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INSECT and RODENT Contamination of GRAIN

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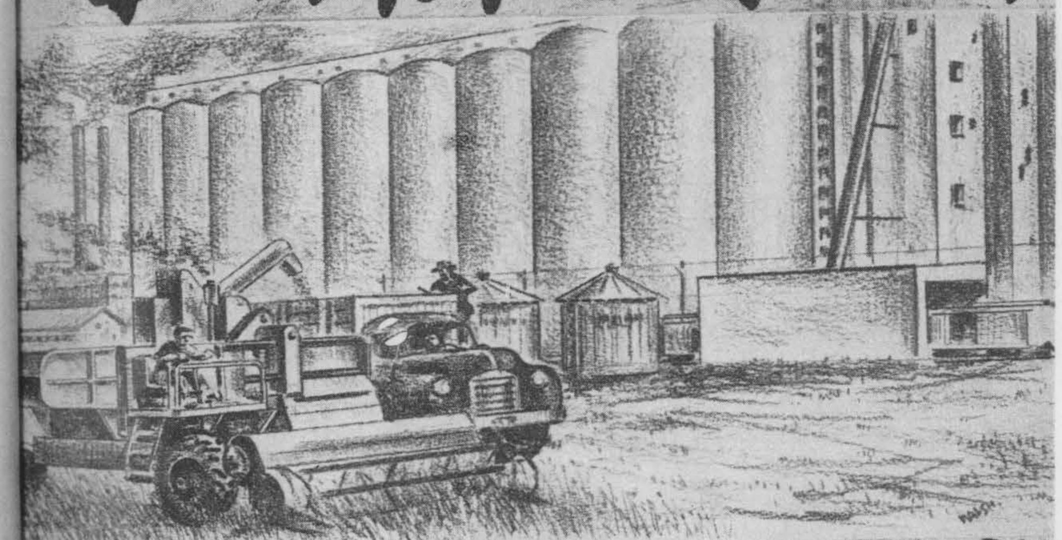
• Robert L. Butler and Clarence E. Mickel



Agricultural Experiment Station
UNIVERSITY OF MINNESOTA

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Insect and Rodent Contamination of Grain in Minnesota, North Dakota, South Dakota, and Montana

Robert L. Butler and Clarence E. Mickel

SINCE 1951 considerable effort has been placed on improving the sanitation of grain. A large part of the effort has come indirectly as a result of an examination of sanitation in the baking and milling industries by the Food and Drug Administration. This examination of wheat and wheat products indicated that some of the adulterants originated on the farm, in marketing, and/or in storage facilities. A subsequent Food and Drug Administration survey of wheat in 29 states entailing analyses of 1,411 samples at 109 mill sites presented evidence that the sanitation problem was widespread.[1]

The Food and Drug Administration in July, 1952, began the seizure of wheat intended for human consumption which contained one or more rodent pellets per pint. This action disregarded the U. S. Grain Standards previously established by the U. S. Grain Standard Act of 1916. The presence of two different governmental agencies defining grain quality on two different bases made the marketing of grain uncertain and financially hazardous.

The Food and Drug Administration 29-state survey showed that a general sanitation problem existed. However, the distributional pattern of the problem in the northwestern states—Minnesota, North Dakota, South Dakota, and Montana — remained unknown. The number of samples, 291, in the survey was too small to be statistically reliable.

Not only was the distributional pattern of the problem unknown, but also the species of animal causing rodent contamination was incorrect, unknown, or vague. Inasmuch as rats have always been associated with filth and some of the most vigorous rodent control campaigns have been concerned with rats, it has been assumed that rat control means cleaner grain.

The granary insect problems of Oklahoma, Kansas, and Nebraska are of much greater consequence than those of the states included in this survey.[2,3] However, grain losses in these northwest states are frequently great enough to warrant more careful examination regarding the seasonal and geographic distribution of granary insect species.

The Minneapolis Grain Exchange recognized the need for information concerning the nature and extent of grain contamination in Montana, North and South Dakota, and Minnesota. After full knowledge of the problem was gained, necessary control measures could be economically and efficiently

[1] Harris, Kenton L., Nicholson, J. F., Randolph, Lila K., and Trawick, J. L. An investigation of insect and rodent contamination of wheat and wheat flour. Jour. Assoc. Off. Agr. Chem. 35:115-158. 1952.

[2] Cotton, R. T., Walkden, H. H., White, G. D., and Wilbur, D. A. Causes of outbreaks of stored-grain insects. Kans. Agr. Expt. Sta. Bul. 359. 1953.

[3] Walkden, H. H., Wilbur, D. A., and Gunderson, Harold. Control of stored grain insects in the north central states. Minn. Agr. Expt. Sta. Bul. 425. 1954.

developed, and marketing could proceed with less instability. The Duluth Board of Trade and the Association of American Railroads were also interested in determining what the problems were and joined the Minneapolis Grain Exchange in support of this study which was begun in October, 1952.

The Program

SAMPLING

Basic to the entire study was the development of a system of sampling which would insure reliable representation from all points, and yet not make the procurement and analysis of samples too difficult. The variability of contamination by seasons, sampling points, or geographic areas was unknown; thus it was necessary to initiate a sampling program having sufficient flexibility to meet any desired data analysis. It was felt that this could be realized by increasing or decreasing the sampling intensity at all points in the original sampling design.

At the outset the sampling distribution was based upon two factors:

1. Volume of wheat from each district which reaches the Minneapolis-St. Paul-Duluth terminals.

2. District size represented, for the most part, by the number of counties.

Since accepted crop reporting districts are defined by the factors of soil, crop, and climate, these were generally retained as geographic sampling units (figure 1). In a few cases the crop reporting districts were consolidated, but in no instance was any one district split.

The sampling design was developed for two systems: (1) alternating reduced and (2) scattered sampling from district to district. The number of counties from each district which was to be sampled by either of the two approaches was dependent upon the number of counties per district (table 1). Four sample types were proposed for each randomly selected county: combine, farm bin, country elevator, and boxcar at load.

An exception to this type of sampling was made in Minnesota. To get the program started, the first sampling stations prior to the completion of the sampling design were assigned in this state. Since northwestern Minnesota is the wheat producing area for the state and contributes heavily to the wheat receipts at the Minneapolis Grain Exchange and the Duluth Board of Trade, at the outset considerable emphasis was placed here.

