

The bins were divided vertically into 1.2-m strata beginning at the bottom. A surface sample was taken from the layer of grain remaining above the last complete 1.2-m stratum. Sampling points were identified within each of these strata by randomly selecting a depth of 0, 0.3, 0.6, or 0.9 m within each stratum. A floor sample was also taken (Fig.

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Table 1. Bin dimensions, quantity of grain sorghum, year of harvest, and sampling date for six grain bins, Kansas, 1980

Bin	Dimensions (m) (diam by ht)	Size (m^3)[a]	Year of harvest	Date sampled
1	5.5 by 4.6 (18 by 15 ft)	109.6 3,045 bu	1976	7 June
2	7.3 by 6.4 (24 by 21 ft)	273.7 7,602 bu	1978	2 July
3	7.3 by 4.0 (24 by 13 ft)	169.4 4,706 bu	1978	1 Aug.
4	5.5 by 5.2 (18 by 17 ft)	124.2 3,451 bu	1978–1979	21 Aug.
5	7.3 by 6.7 (24 by 22 ft)	286.7 7,964 bu	?	31 Oct.
6	9.8 by 5.5 (32 by 18 ft)	429.6 11,934 bu	?	7 Nov.

[a] Calculated using radius of bin and depth of grain (1 ft^3 = 0.8 bu, 1 bu = 0.036 m^3).

1). The sampling was done using a commercial pneumatic grain sampler (Cargill Probe-A-Vac) which pulls air carrying the grain up through a 3.2-cm inner tube while replacement air passes down between this tube and an outer 5.1-cm tube. The air with the grain passes into a cyclone collector standing on the grain surface. After sampling was completed with the pneumatic probe, gravity-fill (manual) "bullet" probe samples were taken at the second and third depths for each section.

Samples were weighed in the laboratory and sieved over a sieve (no. 10 Tyler Standard) with 2-mm openings; the material passing through the sieve (fines) was weighed and the amount was expressed as percentage of total sample. The moisture content was electronically measured using either a moisture computer (Burrows Digital Moisture Computer 700) or, if the sample was <250 g, a moisture tester (Insto). Live insects were separated from the fines and placed in vials with 70% isopropanol. Insect mortality during probe collection was not studied although it did not appear excessive; only live insect data were analyzed. Fungal invasion of grain was determined by plat-

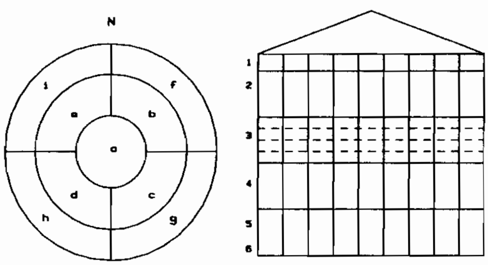

Fig. 1. Horizontal (left) and vertical (right) stratifications used in calculation of sampling cores and points. This example represents a bin with four complete 1.2-m strata, a surface sample (1) and a floor sample (6).

Table 2. Species and total numbers of insects (Cucujidae) collected using a pneumatic probe, Kansas, 1980

Bin	No. of samples	C.f.[a]	C.t.	C.p.	O.s.	Totals
1	45	45	0	2	3	50
2	63	39	32	2	0	73
3	45	468	264	0	98	830
4	54	147	2	0	2,752	2,901
5	63	315	131	10	0	456
6	54	73	54	0	0	127
Totals	324	1,087	483	14	2,853	4,437

[a] C.f., *Cryptolestes ferrugineus* (Stephens); C.t., *C. turcicus* (Grouvelle); C.p., *C. pusillus* (Schönherr); O.s., *Oryzaephilus surinamensis* (L.).

ing kernels that were surface sterilized by 5% sodium hypochlorite on a malt 4% salt agar plate (Tuite 1969). Fungi were identified and divided into two groups. Field fungi were represented by the genera *Alternaria*, *Cladosporium*, *Fusarium*, and *Helminthosporium*, and storage fungi by the genera *Aspergillus* and *Penicillium*. This division is not taxonomically valid, but is primarily based on moisture-content requirements (Christensen and Kaufmann 1974).

Means of insect numbers were separated using Duncan's (1955) multiple range test using the General Linear Model procedure of the Statistical Analysis System (SAS Institute 1982). Comparisons between the pneumatic probe and gravity-fill probe data were made using *t* tests. Regression analysis of the sampling schemes was done using the regression procedure of SAS (SAS Institute 1982).

