ABIOTIC AND BIOTIC CHARACTERISTICS OF GRAIN STORED IN TEMPORARY FARM BINS

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INTRODUCTION

In the Canadian Prairie Provinces, large stocks of grain are stored on farms during years of surplus production. In some years most of the farmers, and in most years some farmers, do not have enough permanent granaries to store all the grain they produce. Because of the lack of storage space many farmers resort to grain storage units that can be constructed more easily and less expensively than more permanent storage units. In a recent survey, 1,517 or 60% of the 2,522 elevator agents in the three Prairie Provinces reported that temporary grain bins were in common use in their district during 1968-69 (R.N. Sinha unpublished).

There are many different types of temporary bins and published recommendations on their design are contradictory. For example, in some instances, it is recommended that the bin be covered with a polyethylene sheet whereas in others it is recommended that the bin be left open. To obtain data on which practical recommendations could be based and to compare the storage stability of major cereals in various types of temporary grain bins that are presently in use, a study was made of the condition of grain stored in these bins on farms in Manitoba.

A descriptive approach was used to analyze the data and is presented in the first part of the paper. Because stored grain involves a complex of variables both univariate and multivariate statistical approaches were also used to analyze the data. These approaches made it possible to detect small changes in certain variables that have relatively slow rates of change during short-term storage of grain.

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MATERIALS AND METHODS

Abiotic (nonliving) and biotic (living) variables were measured in grain bulks stored in 13 temporary grain bins on farms in southwestern Manitoba (Table I, Figures 1 and 2). It was planned to study at least two replicates of open and polyethylene-covered bins containing each of the main cereal crops: wheat, oats, and barley. Seeds of the 1969 crop were stored in bins, overwintered, and first sampled in late spring of 1970. To measure deterioration of stored grain during the summer, four of the bins that were still in use were sampled for a second time in early fall.

Temperature measurements and samples were taken in each bin at the locations shown in Figure 3. Temperatures were measured with a 24-gauge (B&S) copper-constantan thermocouple, which was pushed to the bottom of the bin with a 1.25-cm diam wooden rod notched at the end. The wooden rod was removed immediately to reduce its effect on the temperature of the grain. The temperature of the thermocouple was read on a thermocouple indicator (minimum graduations 0.5 Fahrenheit degrees (0.3 Celsius degrees)) when the indicated temperature became constant. Then the thermocouple was pulled up to measure

Figure 1. Temporary grain bin covered with polyethylene sheet (bin no. 11, Table I).

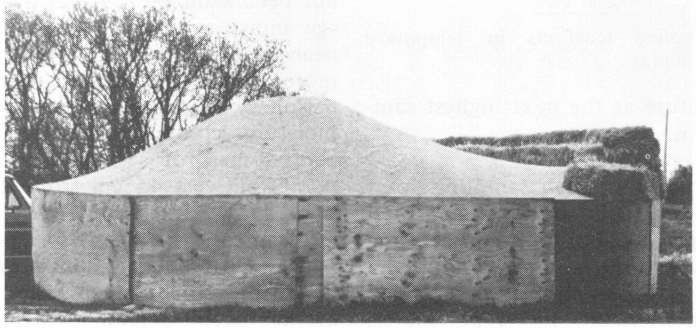

Figure 2. Wind damage to open-topped temporary grain bin (bin no. 3, Table I).

