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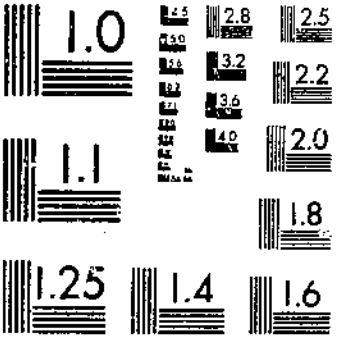

MICROCOPY RESOLUTION TEST CHART
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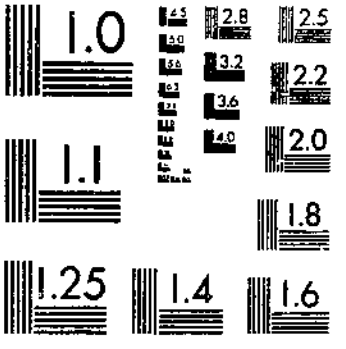

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RELATION OF TEMPERATURE AND MOISTURE CONTENT TO LONGEVITY OF CHEWINGS FESCUE SEED[1]

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INTRODUCTION

Seeds for planting purposes often must be transported long distances from place of production to place of use, and at times it becomes desirable to hold the seed from one season to the next. Although there are many records of the longevity of various types of seeds, there has not been available sufficient information as to the factors influencing longevity on which to base definite recommendation of conditions for shipment and storage of seeds. The fact that large quantities of the seed of Chewings fescue (*Festuca rubra* var. *commutata* Gaud.) received in this country from New Zealand have been of no planting value because of low germination led to an interest in the longevity and best storage conditions for this seed in a general study of the fundamental factors affecting longevity of seeds.

The amount of seed of poor quality received during some seasons and the variation in the quality of seed of different years are shown in table 1. Importations of 1932 and 1934 had a larger quantity of seed of low germination than those of 1933 and 1935.

It seemed desirable to determine the storage factors that influence the longevity of fescue seed. N. R. Foy, seed analyst of the Plant Research Station of New Zealand, had previously initiated a study of the best conditions for the shipment of the seed overseas, in which the Division of Seed Investigations, Bureau of Plant Industry, cooperated by making moisture and germination tests of the seed upon receipt in this country. The seed received from Foy in his shipping experiments was stored under different conditions, and germination tests were made at intervals to determine the loss of viability. More tests

[1] Submitted for publication July 8, 1938.

TABLE 1.—*Germination of Chewings fescue seed received in the United States from New Zealand*

Period	Seed having germination of—									
	0–9 percent		10–19 percent		20–29 percent		30–39 percent		40–49 percent	
	Pounds	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*
May 1932 to April 1933	57,012	7	33,600	4	24,832	3	55,650	7	113,932	14
May 1933 to April 1934	6,615	(1)	17,920	2	1,120	(1)	27,920	2	10,400	1
May 1934 to April 1935	57,840	8	15,680	2	2,352	(1)	15,306	2	66,755	10
May 1935 to August 1935										

Period	Seed having germination of—										
	50–59 percent		60–69 percent		70–79 percent		80–89 percent		90 percent and above		Total
	Pounds	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*
May 1932 to April 1933	96,604	12	271,122	34	98,960	12	30,240	4	23,520	3	805,472
May 1933 to April 1934			47,880	4	16,356	1	603,033	53	412,892	36	1,144,136
May 1934 to April 1935	46,170	7	114,418	17	183,393	27	173,043	25	13,440	2	688,397
May 1935 to August 1935	10,600	5	16,639	7	30,496	14	67,240	31	94,276	43	219,251

[1] Less than 1 percent.

were undertaken on recently harvested seed to determine more definitely the effect of moisture content of seed and of temperature of storage on the viability of fescue seed. For this purpose, seed was raised at the Arlington Experiment Farm, Arlington, Va., and in addition commercial seed raised in Oregon was obtained through the courtesy of H. A. Schoth, of the Division of Forage Crops and Diseases, Bureau of Plant Industry.

HISTORICAL REVIEW

A great deal has been published on the longevity of crop seeds, but in most cases the conditions of storage were not controlled. Heinrich [2] made a study of the factors influencing the keeping of seeds and gives moisture and temperature as the prime factors in the storage of seeds. He states that the ability of seed to withstand higher temperatures is dependent on the water content. Rye stored at 30° C. with a moisture content of 5 percent germinated 94 percent at the end of 69 weeks; with 15 percent moisture it germinated less than 3 percent after 32 weeks; and with 22 percent moisture it showed no germination at the end of 2 weeks.