Results and Discussion

Specific statistical comparisons among bins were not possible because of different bin constructions,

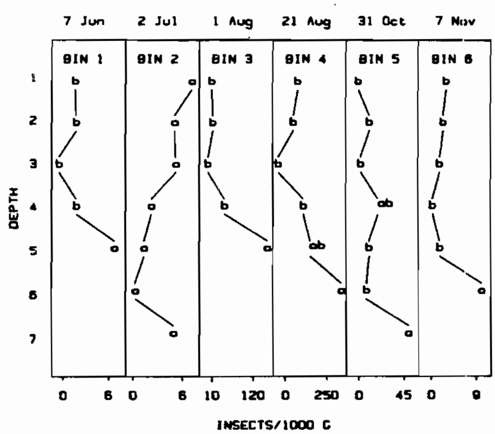

Fig. 2. Vertical distribution of insects per 1,000 g in bins 1–6. Points represented by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

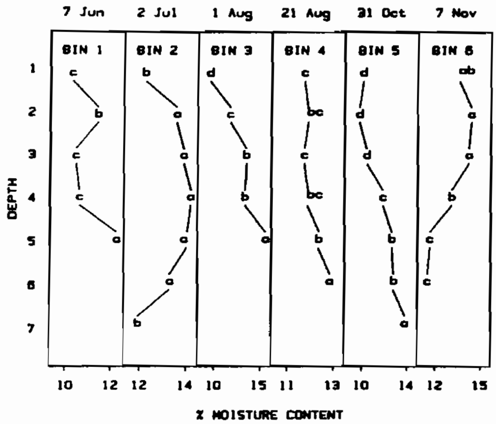

Fig. 3. Vertical distribution of percent moisture content in bins 1–6. Points represented by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

grain histories, and sampling dates. The bins were not replicates of each other. Generalized comparisons of the insect species collected and of the spatial patterns of these insects in each of the bins, however, were important. *Cryptolestes ferrugineus* (Stephens) was the only insect species collected in all six bins. *Oryzaephilus surinamensis* (L.) was collected in large numbers in bin 4, but was scarce in the other bins (Table 2). The collection of *C. turcicus* (Grouvelle) and the small numbers of *C. pusillus* (Schönherr) found were unexpected. *C. turcicus* was collected and identified in only one other stored-grain survey in Kansas (K.O. Bell, G. Partida, and R.B.M., unpublished data). Bishop (1959) reported the presence of *C. turcicus* in the northern growing regions of the United States. LeCato (1974) reported *C. pusillus* as the *Cryptolestes* species of most economic importance in the southern United States. Perhaps northeast Kansas is in a climatic transition zone for the two species. *Cryptolestes* spp. have also infested other types of stored grain in other states, including

Table 3. Average percent fungal-invaded kernels per sample for six grain sorghum bins, Kansas, 1980

Bin	% field fungi/sample	% storage fungi/sample
1	0.2	2.8
2	11.7	48.6
3	6.1	50.3
4	85.1	0.6
5	8.1	22.3
6	42.1	28.8

shelled corn (Farrar and Flint 1942, Osmun 1954, Barak and Harein 1981), wheat (Winburn 1940, Sinha 1961, Barak and Harein 1981, Storey et al. 1983), and oats (Sinha 1961, Storey et al. 1983). Other stored-product insects collected were *Tribolium castaneum* (Herbst) (4), *Rhyzopertha dominica* (F.) (2), *Trogoderma* spp. (6), *Typhaea stercorea* (L.) (2), and Lathridiidae (3). Other arthropods collected but not included in the analysis were Pscoptera, Acari, and Bethylidae (Hymenoptera).

In five of the six bins, more insects were found on or near the floor than in the upper part of the grain mass (Fig. 2). Several studies have described higher numbers of insects along the surface or in the center of the grain, where temperatures and moisture levels were favorable (Sinha 1961, Smith 1978, Loschiavo 1985). In smaller bins, Smith (1983) found a rapid increase in *C. ferrugineus* populations on bin floors in early fall, but a dispersal of the population to higher levels in the grain in mid-fall. Most other stored-product insect studies and surveys did not sample in the lower areas of the grain mass. Consequently, results describing higher numbers of insects along the surface or in the center may be unsubstantiated.