TABLE I DETAILS OF TEMPORARY GRAIN BINS STUDIED ON FARMS IN SOUTHWESTERN MANITOBA IN 1970

	Construction§				Size			Crop			Sampling			
Bin code no.	Walls	Bottom	Cover	Vent	Center depth (m)	Diam (m)	Capacity (t)	Species§	Cult	Density (kg/hl)	Date	Storage time (mo)	Air temp† (C)	No. samples
1	Ply	Plas	Plas	Y	2.6	7.5	42	B	Herta	57.5	May 8	8	10	68
2	Tar	Stub	Open	-	2.1	6.1	24	B	Montcalm	57.5	May 19	8	6	55
3	Ply	Sod	Open	-	2.3	7.5	35	O	Harmon	51.2	May 20	8	10	62
4	Tar	Plas	Plas	Y	2.4	6.4	26	O	Harmon	48.7	May 21	8	14	66
5	Ply	Sod	Plas	Y	2.1	6.1	33	W	Manitou	75.0	May 21	8	14	64
6	Ply	Sod	Open	-	2.0	5.2	24	W	Unknown	77.4	May 22	8	13	58
7	Ply	Stub	Plas	N	2.1	6.7	31	B	Conquest	57.5	May 27	9	9	60
8	Ply	Plas	Plas	N	2.3	6.7	29	O	Unknown	52.5	June 1	9	14	62
9	Ply	Str	Bal	-	2.3	6.1	26	B	Unknown	57.5	June 2	9	17	62
10	Bal	Plas	Plas‡	N	1.7	6.1	32	W	Manitou	78.7	June 2	9	17	51
11	Ply	Plas	Plas	Y	2.3	6.7	44	W	Manitou	78.7	June 3	9	19	63
12	-	Stub	Open	-	1.4	4.3	3	O	Harmon	52.5	June 3	9	19	30
13	Ply	Stub	Str	-	2.6	7.5	34	O	Unknown	46.2	June 4	9	21	87
3A	Ply	Sod	Open	-	2.0	7.5	24	O	Harmon	52.5	Sept. 1	12	21	47
4A	Tar	Plas	Plas	Y	2.1	6.4	24	O	Harmon	48.7	Sept. 2	12	20	67
10A	Bal	Plas	Plas‡	N	1.7	6.1	32	W	Manitou	78.7	Sept. 2	12	20	50
12A	-	Stub	Open	-	0.8	2.5	1	O	Harmon	48.7	Sept. 3	12	19	15

† Mean temperature during sampling date measured at Winnipeg Meteorological station.
‡ Loose straw on top of cover, 15 cm thick.
§ Ply = plywood; Tar = tar paper; Bal = bales; Plas = plastic; Stub = stubble; Sod = sod; Str = straw; Open = open; Y = yes; N = no; B = barley; O = oats; W = wheat.

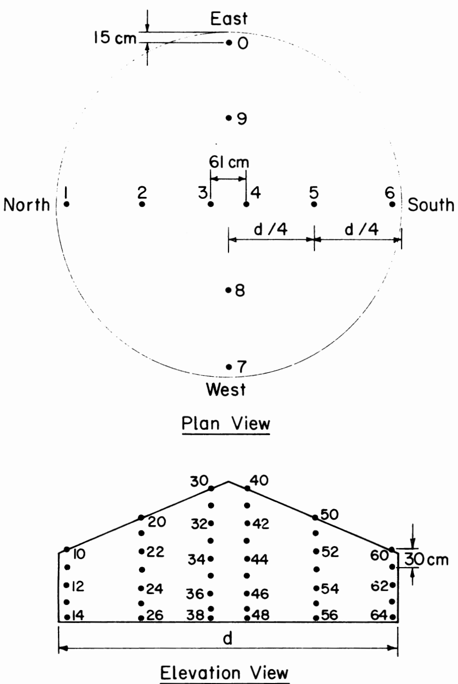

Figure 3. Sampling locations in temporary grain bins.

the temperature at the next highest sampling location.

Samples taken at each sampling point with a 250-g torpedo probe were stored in plastic bags in a cool room until testing could be done in the laboratory. Moisture content of each sample was determined twice with a capacitance-type meter. Moisture determinations for samples having moisture contents outside the range of the meter were determined by oven-drying. Bulk densities were determined for samples from locations 10, 12, 30, 33, and 53 (Figure 3).

Viability (germination) of cereal seeds and the fungal flora associated with them were determined using 25 seeds selected at random from each sample. The seeds were incubated for 1 wk at room temperature (17-24°C) on filter paper saturated with sterile water (6). Insects and mites were extracted from 200-g portions of each sample by placing the portions in Berlese funnels under 100-W incandescent electric bulbs for 24 h (3).

Moisture content is one of the main abiotic characteristics of stored grain that can be used to indicate the efficacy of a temporary grain bin. Changes in moisture content of the grain during winter storage had to be estimated because the grain had not been sampled the previous fall. Average moisture content of the grain mass near the center of a small bin changes more slowly and less than that of the periphery of the grain bulk. The average moisture content of samples for the central mass of a bulk was taken from points at least 45 cm from the surface, base, and walls of a bin (Table I), and was referred to as the "center average" in this paper. Differences in moisture content between peripheral regions and the center average were assumed to indicate the approximate magnitude of changes in the moisture content of the peripheral regions during winter storage. Bins used in each of the comparisons given in the tables of results were chosen so that all major independent variables were the same except for the variable being studied.