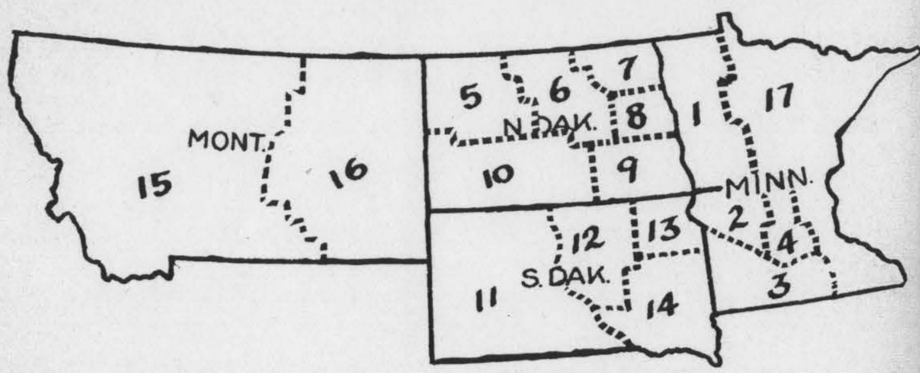

Fig. 1. Coded districts from which wheat samples were obtained for analysis of rodent, bird, and insect contamination. (No. 17 included only terminals.)

Table 1. Number of Counties Used for Reduced Sampling or Scattered Sampling as Related to the Number of Counties per District

Counties per district	No. of counties* for Reduced sampling	Scattered sampling
5 or under	2	3
6 to 10	3	5
11 to 15	4	7
16 to 20	5	9
21 to 26	6	11

* Counties selected from table of random numbers.

Although it would have been desirable to have randomized the stations within each randomly selected county, the voluntary nature of the sampling necessitated an arbitrary selection of stations. Stations were chosen without knowledge of size or condition of premises from a directory of country elevators in each of the four states.

To further insure randomness an attempt was made to distribute the sampling equitably among independent, line, and cooperative country elevator groups. From time to time it was found necessary to make sampling station substitutions. In each case the same type of station in the same county was retained where possible. If the sampling station possibilities of a particular county had been exhausted, the nearest elevator in an adjoining county was requested to take part in the sampling.

In addition to the sampling at combines, farm bins, country elevators, and boxcars at load, a measure of contamination was to be made at the terminal elevators. Two sample types were proposed for Minneapolis-St. Paul-Duluth terminals: boxcar at unload and terminal elevator bin samples. Terminal elevators were to provide a resampling of boxcars previously sampled at loading in the country. In addition, each of the 10 terminal elevators representing different storage facilities and business affiliations was to provide samples for each month of the survey from its bins.

After the study had begun, a request was made by the University of Minnesota to the Production and Marketing Administration (P.M.A.) for a county replication of farm bin samples taken by the grain trade in the districts of Montana, North Dakota, and South Dakota. The P.M.A. agreed to obtain farm bin samples for April, May, September, October, and November, 1953. Later, the P.M.A. agreed to obtain samples for April, 1954, from the same areas. The major portion of the combine samples and another replication of farm bin samples were obtained by local Future Farmers of America (F.F.A.) chapters in all four states.

Of equal importance to the random selection of stations is the random sampling of grain by and at those stations. Sampling done at most grain trade and P.M.A. stations is believed to be as adequate as time and facilities permit. Sampling of any one lot of grain is part of the necessary business at either of these two stations. Here considerable quantity of grain is bought and sold or loans are made on the grain. The selling price or loan value is dependent upon the quality of the grain determined by methods and measures of the U. S. Grain Standards. It is, therefore, necessary that adequate representative samples be taken to assure a just measure.

Various improvised and standard methods are used to approach a correct measure of grain. However, no one technique can provide an exact average value for the grain quality from a particular lot. In most cases the two-quart sample obtained for the survey was the same or part of the same sample used to determine the grade. In an effort to standardize sampling for the survey, two sets of suggested sampling instructions were prepared and distributed to all samplers. One set delineated sampling techniques to be used at the combine, farm bin, country elevator, and boxcar at load. The other set was prepared for sampling terminal elevator bins and the boxcars at unload.

LABORATORY ANALYSIS

At present there is no one simple and rapid method for detecting rodent, insect, and bird adulterants in wheat. The immediate objective of the methods used in the laboratory analysis for this study was to recover the maximum amount of contaminants in the shortest length of time with the available equipment. Complete recovery with the best of facilities would take an inordinate length of time.

Although various indirect forms of contamination were noted in the laboratory procedures, insect infestation in the final analysis was defined as the actual presence of one or more of the granary insects. The presence of rodent hair was considered essential to all particles classed as rodent pellets.

The analytical methods developed and used by Harris *et al*,[4] were adapted in part. A grain X-ray unit was used to detect hidden infestation. In place of the more often used "cracking-flotation" technique, a system of reading the grain radiograph coupled with kernel dissection was used throughout the study. A Stedman insect damage tester was used to further evaluate insect damage in a given sample. Processing a sample at the laboratory consisted of the following steps:

1. Arrival of sample recorded and sample treated to kill all granary insects.
2. Liquid pint sample taken from submitted sample.
3. Sample sieved with scalper and buckwheat sieves, and (a) dockage examined for rodent and bird excrement and granary insects and (b) cleaned grain examined for rodent pellets, granary insects, and insect damage.
4. Examination for internal infestation made with (a) Stedman insect damage tester, (b) Apt ferric-nitrate flotation, and (c) X-ray with dissection.
5. "Sampling Record" transcribed and "Laboratory Record" completed.
6. All data coded for I.B.M. tabulation.

Results

AT THE OUTSET there was some question as to whether the investigation would receive the cooperation of the sampling stations. Some of the stations cooperated throughout the study, others supported the study for a few months, and some did not handle sufficient quantities of wheat to take part.

SAMPLES ANALYZED

From the grain trade 485 stations were requested at one time or another to send samples to the laboratory (table 2). Of these, 301 had one or more samples analyzed for contamination. The P.M.A. was originally to be represented by 87 stations; however, only 78 mailed samples. No particular number of stations was ever selected for the F.F.A. chapters, but 40 shipped farm bin samples and 28 combine samples. A total of 447 sampling stations contributed samples.