The moisture content of the grain in four of six bins was greater on the floor (Fig. 3). These results can be partially explained by convection currents within the bins, the movement of warm dry air up near the walls, and cool moist air down during the spring and summer months (Johnson 1957, Christensen and Kaufmann 1974). The spatial pattern results of this study are probably related to the

Table 4. Comparisons between total insects and percent fines collected using the pneumatic and gravity-fill probes, Kansas, 1980

Bin	I.P.[a]	I.M.[b]	d[c]	SE	TS[d]	F.P.[e]	F.M.[f]	d[c]	SE	TS[d]
2	4.1	6.1	2.0	1.78	1.12	1.4	1.8	0.4	0.23	1.74
3	17.8	41.8	24.0	13.2	1.82	2.1	2.2	0.1	0.17	0.59
4	46.5	51.2	4.8	17.42	0.28	1.3	1.5	0.2	0.14	1.43
5	11.6	14.4	2.8	4.32	0.65	1.6	1.7	0.1	0.14	0.71
6	4.2	6.9	2.7	2.09	1.29	0.6	0.4	0.2	0.07	2.86

[a] No. of live insects per 1,000 g collected from pneumatic probe.
[b] No. of live insects per 1,000 g collected from manual probe.
[c] Absolute difference between two collections.
[d] Test statistic (d/SE), significant (t_{17} at $P = 0.05 = 2.11$).
[e] Percentage fines collected from pneumatic probe.
[f] Percentage fines collected from manual probe.

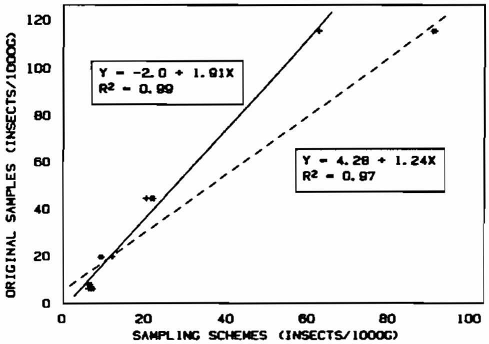

Fig. 4. Regression of the original pneumatic probe samples to two practical sampling schemes using the upper three depths within the nine areas (27 samples) (——), and using only the surface samples in nine areas (nine samples) (- - -).

false, perforated aeration floors of the bins. Broken kernels and grain dust can sift through the perforations and provide nutritional material underneath for residual insect populations. Since the false floors are bolted in place, they are rarely removed for cleaning. Five of the six bins had this type of arrangement. Bin 3, which had high numbers of insects on the floor, had aeration ducts lying on the concrete floor. Broken sorghum and nutritional dust could have been inside these ducts. Bin 2, which did not have significantly high numbers of insects on or near the floor, had a slight odor of the insecticide malathion from its floor samples. Apparently, some parts of the bin were treated at an earlier time.

The age of grain and the type of fungi found were related. Bins 1–3 contained 1978 or older grain and had higher percentages of storage fungi-infected kernels (i.e., *Aspergillus glaucus* group, *A. flavus* group, and *Penicillium* spp.) (Table 3). Bin 4 contained an uneven mixture of 1979 and 1978 grain and had higher percentages of field fungi. The age of the grain in bins 5 and 6 was unknown. Microorganism activity can cause heating of stored grain, and can be a factor in the increase of certain stored-grain beetle infestations (Wright and Burroughs 1983).

Comparisons were made between the pneumatic and gravity-fill probes to test the hypothesis that both yielded similar results. These tests were based on data collected from two variables, total live insects and the percentage of fines, and were performed only on the results from bins 2–6. Bin 1 had high numbers of dead insects throughout the bin, which leads to the conclusion that control measures were taken. The data from the gravity-fill probe were similar to those from the pneumatic probe in all cases except for the percent fines in bin 6 (Table 4). This demonstrated that the pneumatic probe was not picking up more fines or insects due to the air flow and supports Hurburgh and Bern's (1983) findings that pneumatic core probes do not pick up more foreign material compared to manual probes. Although the pneumatic probe can sample grain at much greater depths than manual probes, it is expensive and time-consuming to use. Manual probes are easier to handle and more practical to use, and, as the results of this study indicated, will yield similar results.

Selected sets of samples within the total original complement of pneumatic probe samples were analyzed to determine whether fewer samples from each of the bins would have provided information statistically similar to that obtained from the total. Two of the sampling schemes selected appeared practical. One involved samples from the upper three depths within the nine areas (27 samples), while the second sampling scheme used only the surface samples from each of the nine areas (Fig. 4). Both selected sampling schemes correlated well with the complete sampling.