For statistical analyses (analysis of variance and discriminant analysis) the grain bins were divided into six cereal and structural categories: (*i*) wheat, covered; (*ii*) oats, covered; (*iii*) barley, covered; (*iv*) wheat, uncovered; (*v*) oats, uncovered; and (*vi*) barley, uncovered. Oats and barley covered with straw or straw bales were not included, because none of the wheat bins were covered with straw. Angular transformations (to degrees) were used for moisture content, viability, and fungal infection. The transformation, log $(x + 1)$, was used for Acarina. Analysis of variance by fitting constants was performed. Based on previous experience we chose viability, Acarina and *Helminthosporium* as dependent variables in these analyses.

Discriminant analysis (1, 2) was used to determine which abiotic and biotic characteristics best differentiated between the six cereal and structural categories. The homogeneity and the covariance matrices of the six groups were tested. Because the test revealed unequal matrices, the test of significance could not be applied to the results of the discriminant analysis. Nevertheless, the discriminant function matrix could be

TABLE II EFFECTS OF POLYETHYLENE COVER AND GROUND SHEET ON ABIOTIC AND BIOTIC CHARACTERISTICS OF GRAIN IN TEMPORARY BINS

Characteristic	Polyethylene covered	Open top	Polyethylene covered: With vent	Polyethylene covered: Without vent	Polyethylene ground sheet	Grain on ground
Bin code no.	5, 8, 11	6, 3	1, 4	7, 8	1, 11	5, 7
			Moisture content (%)			
Bin avg	13.5	13.9	13.5	14.3	13.1	14.6
Center avg	13.6	12.8	13.0	14.0	13.1	13.7
Increase at top surface‡	−1.3	1.3	−0.1	6.3	-	-
Increase at peak‡	−0.7	1.0	2.6	20.8	-	-
Increase at 30-cm depth‡	0.2	2.7	1.4	1.1	-	-
Increase at near walls‡	0.5	2.5	1.1	0.8	-	-
Increase near bottom‡	-	-	-	-	0.3	0.1
			Temp (C)			
Bin avg	11	11	8	11	7	12
30-cm Depth avg	14	11	13	14	-	-
Bottom avg	-	-	-	-	6	8
			Viability (%)			
Frequency of occurrence	100	100	98	98	100	98
Kernel avg	95	96	85	88	88	88
Avg low	78	80	6	34	52	42
Avg high	100	100	98	100	98	100
			Insects and mites (frequency of occurrence in samples)(%)			
Attagenus megatoma (Fabricius)	1	0	6	0	6	0
Cryptolestes ferrugineus (Stephens)	0	1	0	3	0	3
Androlaelaps casalis (Berlese)	0	0	4	7	4	7
Psocoptera	1	0	†	0	3	0
Acarus siro L.	5	5	0	14	0	9
Cheyletus eruditus (Schrank)	2	0	0	2	0	3
Tydeus interruptus Thor	0	1	0	4	0	4

† Less than 1%.
‡ Increase in moisture content above center average.

used to interpret the biological data given in the results.

Frequency of occurrence in samples (%) as used in the text was calculated by dividing the number of affected samples (a sample that contained at least one viable kernel, one fungus-infected kernel, or one insect-infested kernel) by the total number of samples and multiplying by 100%. Frequency of occurrence of kernels (%) was calculated by using the number of affected kernels individually examined over the total number of kernels examined.

RESULTS AND DISCUSSION

Spring Measurements

Polyethylene-covered vs. open-topped bins

Grain in the polyethylene-covered bins with or without vents and in the open-topped bins had equally high viability (Table II). Temperatures and frequencies of insects and mites were low and about equal in both types of bins. A decline in the field fungi, *Alternaria* and *Helminthosporium,* usually indicates either aging or deterioration (6). The level of *Alternaria,* however, was similar in both types of bins (Table III). The abundance and frequency of *Helminthosporium* was lower in the open-topped bins than in covered bins. These results are probably due to *Alternaria* not being restricted by crop or variety, and hence all lots are infected, compared with *Helminthosporium,* which is a pathogen, and varied greatly among bins.