A total of 7,837 wheat samples were received during the 17 months of sampling. Of these, 196 arrived late and are not included in the tabulation. Samples

[4] Harris, K. L., *et al., op. cit.*

Table 2. Number of Sampling Stations from Trade, P.M.A., and F.F.A. Requested To and Obtaining Grain Samples of Various Types, by States

State	Trade (combine, farm bin, boxcar, and terminal samples)		P.M.A. (farm bin samples)		F.F.A.		Total sampling stations contributing samples
	Requested	Contributed	Requested	Contributed	Farm bin	Combine	
	number		number		number		number
Minnesota	54	31	0	2	3	3	39
	26*	21*					21*
North Dakota	232	158	34	29	23	14	224
South Dakota	127	53	34	29	11	6	99
Montana	46	38	19	18	3	5	64
Total	485	301	87	78	40	28	447

* These values refer specifically to the terminal elevator sampling stations in Minnesota and Wisconsin.

of barley, corn, and oats accounted for 282 samples. The final number of wheat samples involved in the tabulation was 7,641.

The maximum number of wheat samples used in any one tabulation was 6,964. The discrepancies in the number of available samples and the number used is the result of having incomplete, illegible, or inappropriate data recorded on the sampling record. Consequently each table presented will be consistent only within itself. The more factors involved in each tabulation the greater are the number of samples eliminated on the bases of inadequate data.

BUSHELS REPRESENTED

Of 6,964 samples received with complete designation of station sample type, the 4,466 with bushel designation reported a total volume of 60,450,737 bushels of wheat from which the samples were taken (table 3). The terminal samples were represented by almost 55 million bushels, the country elevator by 3.5 million, and farm bin sampling done by the grain trade and the government groups each by over one-half million bushels.

GENERAL STUDIES

The general studies include only those for which the project was primarily established. These included: (1) measurement of rodent, insect, and bird contamination in wheat over the entire Northwest; (2) geographic distribution of the contaminants; and (3) seasonal distribution of contamination. The Association of American Railroads wanted to obtain additional information concerning the contamination effects of boxcars.

Level of Contamination

In the over-all study of seven station sample types, 6,964 samples were used. Of these, 17.2 per cent contained one or more pellets per pint (table 4), 14.8 per cent had one or more of the granary insect forms and 3.9 per cent of the samples contained bird excrement.

Table 3. Volume of Wheat Represented by the Number of Samples Received from Each Type of Sampling Station

Station sample type	Number of bushels	Number of samples
Combine	173,176	218
Farm bin	684,089	1,293
Government grain	572,647	758
Country elevator	3,509,287	1,814
Terminal elevator	54,772,236	2,085
Boxcar at unload (complete)	235,359	297
Boxcar at unload (incomplete)	503,318	499
Total	60,450,737	6,964

Table 4. Rodent and Bird Contamination and Insect Infestation in Wheat Samples, by Place of Sampling

Station sample type	Number of samples	Rodent contamination: Number of samples	Rodent contamination: Percentage contaminated	Insect infestation: Number of samples	Insect infestation: Percentage infested	Bird contamination: Number of samples	Bird contamination: Percentage contaminated
Combine	218	14	6.4	6	2.8	6	2.8
Farm bin	1,293	299	23.1	108	8.2	67	5.2
Government wheat (P. M. A. and C.C.C.)	758	126	16.6	63	8.3	51	6.7
Country elevator	1,814	295	16.2	274	15.1	68	3.7
Boxcar at unload (complete)	297	36	12.1	51	17.2	9	3.0
Boxcar at unload (incomplete)	499	65	13.0	94	18.8	18	3.6
Terminal elevator	2,085	360	17.3	436	20.9	51	2.4
Total	6,964	1,195	17.2	1,032	14.8	270	3.9

Field Contamination

Rodent pellets were present in combined wheat in districts 5, 6, 10, and 12. The sampling instructions given for this type of sample stated that the sample was to be obtained directly from the combine. To see how well these instructions were followed, a report of the analyses made on samples from each sampling group was returned with a letter of further inquiry.

Answers received from the letter indicated that the highest incidence of rodent pellet contamination in the field comes from fields in which the grain is swathed. It is possible that field mice or feral house mice play and feed over the downed grain. Another probable source of contamination comes from combines which are not cleaned prior to field work. Furthermore, the entry of mice into the equipment left in the fields or barns is certain.

Field infestation with granary insects is highly improbable in spite of the recovery found (table 4). Inasmuch as the insects noted were of the families, *Mycetophagidae*, *Lathridiidae*, and *Dermestidae*, one can only assume the combines were not clean. These insect families are noted for living in moldy residues.

Storage Facility Contamination

With reference to type of storage facility, farm bins returned the highest percentage of samples containing one or more rodent pellets per pint (23.1 per cent) and the lowest percentage of samples containing one or more insects per pint (8.2 per cent).

The granary insect problem apparently increases with each step removed from the farm. If granary insects are a problem in the Northwest, they are of major importance at the terminal elevators. A total of 20.9 per cent of the terminal elevator samples contained granary insects as contrasted with 8.2 per cent of the farm bins (table 4).

There not only was an increase in the number of samples containing granary insect pests but also a change in the proportion of various species represented. The granary and rice weevils, both primary pests of stored grain, were found in far greater abundance at the terminals (table 12) than at any other point of sampling.

The reverse is true in regard to rodent contamination. Although the trend is not so evident in the percentage of samples containing one or more pellets per pint (table 4), there is a decrease in contamination from the farm to the terminal (table 5). The decrease is observed from farm bin, government, country elevator, and terminal wheat, respectively.