Simpson [3] has shown a definite relation between the moisture content of cottonseed during storage and the rapidity of deterioration. Upland cottonseed stored with from 8.75 to 13.78 percent moisture lost viability quickly when the moisture in the seed remained above 10 percent.

Foy [4] in 1925 called attention to the variation in the quality of the seed of New Zealand Chewings fescue from season to season and also to some of the problems involved in the exporting of this seed. In a later publication, Foy [5] stated that seed with a moisture content of 13 percent stored at 40° C. in the laboratory lost over 20 percent in germination in 7 days. In the same period the germination capacity of seed with a moisture content of 20 percent had fallen almost 30 percent. He contends that the hold temperatures of ships probably exceed 40°. In this publication he gives a detailed account of shipping experiments carried on in cooperation with the Official Seed Testing Station, Cambridge, England, and with the Division of Seed Investigations, Bureau of Plant Industry.

In cooperation with the Cambridge station, Foy found that dried seed shipped in a lined bag lost very little in comparison with dried seed shipped in an unlined bag. In another experimental shipment he showed that seed dried to 6 percent did not lose during transit, and dried to 9 percent the loss was scarcely significant. Seed from the same bulk but undried, having a moisture content of 15 percent, lost practically the same whether shipped in cool storage or hold storage. The seed for this experimental shipment was cut at three stages of maturity: Barely ripe, ripe, and overripe. When seed having a moisture content of 14 percent was shipped either in ordinary hold or in cool storage there was a deleterious effect of early cutting. Manurial treatment of plots did not affect results.

[2] HEINRICH, MARTIN. DER EINFLUSS DER LUFTFEUCHTIGKEIT, DER WÄRME UND DES SAUERSTOFFS DER LUFT AUF LAGERNDES SAATGUT. Landw. Vers. Sta. 81: [289]-376, illus. 1913.

[3] SIMPSON, D. M. RELATION OF MOISTURE CONTENT AND METHOD OF STORAGE TO DETERIORATION OF STORED COTTONSEED. Jour. Agr. Research 50: 449-456, illus. 1935.

[4] FOY, NELSON R. CHEWINGS FESCUE: HISTORY, SEED-PRODUCTION, AND SEED-EXPORT PROBLEMS. New Zeal. Jour. Agr. 31: 356-370, illus. 1925.

[5] FOY, N. R. DETERIORATION PROBLEMS IN NEW ZEALAND CHEWINGS FESCUE. New Zeal. Jour. Agr. 49: 16-24. 1934.

In cooperation with the Division of Seed Investigations, Foy showed that seed shipped in cool storage lost no more during transit than the controls in New Zealand, but under ordinary hold storage the seed lost 18 percent more during transit than the New Zealand control. A later experiment to ascertain the effect of cool storage showed only slight differences between cool storage and hold-stowed lots, which he attributed to the superior quality of that particular crop. An experiment to compare the behavior of stook and stack-threshed seed and the effect of drying and shipping in sealed containers showed very little differences between the stook and stack-threshed seed, and in every case the dried lots carried better than the undried lots.

METHODS

In the writers' experiments an attempt was made to control the storage temperature of all the seed, except that placed at room temperature, and to control the moisture of the seed by storing it in sealed containers. In order to have samples with different moisture contents, from one large original bulk, the moisture content of individual samples was raised by placing a piece of absorbent cotton with a weighed amount of water in the sealed jar with the seed but not in direct contact with the seed; the moisture content was lowered on a sample of seed by allowing the seed to dry out in a heated room.

If the moisture content was raised, the moisture determination [6] was not made until a sufficient length of time had intervened for the seed to absorb the added water. Otherwise the moisture determination was made at the time the seed was placed in sealed jars for storage.

The sealed jars containing the seed were placed in thermostatically controlled chambers at temperatures of −10°, 2°, 10°, 20°, and 30° C. In some cases the seed was stored at room temperature in the container in which it was received.