Although most of the characteristics of the grain stored in the two types of bins were similar, some of the characteristics indicated important differences. Moisture content of the grain in the upper 30 cm of the bins and near the bin walls seemed to have increased more during winter storage in the open-topped bins than in the covered bins. The frequency of occurrence of the storage fungus *Penicillium* in the samples from the open-topped bins was almost twice that of the samples from the bins covered with polyethylene, and the percentage of kernels with *Penicillium* was almost three times greater. The frequency of occurrence in samples and abundance of *Streptomyces* on seeds was also considerably greater in the open-topped bins than in the covered bins. These differences in the abiotic and biotic characteristics of the grain seem to indicate that the potential for rapid and extensive deterioration by microflora was greater in the open-topped bins than in the polyethlene-covered bins.

A vent in the top of the polyethylene cover reduced the moisture increase at the peak and along the top surface of the grain cone (Table II). Bins without a vent in the polyethylene cover provided a more suitable environment for the development of insects, mites (Table II) and *Penicillium* (Table III) than bins with a vent. Grain viability and infection by field fungi, however, were about the same in the two types of bins.

The increase in moisture content of grain 15-20 cm above the base of the bin was not greatly affected by a polyethylene sheet placed on the ground before filling the bin (Table II). Samples could not be taken closer to the ground because of the design of the sampling probe. Temperature measurements taken at the bottom of the bins indicated that the grain directly on the ground was slightly warmer than the grain on the polyethylene.

TABLE III EFFECTS OF POLYETHYLENE COVER AND GROUND SHEET ON MICROFLORA ASSOCIATED WITH GRAIN IN TEMPORARY BINS

Characteristic		Polyethylene covered	Open top	Polyethylene covered: With vent	Polyethylene covered: Without vent	Polyethylene ground sheet	Grain on ground
Absidia	S‡	0	0	0	7	0	7
	K§	0	0	0	†	0	†
Alternaria	S	100	100	99	91	100	91
	K	64	63	68	61	63	67
Cladosporium	S	84	94	58	73	59	48
	K	24	18	7	23	7	5
Cephalosporium	S	19	24	76	14	47	10
	K	1	2	12	†	9	†
Curvularia	S	4	13	0	4	0	0
	K	†	†	0	†	0	0
Epicoccum	S	5	15	4	2	4	7
	K	†	1	†	†	†	†
Fusarium	S	45	55	44	41	14	37
	K	3	9	5	2	1	3
Fusidium	S	0	0	2	0	2	0
	K	0	0	†	0	†	0
Helminthosporium	S	75	57	91	91	72	71
	K	15	4	51	24	48	12
Nigrospora	S	0	28	0	4	0	4
	K	0	1	0	†	0	†
Penicillium	S	17	30	16	38	10	35
	K	1	3	2	8	†	8
Rhizopus	S	2	13	0	0	1	3
	K	†	†	0	0	†	†
Streptomyces	S	27	65	54	52	17	68
	K	4	23	9	15	1	16
Trichothecium	S	7	37	18	1	2	11
	K	1	5	4	†	†	3

† Less than 1%.
‡S, Frequency of occurrence in samples, %.
§K, Frequency of occurrence on kernels, %.

TABLE IV ABIOTIC AND BIOTIC CHARACTERISTICS OF DIFFERENT CEREALS STORED IN TEMPORARY BINS

Characteristics	Wheat	Oats	Barley
Bin code no.	6, 11	3, 4	1, 2
		Moisture content (%)	
Bin avg	13.5	13.2	14.3
Center avg	13.5	12.1	13.7
Increase at top surface‡	−1.3	1.3	−0.9
Increase at 30-cm depth‡	0.4	3.2	1.9
Increase near walls‡	0.3	2.8	1.1
		Temp (C)	
Bin avg	11	11	12
30-cm Depth avg	13	14	14
		Viability (%)	
Frequency of occurrence	100	98	98
Kernel avg	97	93	84
Avg low	86	40	6
Avg high	100	100	98
		Insects and mites (frequency of occurrence) (%)	
Attagenus megatoma	2	1	9
Cryptolestes ferrugineus	1	0	0
Androlaelaps casalis	0	0	6
Psocoptera	3	0	†
Acarus siro	4	1	5
Tydeus interruptus	0	1	1

† Less than 1%.
‡ Increase in moisture content above center average.

Wheat vs. barley vs. oats

The increase in moisture content of grain at and near the top surface and near the walls was greatest in oats and least in wheat (Table IV). Barley had the lowest viability and highest frequency of insects and mites. Although wheat had the second highest frequency of occurrence of insects and mites (their level of infestation was unusually low despite the presence of species that usually cause large financial crop losses), it appears to have stored better than the other two cereals and consequently would have the least potential for further deterioration. The comparative frequencies of occurrence of the different species of insects, mites, and fungi on the three different grains (Tables IV and V) are similar to those found previously (5).