Table 5. Level of Rodent Contamination in Samples from Different Sources

Rodent pellets per pint	Combine: Number	Combine: Per cent	Farm bin: Number	Farm bin: Per cent	Government grain: Number	Government grain: Per cent	Country elevator: Number	Country elevator: Per cent	Terminal: Number	Terminal: Per cent
9 or more	1	0.5	21	1.6	7	0.9	4	0.2	....	....
8 or more	1	0.5	26	2.0	8	1.0	5	0.3	....	....
7 or more	1	0.5	27	2.1	9	1.2	7	0.4	....	....
6 or more	1	0.5	36	2.8	11	1.4	9	0.5	....	....
5 or more	1	0.5	44	3.4	14	1.8	12	0.7	....	....
4 or more	2	0.9	64	4.9	25	3.3	16	0.9	4	0.2
3 or more	3	1.4	87	6.7	30	4.0	38	2.1	16	0.8
2 or more	6	2.8	146	11.3	66	8.7	95	5.2	88	4.2
1 or more	14	6.4	299	23.1	126	16.6	295	16.2	360	17.2
None	204	93.6	994	76.9	632	83.4	1,519	83.8	1,725	82.8

Bird contamination figures cannot be considered accurate. Since bird pellets are friable, much of the evidence can be destroyed through the movement and handling of grain prior to laboratory examination. Bird pellets were found to some extent in all station sample types and varied only from 2.4 to 6.7 per cent (table 4). Differences from station to station cannot be determined from these data.

Geographic Distribution

Geographic differences in grain contamination were well demonstrated in the Northwest. Rodent contamination was lowest in district 16 and highest in district 13 (table 6). Districts 9, 12, 13, and 14 as one general area had more than one-fifth of their samples contaminated with rodent pellets. The level of rodent contamination found in districts 15 and 16 of Montana was 7.8 per cent below the average for the four states (table 7). Although Minnesota had the highest percentage of rodent contaminated samples, the eastern area of South Dakota and southeastern North Dakota had an equally serious problem. Districts 2, 3, and 4 of Minnesota were not sufficiently sampled to consider them separately.

It is surprising to note the similar geographic distribution of granary insects with that of apparent rodent abundance. Montana had a low level of both rodent contamination and granary insect infestation. North Dakota, however, showed a slightly lower average level of insect infestation. Three of the same districts in South Dakota having the highest levels of rodent contamination also stood above all other districts in levels of insect infestation. More than 30 per cent of the samples from districts 12, 13, and 14 have contained granary insects. South Dakota had a level of insect infestation 18.4 per cent above the four-state average.

Seasonal Distribution

To complete the examination of all the facets of grain contamination seasonal distribution was considered at each of the types of sampling stations.

To describe the existence of general seasonal trends of all contamination from the data (table 8) in this study would be attempting too much rationalization. There is a strong suggestion that each sample type has its own independent seasonal variation. Furthermore, it appears that the greater the difference in capacity storage the less chance, probably with good biological reason, there is for similarity of seasonal trends among the types of stations.

Table 6. Rodent and Bird Contamination and Insect Infestation in Wheat Samples, by Districts

District	Number of samples	Rodent contamination: Number of samples	Rodent contamination: Percentage contaminated	Insect infestation: Number of samples	Insect infestation: Percentage infested	Bird contamination: Number of samples	Bird contamination: Percentage contaminated
1	320	75	23.4	32	10.0	22	6.9
2	28	5	17.9	7	25.0	3	10.7
3	8	0	0.0	4	50.0		0.0
4	9	2	22.2	3	33.3		0.0
5	510	107	21.0	43	8.4	30	5.9
6	632	118	18.7	31	4.9	30	4.7
7	378	64	16.9	24	6.3	22	5.8
8	148	28	18.9	17	11.5	6	4.1
9	276	64	23.2	22	8.0	5	1.8
10	364	68	18.7	25	7.4	22	6.0
11	183	30	16.4	39	21.3	10	5.5
12	253	53	20.9	82	32.4	11	4.3
13	132	35	26.5	44	33.3	6	4.5
14	52	11	21.1	17	32.7	5	9.6
15	402	44	10.9	19	4.7	10	2.5
16	397	38	9.6	43	10.8	10	2.5
17*	2,861	459	16.0	581	20.3	80	2.8
Total	6,953	1,201	17.3	1,033	14.9	272	3.9

* Terminal only.

Government grain, most of which was sampled on the farm, and farm binned grain not under loan agree more closely from season to season on both insect and rodent measures than with any other two station types (table 8). From the winter of 1953 there was a trend to relatively high numbers of insects for the winter of 1954.

In general, samples taken of the 1953 wheat crop did not appear to effect expected changes. A general decline in contamination presumably should have been observable from summer to fall as a result of dilution with the 1953 wheat, but the contrary condition is apparent. Although the sampling for the previous analysis was adequate, there is no way of knowing whether such a standard of sampling has been realized for season analysis. Any number of reasons could be proposed to explain the lack of uniform trends; however, one should avoid such reasoning from these data. The points supporting this suggestion are as follows:

1. There is not consistent agreement for contamination measures made in each of the four sampling stations during the winters of 1953 and 1954. This situation is particularly evident in the insect levels for farm, government, and country elevator grain. Differences in

Table 7. Rodent Contamination and Insect Infestation in Wheat Samples, by States

State	Number of samples	Rodent contamination: Number of samples	Rodent contamination: Percentage contaminated	Insect infestation: Number of samples	Insect infestation: Percentage infested
Minnesota	365	82	22.5	46	12.6
North Dakota	2,308	449	19.4	162	7.0
South Dakota	620	129	20.8	182	29.4
Montana	799	82	10.3	62	7.8
Total	4,092	742	18.1	452	11.0

Table 8. Rodent Contamination and Insect Infestation in Wheat Samples, by Place of Sampling and Season