All germination tests were made by placing 100 seeds on moistened paper toweling in Petri dishes at an alternating temperature of 15° to 25° C. All tests were made in quadruplicate and were continued for 21 days.[7]

EXPERIMENTS

SEED SHIPPED OVERSEAS UNDER COOL STORAGE

A shipment of three 1-bushel sacks of seed from New Zealand was received February 10, 1933. One lined sack (sample 751444) and one ordinary sack (sample 751445) were shipped in cool storage, and one ordinary sack (sample 751446) in the hold of the ship. The effect of conditions during shipment has been reported by Foy.[8] On February 11, 1933, seed from each bulk was stored in sealed jars in the laboratory and in thermostatically controlled chambers at temperatures of −10°, 2°, 10°, 20°, and 30° C. A moisture test of the seed was made at this date. Another portion of the three bulks was allowed to dry out in the laboratory until April 19, 1933, when moisture tests were made and the seed was placed in storage in a cloth bag in the laboratory and in sealed jars at the five temperatures listed above. The percentage of germination and moisture content

[6] The moisture content of the seed was determined by D. A. Coleman, Grain Division, Bureau of Agricultural Economics.

[7] KEARNS, VIVIAN, and TOOLE, E. H. TEMPERATURE AND OTHER FACTORS AFFECTING GERMINATION OF FESCUE SEED. U. S. Dept. Agr. Tech. Bull. 638. (In press.)

[8] FOY, N. R. See footnote 5.

on arrival and the moisture content of the portion of seed allowed to dry out in the laboratory are given in table 2, and the results of the subsequent germination tests in table 3.

TABLE 2.—*History of 3 samples of seed of Chewings fescue from New Zealand before storage at various temperatures*

Sample No.	Condition of storage during transit	Germination on arrival	Moisture content on arrival	Moisture content after drying in laboratory 2 months
		Percent	*Percent*	*Percent*
751444 (C1)	Cool storage; lined sack	81	15.3	8.6
751445 (C2)	Cool storage; unlined sack	81	15.2	9.8
751446 (C3)	Hold storage; unlined sack	64	13.5	9.0

Although the seed shipped under cool storage conditions had a much higher germination upon arrival in this country, this advantage was lost after 4 months' storage with the original moisture content. After 4 months the three samples stored at 10° C. showed approximately the same germination value. When stored at higher temperatures (20° and 30°) the sample shipped under hold storage had a higher germination. Only when the seed was kept at cool temperatures (2° and −10°) did the seed shipped in cool storage show a higher percentage of germination than that in the hold during transit, and after 8 months this difference had disappeared. The reason that the seed shipped in the hold retained its vitality longer during subsequent storage is, no doubt, that it contained approximately 2 percent less moisture than that shipped in cool storage. This view is confirmed by the results of the tests with the seed that was dried out 4 to 6 percent before storage. When the seed was dried before being placed in storage, the seed that had been shipped in cool storage retained its viability longer than that which had been sent in the hold.

Another lot of seed, shipped from New Zealand March 22, 1933, arrived in New York on May 6. The seedsman receiving the commercial shipment forwarded seed from each bulk to Washington in large airtight cans holding approximately 1 gallon, May 10. The bulk of each sample was divided and placed in storage in sealed jars at 30° and 2° C. Moisture tests were made upon receipt of the samples. The results are given in table 4. As pointed out by Foy, all of this seed arrived in excellent condition regardless of the shipping condition. However, 2 months after arrival, tests of the seed stored at 30° indicated the beginning of a decline in germination. The thermostat control of the 30° storage chamber failed after this date, so no further test was made on the seed at this storage condition. Tests made on the seed stored at 2° showed a high germination 19 months after storage and only a slight decline after 34 months of storage. In order to test further the effect of storage at 30° C., a portion of each sample of the seed stored at 2° was transferred to 30° in October 1933. A test was made of this seed and the check samples at 2° in February 1934, when the eight samples transferred to 30° showed from 0- to 12-percent germination and the check samples showed from 87- to 92-percent germination.

TABLE 3.—*Germination of seed of Chewings fescue, with high and low moisture content, stored at various temperatures after arrival from New Zealand*

HIGH MOISTURE [1]