Miscellaneous bin constructions

The bin of barley covered with bales of straw had a greater increase in moisture content near the top surface and walls than other open-topped and polyethylene-covered bins of barley (Table VI). Because viability and frequency of field fungi were higher in the bin covered with

TABLE V MICROFLORA ASSOCIATED WITH DIFFERENT CEREALS STORED IN TEMPORARY BINS

Characteristic		Wheat	Oats	Barley
Alternaria	S‡	100	99	100
	K§	58	83	69
Cladosporium	S	91	93	49
	K	14	16	4
Cephalosporium	S	4	52	52
	K	†	5	9
Curvularia	S	0	13	0
	K	0	†	0
Epicoccum	S	2	15	3
	K	†	1	†
Fusarium	S	13	86	8
	K	1	13	†
Fusidium	S	0	0	2
	K	0	0	†
Helminthosporium	S	47	73	91
	K	3	7	53
Nigrospora	S	0	28	0
	K	0	1	0
Penicillium	S	25	24	24
	K	2	2	4
Rhizopus	S	14	0	7
	K	1	0	†
Streptomyces	S	18	90	60
	K	1	29	9
Trichothecium	S	4	52	0
	K	†	9	0

† Less than 1%.
‡S, Frequency of occurrence in samples, %.
§F, Frequency of occurrence on kernels, %.

bales than in the open and polyethylene-covered bins, the higher surface moisture could not have adversely affected the grain. Oats covered with loose straw had higher moisture contents and temperatures, more storage fungi, insects, and mites, and had lower viability and field fungi than oats covered with polyethylene or open-topped (Table VI).

Bins made with snow fence and tar paper walls had higher temperatures near the walls than bins with plywood walls (Table VI). The bin with walls of straw bales had higher moisture contents but slightly lower temperatures near the walls than bins with plywood walls (Table VI).

Fall Measurements

Wheat and oats stored in bins covered with polyethylene tended to be in poorer condition after the summer storage period than oats in an open-topped bin (Tables VII and VIII). The polyethylene cover on the bin of oats was badly torn by the end of summer but the cover on the wheat bin was still intact. Average moisture contents increased during the summer storage period with the greatest increases in the two covered bins. The increase in moisture content may have been partly caused by respiration of organisms on or in the grain but was probably chiefly caused by precipitation entering the bins through tears in the polyethylene coverings. Grain near the walls and surface dried in the open-topped bin, whereas that in the covered bins increased considerably in moisture content.

The covered bin of wheat had higher moisture contents, higher frequencies of the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), and the grain mite, *Acarus siro* L., and considerably more *Penicillium* than the covered bin of oats. However, the wheat had lower temperatures and retained more *Alternaria* and *Helminthosporium*. Viability of the wheat was about equal to or higher than that of the oats. Therefore, the deterioration of the wheat was equal to or less than that of the oats, but the wheat showed potential for further extensive and rapid deterioration. The frequency of occurrence of *Penicillium* on the samples of oats taken in the fall from the covered bins was double that of samples taken in the spring; by contrast, the frequency of occurrence of *Penicillium* in samples taken from wheat in the fall was nine times higher than the count taken in the spring (Table VIII). The rusty grain beetle, considered the most destructive

TABLE VI EFFECTS OF MATERIALS USED FOR COVERING AND WALLS ON ABIOTIC AND BIOTIC CHARACTERISTICS OF GRAIN IN TEMPORARY BINS