Bin structures and the way farmers store their grain are important in sampling. It is desirable that the bottom areas be made accessible by bin modification so they can be sampled. Also, accessibility to areas beneath the false floors when the bin is empty would permit inspection, cleaning, and treating. Present methods of sampling and grading of grain at local elevators are not known or are inconsistent (Barak and Harein 1981). Better techniques are needed to assure more representative sampling of grain.

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References Cited

Anderson, J. A., and V. C. Martin. 1943. Probe for sampling deep grain bins. Grain Res. Comm., Dept. of Trade and Commerce, Canada. Bull. 3.

Bains, S. S., G. S. Battu, and A. S. Atwal. 1976. Distribution of *Trogoderma granarium* Everts and other stored grain insect pests in Punjab and losses caused by them. Bull. Grain Technol. 14: 18–29.

Barak, A. V., and W. E. Burkholder. 1976. Trapping studies with dermestid sex pheromones. Environ. Entomol. 5: 111–114.

Barak, A. V., and P. K. Harein. 1981. Unpredictable penalties at time of sale applied to insect-infested, farm-stored grain in Minnesota. Bull. Entomol. Soc. Am. 27: 166–169.

Bishop, G. W. 1959. The comparative bionomics of American *Cryptolestes* (Coleoptera: Cucujidae) that infest stored grain. Ann. Entomol. Soc. Am. 52: 657–665.

Burges, H. D. 1960. A spear for sampling bulk grain by suction. Bull. Entomol. Res. 51: 1–5.

Christensen, C. M., and H. H. Kaufmann. 1974. Microflora, pp. 158–193. *In* C. M. Christensen [ed.], Storage of cereal grains and their products, 2nd ed. American Association of Cereal Chemists, St. Paul, Minn.

Duncan, D. B. 1955. Multiple range and multiple *F* tests. Biometrics 11: 1–41.

Farrar, M. D., and W. P. Flint. 1942. Control of insects in fourteen thousand corn bins. J. Econ. Entomol. 35: 615–619.

Hurburgh, C. R., Jr., and C. J. Bern. 1983. Sampling corn and soybeans. I. Probing methods. Trans. Am. Soc. Agric. Eng. 26: 930–934.

Johnson, H. K. 1957. Cooling stored grain by aeration. Agric. Eng. 38: 238–246.

LeCato, G. L. 1974. Increase in populations of *Cryptolestes pusillus* and *C. turcicus* on diets of natural products. Fla. Entomol. 57: 309–312.

Loschiavo, S. R. 1985. Post-harvest grain temperature, moisture, and insect infestation in steel granaries in Manitoba. Can. Entomol. 117: 7–14.

Loschiavo, S. R., and J. M. Atkinson. 1967. A trap for the detection and recovery of insects in stored grain. Can. Entomol. 99: 1160–1163.

Osmun, J. V. 1954. Protection of stored shelled corn with a protectant dust in Indiana. J. Econ. Entomol. 47: 462–465.

SAS Institute. 1982. SAS user's guide: statistics. SAS Institute, Cary, N.C.

Sinha, R. N. 1961. Insects and mites associated with hot spots in farm stored grain. Can. Entomol. 93: 609–621.

Smith, L. B. 1978. Ecology of stored grain in the Canadian provinces. I. The distribution and size of a low density population of *Cryptolestes ferrugineus* (Coleoptera: Cucujidae). Can. Entomol. 110: 1281–1292.

1983. The relationship between wet grain, *Cryptolestes ferrugineus* (Coleoptera: Cucujidae) populations, and heating in wheat stored in granaries. Can. Entomol. 115: 1383–1394.

Storey, C. L., D. B. Sauer, and D. Walker. 1983. Insect populations in wheat, corn, and oats stored on the farm. J. Econ. Entomol. 76: 1323–1330.

Strong, R. G. 1970. Distribution and relative abundance of stored-product insects in California: a method of obtaining sample populations. J. Econ. Entomol. 63: 591–596.

Tuite, J. 1969. Plant pathological methods, fungi and bacteria. Burgess, Minneapolis, Minn.

Watters, F. L., and G. A. Cox. 1957. A water-trap for detecting insects in stored grain. Can. Entomol. 89: 188–192.

Winburn, T. F. 1940. Insect infestation in farm-stored grain in Kansas. Trans. Kans. Acad. Sci. 43: 289–290.

Wright, V. F., and R. Burroughs. 1983. Mold-damaged grain sorghum as a diet for three stored-grain beetles (Coleoptera). Environ. Entomol. 12: 558–560.

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