Station sample type	Season	Number of samples	Rodent contamination: Number	Rodent contamination: Per cent	Insect infestation: Number	Insect infestation: Per cent
Combine		218	14	6.4	6	2.8
Farm Bin	Winter	276	71	25.7	16	5.8
	Spring	280	63	22.5	18	6.4
	Summer	145	25	17.2	18	12.4
	Fall	315	70	22.2	24	7.6
	Winter	235	58	24.7	28	11.9
	Total	1,251	287	22.9	104	8.3
Government grain (P.M.A. and C.C.C.)	Winter	49	11	22.4	2	4.1
	Spring	370	54	14.6	17	4.6
	Summer	51	8	15.7	5	9.8
	Fall	238	44	18.5	32	13.4
	Winter	47	9	19.1	7	14.9
	Total	755	126	16.7	63	8.3
Country elevator	Winter	429	84	19.6	54	12.6
	Spring	193	36	18.7	17	8.8
	Summer	291	46	15.8	24	8.2
	Fall	436	56	12.8	73	16.7
	Winter	405	56	13.8	98	24.2
	Total	1,754	278	15.8	266	15.2
Boxcar at unload (complete)	Winter	34	7	20.6	1	2.9
	Spring	14	1	7.1	0	0.0
	Summer	54	7	13.0	7	13.0
	Fall	95	8	8.4	18	18.9
	Winter	91	9	12.1	23	25.3
	Total	288	32	11.1	49	17.0
Boxcar at unload (incomplete)	Winter	39	5	12.8	4	10.3
	Spring	17	5	29.4	8	52.9
	Summer	166	25	15.1	22	13.3
	Fall	175	20	11.4	36	20.6
	Winter	102	10	9.8	23	22.5
	Total	499	65	13.0	93	18.6
Terminal elevator	Winter	282	48	17.0	60	21.3
	Spring	147	21	14.3	32	21.8
	Summer	472	73	15.5	108	22.9
	Fall	612	131	21.4	131	21.4
	Winter	500	70	14.0	90	18.0
	Total	2,013	343	17.0	421	20.9
Total	Winter	1,109	226	20.4	137	12.3
	Spring	1,023	180	17.6	92	9.0
	Summer	1,343	194	14.4	188	14.0
	Fall	1,901	331	17.4	314	16.5
	Winter	1,384	213	15.4	269	19.4
	Total	6,760	1,144	16.9	1,000	14.8

Table 9. Percentage of the Number of Boxcar Samples at Load and Unload Showing Various Levels of Insect Infestation

Sample type	Number of boxcar samples					
	1 or more	2 or more	3 or more	4 or more	5 or more	6 or more
At load	13.9	5.1	4.2	3.0	2.1	1.5
At unload	15.8	9.3	6.9	4.2	3.6	3.0

insect levels may indicate possible great differences from year to year.

2. The obvious differences in insect infestation from farm to terminal suggest real differences in storage facilities. The larger the storage capacity, the smaller the effect of seasonal change on the stored wheat. And, to the contrary, the smaller the unit volume of storage to total surface exposed, the greater the influence of seasonal change.

3. There is no way of knowing the age of the grain after it leaves the farm. Blending of recent and past crops may completely mask seasonal effects.

4. A one year study may show expected changes from season to season for that year, but the variation of another year may obscure any previously known seasonal trends.

Contamination in Boxcars

Although in this study it was not possible to follow the changes in contamination of the same lots of wheat from a series of farm bins, country elevators, or terminals, an attempt to follow such changes which might occur in boxcars was made. Only those boxcars were considered in which sampling was done both at origin and destination. Inasmuch as the primary interest was to find changes which occur in the levels of insect infestation, all wheats and barleys were included in the tabulation. For some reason, not now possible of correction, 332 samples are listed at load and 335 samples at unload. However, the statistical analysis which follows should not be invalid on the basis of three samples.

Paired samples were obtained from 332 boxcars during the study. The percentage of samples at load which contained one or more granary insects per pint was 13.9, and 15.8 per cent of samples obtained from these same boxcars at unload contained one or more insects per pint. One might readily assume that the small difference of 1.9 per cent between the two measures would be insignificant. Upon further examination, however, a quantitative change in the levels of infestation can be seen (table 9).

A total of 114 insects in the 332 samples at load gives a mean value of 0.34 insects per sample, and a total of 155 insects in the 335 samples at unload gives a mean value of 0.46 insects per sample. In testing for the significance of the difference of the means it was found that there is less than one chance in 10,000 of these two samples representing the same grain. Therefore, in view of the fact that 332 of the samples were known to be from the same grain, condition of grain in boxcars may very definitely change. The increase in insect infestation is statistically significant.

Contamination-Free Samples

Some of the samples were completely free of all contamination (insect, bird, and rodent derivatives). Of the 6,953 samples made on the geographic distribution of contaminants in grain, 4,640 or 66.7 per cent were free of all contamination. In the same tabulation, a total volume of 60,422,508 bushels was reported of which 35,837,163 or 59.3 per

cent was represented by completely clean samples.

SECONDARY STUDIES

The secondary studies made during the course of the survey aided considerably in providing supporting data to the main facets of the study and add to what is known on the techniques of recovering contaminants. Studies made are as follows:

1. Measurements which distinguish rat and mouse pellets.
2. Grain contamination in nine organized sampling groups or companies.
3. Relationship of grain grade to rodent and insect contamination.
4. Geographic distribution of the rust-red flour beetle, *Tribolium castaneus* (Hbst.), the rice weevil, *Sitophilus oryza* (L.), and the granary weevil, *Sitophilus granarius* (L.).
5. A study of the flat grain beetle as a primary infestor.

Rat vs. Mouse Contamination

In the past, rodent control at grain storage facilities usually referred to rats. During the early part of this study rodent pellet contamination was assumed to be of rat origin. It was noted, however, that the pellets found in the examination of grain were rather small.

To check this inconsistency further, 1,652 rodent pellets were examined of which the greatest number was taken directly from a known mouse harborage. The length and diameter measurements provided a distinct grouping (figure 2). Although the known rat pellets were poorly represented in numbers, the distinct size set them apart from mouse pellets. There is undoubtedly some overlap of measurements and, therefore, some chance of error at the upper limits of mouse pellet size and lower limits of rat pellet size.

The great majority of mouse pellets, however, fall below the general out-

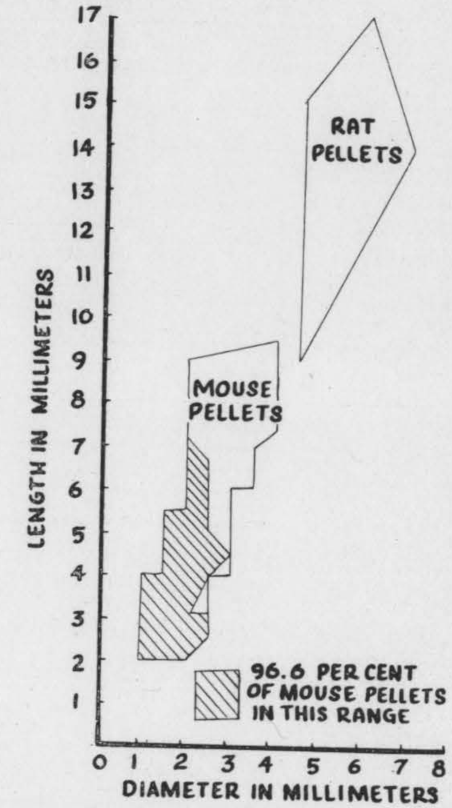

Fig. 2. The diameter-length distribution of 1,652 rodent pellets.

lined size range presented in figure 2. This is more clearly discernable if one considers the size distribution below 7 millimeters length. Here (the hatched area of figure 2), 96.6 per cent of the mouse pellets were concentrated. Separation of the two forms, therefore, can largely be made on the difference in diameter.