Characteristic	Straw bale cover	Open top and polyethylene cover	Loose straw cover	Open top and polyethylene cover	Tar paper walls	Plywood walls	Straw bale walls	Plywood walls
Bin code no.	9	1,2	13	3,4	2,4	1,3	10	5,11
				Moisture content (%)				
Bin avg	15.1	14.3	15.2	13.2	13.9	13.5	12.8	12.8
Center avg	14.1	13.7	12.9	12.1	13.4	12.9	11.6	13.2
Increase at top surface‡	1.4	−0.9	6.7	1.3	−1.8	2.2	1.6	−2.3
Increase at 30-cm depth‡	2.6	1.9	3.6	3.2	2.2	2.9	2.1	−0.1
Increase near walls‡	2.5	1.1	5.7	2.8	1.7	2.2	3.0	−0.7
				Temp (C)				
Bin avg	12	12	18	11	16	7	11	12
Near walls	14	21	28	16	24	12	13	16
				Viability (%)				
Kernel avg	95	84	73	93	90	87	90	97
				Insects and mites (frequency of occurrence) (%)				
Cryptolestes ferrugineus	0	0	0	0	0	0	0	0
Androlaelaps casalis	5	6	1	0	2	4	0	0
Acarus siro	5	5	2	1	5	1	0	0
Tydeus interruptus	6	1	2	1	1	1	0	0
				Microflora (frequency of occurrence on kernels) (%)				
Alternaria	90	69	73	83	84	68	54	70
Fusarium	2	†	3	13	4	10	0	3
Helminthosporium	41	53	3	7	12	48	4	4
Penicillium	4	4	13	2	4	†	1	†
Streptomyces	11	9	32	29	15	23	†	3

† Less than 1%.
‡ Increase in moisture content above center average.

TABLE VII CHANGES IN THE ABIOTIC AND BIOTIC CHARACTERISTICS OF GRAIN STORED DURING SUMMER IN TEMPORARY BINS

Characteristics	Oats Open top		Oats Polyethylene cover		Wheat Polyethylene cover	
	Spring	Fall	Spring	Fall	Spring	Fall
Bin code no.	3	3A	4	4A	10	10A
			Moisture content (%)			
Bin avg	13.2	13.8	13.1	14.3	12.8	15.0
Center avg	11.4	13.4	12.7	13.5	11.6	12.6
Surface avg	14.9	12.5	11.7	15.0	13.2	16.8
30-cm Depth avg	16.0	14.6	14.4	15.0	13.7	15.9
Near walls avg	15.3	14.0	14.4	16.3	14.6	17.4
Near bottom avg	12.2	14.3	13.5	14.4	12.2	14.7
			Temp (C)			
Bin avg	9	36	11	37	11	29
Top surface avg	11	31	19	28	17	26
30-cm Depth avg	12	31	16	33	13	29
Near walls avg	12	33	20	37	13	29
Near bottom avg	7	38	6	42	5	32
			Viability (%)			
Frequency of occurrence	100	89	96	81	100	82
Kernel avg	95	64	91	67	90	72
Low	80	0	0	0	68	0
High	100	100	100	100	100	100
			Insects and mites (frequency of occurrence in samples) (%)			
Attagenus megatoma	0	0	2	0	0	0
Cryptolestes ferrugineus	0	30	0	36	0	52
Androlaelaps casalis	0	28	0	21	0	24
Acarus siro	2	0	0	9	0	22
Cheyletus eruditus	0	2	0	0	0	0
Glycyphagus destructor (Schrank)	0	38	0	4	0	0
Tarsonemus sp.	0	34	0	0	0	2
Tydeus interruptus	2	6	0	0	0	0

pest of stored grain in Canada, occurred more often in wheat than in oat samples in the fall; none occurred in the spring (Table VII).

In the fall, maximum temperatures occurred at the bottom of the bins, indicating that the most rapid deterioration was occurring in this area. Also, all bins had average temperatures well above summer ambient temperatures, indicating that a considerable amount of metabolic heat caused by respiration of various organisms was being produced in the grain. Two other biotic characteristics of the three bins were the infestation with *Cryptolestes ferrugineus* and the disappearance of field fungi *(Cephalosporium, Curvularia, Epicoccum, Fusarium)* during the summer. It is notable that about one-third of all samples in all types of bins sampled in the fall contained *C. ferrugineus*. This seems to indicate that the common practice of storing grain in temporary structures outdoors creates favorable conditions for infestation by this insect. Covering of these structures does not prevent multiplication of this species. Rapid disappearance of field fungi could be caused by aging and may indicate deterioration of the grain.

Statistical Analyses

Discriminant analysis revealed that the two seed-borne pathogens, *Helminthosporium* and *Fusarium* and a single storage fungus, *Penicillium*, distinguish the first category (wheat, covered) from other categories involving two coverings and three grains (Table IX). Because it is well known that these two seed-borne pathogens do not contribute to the spoilage of grain in storage, the third variable, *Penicillium*, serves as an indicator of potential spoilage in the covered wheat category compared with the other five categories.