Date of germination test	Time after arrival	Germination at temperature of—																	
		−10° C.			2° C.			10° C.			20° C.			30° C.			Laboratory		
		Sample 751444	Sample 751445	Sample 751446	Sample 751444	Sample 751445	Sample 751446	Sample 751444	Sample 751445	Sample 751446	Sample 751444	Sample 751445	Sample 751446	Sample 751444	Sample 751445	Sample 751446	Sample 751444	Sample 751445	Sample 751446
	Months	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
June 13, 1933	4	75	69	61	71	70	62	64	64	59	36	32	44	0	3	20	0	1	7
July 18, 1933	5	73	75	55	67	71	63	52	64	56	18	23	44	0	0	12	0	0	4
Oct. 17, 1933	8	71	67	65	60	66	57	36	42	47	1	5	26						
Feb. 6, 1934	12	68	70	61	51	60	51	27	31	38	0	0	19						
June 8, 1934	16	53	65	59	37	54	42	14	21	33	0	0	8						
Dec. 6, 1934	22	49	64	48	31	43	44	3	8	25			3						
Mar. 13, 1936	37	41	57	53	9	28	30	0	2	13									
LOW MOISTURE [2]																			
June 13, 1933	4				60	62	53	62	67	54	61	64	44	61	58	37	59	59	43
July 18, 1933	5				66	67	54	63	70	57	59	71	44	56	57	48	53	55	36
Oct. 17, 1933	8				61	63	56	52	62	45	48	55	34				36	37	21
Feb. 6, 1934	12				59	66	46	51	59	38	38	44	28				28	25	18
June 8, 1934	16				62	65	47	47	48	34	35	39	21				22	18	12
Dec. 6, 1934	22				56	57	41	42	46	25	24	33	17				9	13	7
Mar. 13, 1936	37				49	47	33	23	30	18	16	14	7				2	2	0

[1] Seed with moisture content on arrival as shown in table 2, column 4; put in storage immediately after arrival.
[2] Seed stored after drying in laboratory for 2 months; moisture content shown in table 2, column 5.

TABLE 4.—*Germination of seed of 1933 crop of Chewings fescue received in May 1933 as a commercial shipment from New Zealand*

Sample No.	Foy's distinguishing mark	Method of storage during shipment	Moisture content		Germination of seed		
			On arrival, May 1933	Mar. 13, 1936	On arrival	After storage for 2 months at—	
						2° C.	30° C.
			Percent	*Percent*	*Percent*	*Percent*	*Percent*
395686a	WO–A	Refrigerating chamber, temperature about 18° F	13.8		94	92	83
395686b	WO–B	do	13.6		95	94	89
395687a	OM–A	Domestic chamber, 27° to 30° F	13.6	12.84	92	91	86
395687b	OM–B	do	14		93	92	80
395688a	EG–A	Vegetable chamber, 30° to 36° F	13.6	12.96	93	92	89
395688b	EG–B	do	12.9		94	94	88
395689a	AT–A	Ordinary hold	12.5	12.09	92	91	87
395689b	AT–B	do	12.7		91	93	84

Sample No.	Foy's distinguishing mark	Method of storage during shipment	Germination of seed after storage for—				
			4 months at 2° C.	9 months at 2° C.	16 months at 2° C.	19 months at 2° C.	34 months at 2° C.
			Percent	*Percent*	*Percent*	*Percent*	*Percent*
395686a	WO–A	Refrigerating chamber, temperature about 18° F	93	92	90	90	85
395686b	WO–B	do	94	91	89	91	92
395687a	OM–A	Domestic chamber, 27° to 30° F	88	92	90	89	87
395687b	OM–B	do	94	92	89	91	87
395688a	EG–A	Vegetable chamber, 30° to 36° F	91	90	91	91	87
395688b	EG–B	do	93	91	92	95	93
395689a	AT–A	Ordinary hold	92	91	90	87	82
395689b	AT–B	do	90	86	87	84	83

SEED DRIED BEFORE SHIPMENT OVERSEAS

Several samples of seed from New Zealand were received in the laboratory February 25, 1932. Part of the seed had been dried before shipment and part was not dried. The seed was stored in the laboratory in the tin containers in which it was received. From a study of table 5 it is seen that the average of the three samples of seed dried before shipment showed practically the same percentage of germination after 18 months, storage in the laboratory as the nondried seed showed on arrival in this country.

TABLE 5.—*Germination of seed of Chewings fescue received from New Zealand Feb. 25, 1932*

Sample	Moisture content on arrival	Germination of seed							
		Feb. 26, 1932 (day after arrival)	Apr. 13, 1932 [1]	May 25, 1932 [1]	July 7, 1932 [1]	Sept. 15, 1932 [1]	Oct. 26, 1932 [1]	Mar. 10, 1933 [1]	Aug. 1, 1933 [1]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Dried:									
748780 (1a)	8.8	72	78	81	77	67	71	67	53
748781 (2a)	7.8	53	59	51	49	38	37	37	23
748782 (3a)	7.8	67	77	59	56	52	48	45	39
Nondried:									
748783 (1ac)	14.8	28	27	3	2	0			
748784 (2ac)	13.0	14	15	7	7	2	2	2	1
748785 (3ac)	12.9	55	59	48	41	28	25	24	12

[1] After storage in tin containers in the laboratory from time of arrival.