Undoubtedly there has been some error in distinguishing the two forms. Smaller rats and larger mice produce rodent pellets of similar size. It is doubtful that this could change the results of the study significantly.

From 4,460 samples examined through November, 1953, only 0.2 per cent contained rat pellets and these did not exceed the one pellet per pint measure. One or more mouse pellets were found in 17.0 per cent of this sample group. Midway through the investigation, the Food and Drug Administration withdrew their seizure measure of one or more rodent pellets per pint. It was assumed that the samples taken by the country elevators during the Food and Drug Administration activities would show a lower level of contamination than that presented by samples taken subsequent to withdrawal of the one-pellet-per-pint measure. Furthermore, it was assumed that a relatively high level of insect infestation would precede the insect contamination control measure which had been proposed for July, 1953. The warehouses would have disposed of infested grain prior to this date. It was essential to consider the effects these changes in regulations might have on the results of the study.

The seasonal fluctuation of insect and rodent contamination was not related in any way to the change of Food and Drug Administration regulations. To the contrary, insect infestation increased from the spring of 1953 through the winter of 1953-1954 (table 10), and the extent of rodent contamination decreased from summer to fall and then increased during the following winter. Insect infestation increased from summer to fall in all lines except line 4 (line 3 must be disregarded on the basis of sample size), and again an increase in infestation was noted from fall to winter in seven of the eight lines. No uniform seasonal trend was apparent with respect to rodent contamination. In the total for all lines both the winter of 1953 and 1954 presented the greatest seasonal abundance of granary insects.

Relationship of Grain Grade to Contamination

Harris *et al*[5] demonstrated an increase in the average number of pellets

[5] Harris, K. L., *et al.*, *op. cit.*

Table 10. Rodent Contamination and Insect Infestation in Wheat Samples by Seasons and for Total Period for Each Elevator Line or Elevator Group, and Amount of Wheat Represented by the Sampling, 1953-54

Line	Season	Number of samples	Rodent contamination: Number	Rodent contamination: Per cent	Insect infestation: Number	Insect infestation: Per cent	Number of bushels represented
1	Winter	56	15	26.8	4	7.1	102,526
	Spring	48	9	18.7	4	8.3	20,108
	Summer	84	15	17.9	8	9.5	52,199
	Fall	86	8	9.3	15	17.4	108,485
	Winter	84	17	20.2	23	27.4	63,088
	Total	358	64	17.9	54	15.1	346,406
2	Winter	21	5	23.8	3	14.3	25,078
	Spring	9	2	22.2	0	0.0	26,300
	Summer	26	4	15.4	1	3.8	32,712
	Fall	29	1	3.4	2	6.9	71,571
	Winter	13	0	0.0	3	23.1	7,180
	Total	98	12	12.2	9	9.2	162,841
3	Winter	27	3	11.1	3	11.1	127,265
	Spring	3	1	33.3	0	0.0	5,725
	Summer	1	0	0.0	0	0.0	....
	Fall	11	2	18.2	0	0.0	22,900
	Winter	11	1	9.1	3	27.3	20,276
	Total	53	7	13.2	6	11.3	176,166

Table 10. Continued.

Line	Season	Number of samples	Rodent contamination: Number	Rodent contamination: Per cent	Insect infestation: Number	Insect infestation: Per cent	Number of bushels represented
4	Winter	42	8	19.0	10	23.8	56,739
	Spring	40	8	20.0	2	5.0	39,745
	Summer	17	5	29.4	3	17.6	3,860
	Fall	24	0	0.0	1	4.2	32,815
	Winter	17	5	29.4	2	11.8	19,467
	Total	140	26	18.6	18	12.9	152,626
5	Winter	3	0	0.0	1	33.3	1,520
	Spring	0	0	0.0	0	0.0	....
	Summer	52	3	5.8	1	1.9	14,516
	Fall	59	2	3.4	6	10.2	4,011
	Winter	36	3	8.3	10	27.8	5,400
	Total	150	8	5.3	18	12.0	25,447
6	Winter	54	13	24.1	5	9.3	62,676
	Spring	59	14	23.7	3	5.1	40,304
	Summer	50	7	14.0	4	8.0	42,263
	Fall	83	16	19.3	8	9.6	63,385
	Winter	48	7	14.6	10	20.8	53,420
	Total	294	57	19.4	30	10.2	262,048
7	Winter	26	7	26.9	2	7.7	42,020
	Spring	18	1	5.5	3	16.7	28,730
	Summer	10	2	20.0	1	10.0	14,810
	Fall	11	2	18.2	2	18.2	26,617
	Winter	17	1	5.9	2	11.8	33,510
	Total	82	13	15.9	10	12.2	145,687
8	Winter	60	15	25.0	5	8.3	83,875
	Spring	29	4	13.8	2	6.9	30,036
	Summer	36	5	13.9	3	8.3	109,480
	Fall	40	8	20.0	5	12.5	87,039
	Winter	41	10	24.4	7	17.1	86,860
	Total	206	42	20.4	22	10.7	397,290
9	Winter	21	2	9.5	0	0.0	23,231
	Spring	25	5	20.0	1	4.0	40,390
	Summer	47	2	4.3	1	2.1	55,104
	Fall	69	4	5.8	10	14.5	426,663
	Winter	32	2	6.3	7	21.9	139,966
	Total	194	15	7.7	19	9.8	685,354
Total	Winter	310	68	21.9	33	10.6	524,930
	Spring	231	44	19.0	15	6.5	231,338
	Summer	323	43	13.3	22	6.8	324,944
	Fall	412	43	10.4	49	11.9	843,486
	Winter	299	46	15.4	67	22.4	429,167
	Total	1,575	244	15.5	186	11.8	2,353,865

with increase in the grade number 1 through 4 and an increase in the number of granary insects with increase in the grade number 1 through 5. In the present study ranges above nine in counts of either insects or rodent pel-