In the second category (oats, covered) *Streptomyces* seems to be the only variable that can distinguish this category from all other categories. Because of low loadings on all variables none of the variables in other categories seems to be useful in distinguishing categories.

In a separate discriminant analysis in which only two categories – covered and open-topped bins – were used, *Streptomyces* emerged as the sole variable that could be used to assess storage quality.

Analysis of variance showed that viability was not significantly different in the polyethylene-covered and open-topped bins (Table X). There were significantly fewer mites (Acarina) and more field fungi *(Helminthosporium)* in the covered bins than in the open-topped bins. For all three dependent variables – viability, Acarina, and *Helminthosporium* – the effects of covering appear to be significantly different for the three cereals (Table X), but this is probably due to inherent differences in the seed lots comprising each category, and may not be due to the effect of covering.

POSSIBLE APPLICATION OF RESULTS

Under normal storage conditions, that is when grain is stored indoors in small wooden or metal bins, dry grain (about 14% moisture content) does not appreciably deteriorate in the 1st yr of storage (4). When seed viability is used as the sole criterion for assessing the loss of quality of stored grain, this generalization seems

TABLE VIII CHANGES IN THE MICROFLORA ASSOCIATED WITH GRAIN STORED DURING SUMMER IN TEMPORARY BINS

Characteristics		Oats Open top		Oats Polyethylene cover		Wheat Polyethylene cover	
		Spring	Fall	Spring	Fall	Spring	Fall
Absidia	S‡	0	19	0	39	0	10
	K§	0	3	0	6	0	2
Alternaria	S	100	98	97	43	100	66
	K	83	42	83	4	54	16
Cladosporium	S	97	60	89	27	94	36
	K	20	4	12	2	17	2
Cephalosporium	S	42	0	62	0	0	0
	K	3	0	6	0	0	0
Curvularia	S	26	0	0	0	0	0
	K	1	0	0	0	0	0
Epicoccum	S	27	0	2	0	16	0
	K	1	0	1	0	1	0
Fusarium	S	98	0	73	0	0	0
	K	18	0	8	0	0	0
Helminthosporium	S	63	28	82	10	59	18
	K	4	2	10	†	4	1
Nigrospora	S	56	0	0	0	0	14
	K	2	0	0	0	0	1
Penicillium	S	19	53	29	61	10	94
	K	1	4	3	6	1	31
Rhizopus	S	0	0	0	18	8	42
	K	0	0	0	1	†	3
Scopulariopsis	S	0	0	0	28	0	28
	K	0	0	0	2	0	10
Streptomyces	S	100	100	79	66	4	70
	K	43	47	15	17	†	14
Trichothecium	S	68	0	35	0	6	0
	K	10	0	8	0	1	0

† Less than 1%.
‡S, Frequency of occurrence in samples, %.
§K, Frequency of occurrence on kernels, %.

TABLE IX THE RELATIONSHIPS OF ABIOTIC AND BIOTIC CHARACTERISTICS OF STORED GRAIN BULKS AS SHOWN BY DISCRIMINANT FUNCTION ANALYSIS WITH VECTOR LOADINGS FOR THE FIRST FIVE CANONICAL AXES

Variable	Canonical axes† I	II	III	IV	V
Temperature	0.01	0.03	0.00	−0.05	0.01
Moisture content	−0.05	0.00	−0.15	−0.12	0.08
Viability	0.00	−0.01	−0.01	0.00	0.02
Alternaria	−0.01	0.01	0.03	−0.03	−0.03
Cladosporium	0.04	0.03	−0.04	0.00	0.02
Helminthosporium	−0.64	0.03	0.00	0.00	0.02
Cephalosporium	0.00	0.00	−0.07	0.01	−0.06
Fusarium	0.33	0.07	0.02	0.06	−0.04
Penicillium	−0.22	−0.02	−0.01	0.00	−0.01
Streptomyces	0.00	0.33	0.01	0.01	0.04
Acarina	0.05	0.07	0.15	0.09	0.12

† Canonical axes values identify the characteristics that are most likely to influence deterioration of stored grain.

to hold even when the grain is stored in temporary bins more directly exposed to harsh prairie weather. When other less conspicuous indicators of incipient deterioration of the grain are use, it becomes obvious that the potential hazard of storing grain in temporary bins is considerably greater than when similar grain is stored in permanent bins. Relatively warm and moist micro- and macroenvironmental pockets, which are suitable niches for the growth of microflora and fauna, can develop in various areas of a grain bulk. This study has shown that such niches can occur near the bottom, the top surface, and along the walls of temporary bins, depending upon the bin structure and the seasonal weather pattern.