Table 11. Rodent Contamination and Insect Infestation in Wheat Samples, by Grade

Grade	Number of samples	Rodent contamination		Insect infestation	
		Per cent	Average	Per cent	Average
1	3,380	15.0	0.23	13.9	0.47
2	840	18.8	0.28	20.0	0.70
3	665	18.5	0.31	20.2	0.56
4	330	15.2	0.30	14.5	0.43
5	233	23.2	0.37	19.3	0.80
Sample	118	22.0	0.36	21.2	0.63
Total	5,566	16.5	0.26	16.0	0.53

lets were tabulated quantitatively as nine. The significance of an average value is completely lost in a series of samples if extremely high numbers of contaminants are only occasionally encountered. Biologically speaking, an infestation of nine or more insect forms indicates potential complete loss, and a rodent pellet count above nine is already beyond the question of degree of filth.

On the above type of enumeration, grade number 1 wheat shows the lowest average level of rodent pellets, and the percentage of samples in grade 1 are lowest both for pellets and insects (table 11). The highest average rodent pellet count as well as the highest percentage of samples containing rodent pellets falls in the grades 5 and "sample." No consistent gradient of contamination from grade to grade can be demonstrated; however, there is enough agreement in the data to support the conclusion that the lowest levels of contamination will be found in grade 1, and the highest levels will be observed in grades 5 and "sample."

Distribution of Insects

Although 16 different insects were coded for tabulation, only three forms were sufficiently abundant to have any application to studies of geographic distribution. As previously pointed out, the insect problem in the country areas was low as compared with the terminal stations. Therefore, any tabulation of insects within most districts will be low.

The primary infestors, the granary and rice weevils, are largely centered in districts 9, 10, 11, 12, and 13 with some occurring in districts 1, 5, and 16 (table 12). The rust-red flour beetle was limited to districts 6, 9, 10, 11, 12, and 13.

Disregarding district 17, these three forms appear to be based upon a climatic factor. The northern districts have very low insect counts. The high counts of granary and rice weevils at the terminal indicate again the unique nature of large storage.

Grain Beetle Infestation

During the course of laboratory analysis a grain beetle, *Laemophloeus* sp., was found to be the most frequent occurring insect form. It is recognized that *L. minutus* Oliv., the flat grain beetle, *L. turcicus* Grouv, and *L. ferrugineus* Steph., the rust-red grain beetle, are easily confused. The males can be distinguished by the ratio of antennal length to body length. Unfortunately, however, the manner in which grain is handled prior to examination for infestation destroys such fragile insect parts as the antennae.

During the X-ray-dissection studies, the larvae, pupae, and adults of a grain beetle, *Laemophloeus* sp., were found as hidden infestors. Their occurrence without associated granary insect forms was of sufficiently high frequency to suggest the possibility of primary infestation. Cotton, 1950,[6] states with regard to the flat grain beetle:

Table 12. Rust-Red Flour Beetle, Granary Weevil, and Rice Weevil Infestation in Wheat Samples, by Districts

Districts	Number of samples		
	Rust-red flour beetle	Granary weevil	Rice weevil
1	.....	2	.....
5	.....	3	1
6	1	.....	.....
9	2	5	.....
10	2	2	2
11	5	11	1
12	4	18	3
13	1	5	4
14	.....	2	.....
15	.....	.....	1
16	.....	4	.....
17 (terminals)	1	81	82

> "It is cosmopolitan in distribution and is one of the commonest insect pests of stored grain. It is not a primary pest of stored grain, however, and the adult is apparently unable to survive in sound, uninjured grain. It follows up the attack of the more vigorous grain pests and is frequently found in enormous numbers associated with the rice weevil. It is a scavenger by nature and prefers grain and meal that is out of condition."

Although the above indicates that the flat grain beetle is not a primary pest of stored grain, a second statement from the same reference tends to demonstrate otherwise.

> "The small white eggs are placed in crevices in the grain or dropped loosely in farinaceous material. The larvae are particularly fond of the germ of wheat, and in infested grain many kernels will be found uninjured except for the removal of the germ."

Although the present work is not conclusive and the *Laemophloeus* species is not defined, some of the points noted need to be made:

1. From a macroscopic selection for 1,000 sound kernels of number one northern spring wheat it was found upon microscopic examination that 52.8 per cent had fissures over the germ sufficiently large enough to permit oviposition.

2. Although most of the *Laemophloeus* beetle larvae, pupae, and adults occurred in samples containing "primary" insect pests of stored grain, some were found without other insect association.

3. Kernels of wheat were invaded which had not been exposed to infestation (figure 3). The condition of secondary infestation within a particular kernel was noted (figure 7).

4. The "cosmopolitan" distribution suggests the lack of dependency on primary pests of stored grain.

5. It was the most frequently observed insect and when present was found in highest numbers for individual samples.

6. Inasmuch as the rust-red grain beetle is more resistant to cold weather and is more commonly found in stored grain in the northern states (Cotton[7])

[6] Cotton, R. T. Insect pests of stored grain and grain products. Burgess Publ. Co., Minneapolis, Minn. 1950.

[7] Cotton, R. T., *op. cit.*

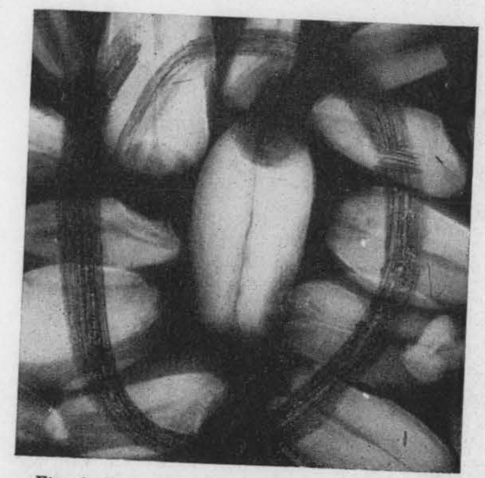

Fig. 3. The typical radiographic appearance of *Laemophloeus* sp. attack.

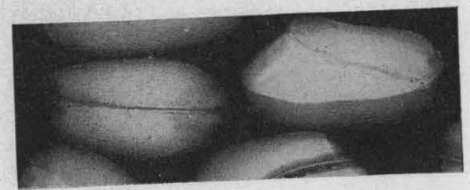

Fig. 4. The radiographic appearance of normal wheat kernels from two views.

Fig. 5. Invasion of the endosperm by *Laemophloeus* sp.

it may be that the radiographic descriptions which follow apply to this species.

At present the grain industry is using X-ray to a limited extent for the detection of hidden infestation. Inasmuch as the prepared radiographs are "read" and the grain itself is not dissected, some errors are inherent in the method. Nevertheless, as an aid to such reading, a series of figures are included here to demonstrate the appearance of kernels with *Laemophloeus* sp. infestation.

This grain beetle characteristically attacks the wheat germ (figure 3), although it may be found elsewhere in the kernel (figure 5). It is often found associated with the rice and granary weevils (figure 7). The excavations in the germ produce an atypical shadow-

Fig. 6. The appearance of what would be incorrectly called larva or pupa.

Fig. 7. Presence of *Laemophloeus* sp. following weevil attack.

ing on the radiograph which can be determined with a fair degree of accuracy. The wheat germ which has been destroyed usually shows a more homogeneous shadow with more sharply defined edges than the normal, uninjured kernel (compare figures 3 and 4). It is questionable, however, whether one could separate the radiographic appear-

ance of this type of attack with the simple loss of the germ. Furthermore, one may be tempted to "read" the presence of insect larvae when observing the frequently occurring forms seen in these radiographs (figure 6). The larvae, pupae, and adults of the insect are not well defined on the radiographs. The light spots appearing as larvae are most often part of the kernel.

As can be seen from the included figures, only a small volume of the kernel is destroyed if comparisons are made with the excavations of weevil attack. It is apparent that the life cycle can be completed within one kernel. A few adults were found within kernels from which no openings of sufficient size were present to indicate entry of larvae or adults.

Conclusions

RODENT PROBLEM

1. In the Northwest the rodent problem is centered on the farm and geographically is of particular importance in eastern South Dakota.

2. A decrease in rodent contamination is certain from farm to terminal, but as to how or why, only suggestions are in order.

Some of the wheat sampled on the farm may never reach the terminal. This wheat may be in great part that which is contaminated. Commingling of grain after it leaves the farm may reduce the rodent level. On the other hand, commingling may be a factor in the subsequent relatively high levels of insect infestation at advanced points of storage.

3. As far as grain contamination is concerned, mouse control needs to be vigorously added to the rat control effort which previously had been the major concern in rodent control. Mice have been tolerated at the expense of grain sanitation.

4. The lack of consistent seasonal trends in rodent contamination indicates that rodent control cannot be a seasonal activity. It must be carried out at all seasons.

INSECT PROBLEM

1. Both insect numbers and the destructiveness of the type of insect increases from the farm to the terminal. It is difficult to explain the change in species represented without stating they must originate, for the most part, from established populations at advanced points of storage.

2. Although there is a statistically significant change in insect numbers within boxcars, it does not follow that the increase has been the result of movement from the boxcar liners into the grain. The natural increase of a given population already present could bring about an increase if the time of boxcar occupancy was long enough. Further analysis needs to be made from the available data of the study to determine if there is a change in the species represented.

3. In the country area, eastern South Dakota needs to watch insect infestation. Where populations do get started the period of growth can be rather well shown to be from summer through fall. At this time the grain on the farm needs to be checked.

EFFECTS OF METHODS USED

1. The insect problems of terminal stations are not seasonal. The large volumes provide sufficient insulation for the establishment of an independent "climate." Furthermore, here the necessary practice of commingling in-

Table 13. Rodent Contamination and Insect Infestation in Wheat Samples Taken by Trade, P.M.A., and F.F.A. Groups from Farm Bins

Sample groups	Number samples	Rodent contamination		Insect infestation		Total bushels represented
		Number	Per cent	Number	Per cent	
Grain trade	671	140	20.9	58	8.6	397,508
P.M.A.	542	88	16.2	46	8.4	332,019
F.F.A.	579	154	26.6	45	7.8	204,081

creases the possibilities of increased infestation.

2. The greater the volume of wheat as related to total exposed surface area, the lower the level of rodent contamination and the higher the level of insect infestation.

When no attempt is made at sanitation, the above generalization is most likely to be observed. Grain in the Northwest that has maximum surface to volume will in most cases cool sufficiently during the winter to kill the insect forms; however, maximum surface provides a favorable habitat for larger mouse populations. Grain in large storage provide little surface for mouse populations but adequate insulation for the development of insect populations.

SAMPLING ADEQUACY

The adequacy of sampling was of primary concern throughout the study. Apparently it was, for the most part, adequate. The following supports this conclusion:

1. The month to month sampling showed consistently the same differences in contamination from farm to terminal.

2. The rather consistent seasonal trends in insect infestation within the smaller types of storage (farm bins and government grain) and the agreement of insect trends in seven out of eight lines during the summer-fall-winter would indicate that sampling for seasonal changes in levels of insect infestation at these respective points has been adequate.

3. No expected change in contamination was noted with change in Food and Drug Administration regulations.

4. A county replication of farm bins sampled by three different groups provided comparable levels on insect infestation and high levels of rodent contamination (table 13).

ADEQUACY OF ANALYSES

No definitive statement can be made with regard to adequacy of analysis. Without having experimentally designed controls against which to measure achievement, the conclusion can only be a matter of judgment. Undoubtedly some rodent contamination was missed, but a greater proportion of hidden infestors was not recovered. The recovery techniques employed by the grain industry are subject to these same limitations. Time required for complete recovery of all contaminants is prohibitive under most circumstances. However, certain refinements can be made similar to the work on hidden infestation as demonstrated in the recovery of the grain beetle, *Laemophloeus* sp.

It is doubtful that the recovery of all insect forms would have changed significantly the results of the study. The very nature of sample size from each large storage receptacle leaves any method for determining the exact extent of contamination in doubt. However, the Northwest can expect to find levels of contamination at least as high as found in the present study, not less

OCTOBER 1955

Rural-Urban Distribution of Hospital Facilities and Physicians in Minnesota

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