Even when the appropriate physical environment is created in a microenvironment, timing of initial storage of grain and the length of storage is crucial for the development of biotic agents that cause grain decay. The ability of each organism to cause deterioration and the rate at which this is done is extremely variable. Although these experiments were undertaken with definite time limitations – owners of the bins did not allow us, in most instances, to hold the bin for the period required for several biotic agents to thrive – useful information about the creation of microenvironments in temporary bins has been obtained. Bin structure affected the occurrence of these microenvironments and provided us with a broad general pattern of changes that lead to deterioration of the stored grain.

Because an objective of this project was to provide practical recommendations, we have attempted to make some tentative conclusions from this exploratory study. Further experimental research under more controlled conditions is needed to substantiate some of these tentative conclusions.

TABLE X ANALYSIS OF VARIANCE BY FITTING CONSTANTS OF THREE BIOTIC-DEPENDENT VARIABLES IN SIX CATEGORIES OF TEMPORARY BINS

		Mean square of variable		
Source of variation	df	Viability	*Helminthosporium*	Acarina
Types of grain (T)	2	7454**	75438**	3.81**
Covered or uncovered (C)	1	220NS	16245**	1.60*
T X C	2	2040**	12716**	2.72**
Residual	809	443	222	0.30
Total	814			

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.
NS, Not significant at the 0.05 level of probability.

In most types of temporary grain bins now in use on Western Canadian farms, some grain is likely to deteriorate during winter storage and considerable deterioration may occur during summer. The rate of deterioration generally increases with the length of storage period. Deterioration and increases in moisture content during winter storage may be reduced by covering the bins with polyethylene sheets. A vent in the plastic cover at the apex of the cone will reduce moisture accumulation under the cover. The vent must be designed to prevent excessive amounts of snow and rain from entering the opening and to prevent wind from ripping the opening or vent cover. Covering the bins with loose straw or baled straw appears to be of little benefit compared with leaving the bins open-topped. Grain in bins with walls of straw bales or snow fence and tar paper may have higher moisture contents than grain stored in bins with plywood walls.

Grain stored in temporary grain bins deteriorates rapidly during the summer with the greatest deterioration occurring in bins covered with polyethylene. Holes in the plastic cover allow water to enter the grain but the cover prevents evaporation to the air. In open-topped bins much of the precipitation entering the bins during the summer evaporates into the air so that increases in moisture content are less in the open-topped bins than in the polyethylene-covered bins.

Temporary grain bins should be protected by windbreaks and sited on elevated well-drained locations. The ground under a bin should be coned or sloped so that water does not run into the grain. Water that runs down the inside or outside of the walls must be allowed to drain away from the bin instead of draining into or being trapped in the bottom of the bin. Wind, birds, and animals can cause depressions in the grain surface where rain and snow will accumulate and soak into the grain. Polyethylene covers may tear in the wind leaving openings for snow and rain.

Most hot spots in the bins surveyed occurred in columns within about 15 cm of the wall. In both open-topped and polyethylene-covered bins water appeared to run down the cone and then soak into the grain in depressions in the surface of the grain cone or through small holes in the polyethylene cover. The bins should be filled to form a good cone shape with the bin filled completely and with no depressions near the walls. Polyethylene covers should be inspected regularly and any holes that develop near the walls should be patched immediately.

SUMMARY

Various types of temporary grain bins were compared in a study involving grain stored in 13 bins on farms in Manitoba. Temperature measurements and samples were taken at about 60 points in each bin. Moisture content, viability, fungal infection, and insect and mite infestation were determined for each sample. Both a conventional descriptive approach and a multivariate statistical approach were used to evaluate the data.

Although the grain had not deteriorated greatly during winter storage, small differences in the abiotic and biotic characteristics of the grain collectively provided the means of assessing differences among the storage structures. It was apparent that the potential hazard of storing grain in temporary bins was considerably greater than when similar grain was stored in permanent bins. The study showed that deterioration and increase in moisture content during winter storage can be reduced by covering the bins with a polyethylene sheet with a vent at the apex of the cone, provided the covering sheet can be kept intact during the storage period. During summer, grain stored in polyethylene-covered bins deteriorated more rapidly than grain in open-topped bins.

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