Another lot of seed was forwarded from New Zealand in October 1932 and received November 17. The seed was stored in the containers in which it was received, the hold-storage seed in cloth bags and the dried seed in metal cans. The results of germination tests made on these samples at different dates are given in table 6. The dried seed showed a germination, after being stored in the laboratory for 2 years 2 months, about equal to the germination of the nondried seed on arrival. Also, the dried seed showed a vitality after 3 years 5 months' storage equal to the nondried after 7 months' storage.

TABLE 6.—*Germination of seed of 1932 crop of Chewings fescue forwarded from New Zealand in October 1932 and received November 17, 1932*

Sample No.	Foy's distinguishing mark	Transit storage	Moisture content on arrival [1]	New Zealand germination before shipment	Germination of seed						
					Nov. 22, 1932 (soon after arrival)	June 2, 1933 (after 7 months)	Sept. 6, 1933 (after 10 months)	Jan. 12, 1934 (after 14 months)	May 2, 1934 (after 18 months)	Jan. 15, 1935 (after 2 years 2 months)	Apr. 24, 1936 (after 3 years 5 months)
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
750945	BW	Hold storage	12.3	95	42	20	15	6	5	2	0
750948	AZ			97	58	26	14	10	7	2	1
750951	AH			98	77	42	23	17	10	7	1
750954	ND			97	40	17	7	6	3	1	0
750957	YB			96	71	60	32	32	23	9	0
750947	BW	Dried to 6 percent and stored in metal cans.	7.3	.....	87	81	75	68	66	47	25
750950	AZ				90	93	84	74	73	57	30
750953	AH				96	93	93	91	82	74	48
750956	ND				85	75	67	65	60	43	19
750959	YB				94	95	89	91	85	68	48
750960	TD	Hold storage	12.3	94	40	11	5	6	3	1	1
750963	TR			99	57	34	13	8	8	3	1
750966	EK			98	58	22	11	5	6	4	0
750969	OG			94	33	12	0	5	2	1	0
750972	ST			97	73	54	39	28	19	15	3
750962	TD	Dried to 6 percent and stored in metal cans.	7.3	.....	87	74	64	58	47	38	16
750965	TR				94	89	87	81	79	60	32
750968	EK				89	86	77	75	68	54	21
750971	OG				72	57	51	49	40	34	13
750974	ST				94	91	90	85	82	69	40

[1] Composite of 10 samples of each group.

Samples from a commercial shipment from New Zealand were received January 27, 1933, through a seedsman in the United States. Foy had dried some of the seed and put it in two paper-lined bags. In one bag he enclosed a control sample of dried seed in a tin container. The commercial concern drew four samples from the main shipment and sent them to this laboratory in tin cans and in paper bags, and also a sample in a tin can from each lined bag of dried seed. The samples were stored in the laboratory in the containers in which they were received. Moisture tests were made immediately on the samples sent in closed containers. The results of the germination tests are given in table 7. The seed that was dried before shipment showed a loss of 32 to 49 percent after being stored 22 months, while the bulk of the shipment not dried showed a loss of 51 to 63 percent.

TABLE 7.—*Germination of seed of Chewings fescue from New Zealand received through a seedsman in the United States, January 1933*

Sample No.	Shipment condition	Moisture content	Germination of seed						Loss in germination after 22 months
			Feb. 3, 1933	June 7, 1933	Oct. 20, 1933	Feb. 23, 1934	June 29, 1934	Dec. 6, 1934	
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
395100	Dried seed in paper-lined bag	9.5	79	69	58	53	43	30	49
395101	Control sample of dried seed in tin can	7.9	79	68	58	47	43	34	45
395299	Dried seed in specially lined bag	9.0	73	71	58	46	49	41	32
395102	Commercial shipment [1]	14.4	58	35	20	15	10	7	51
395103	....do.[1]	14.7	61	18	3	2	2	1	60
395104	....do.[2]		66	52	21	12	14	5	61
395105	....do.[2]		63	50	22	13	10	5	58
219218	Official sample from commercial shipments listed above		67	54	22	17	10	4	63

[1] Samples of 2 lots sent to laboratory from Chicago in tin cans.
[2] Samples of 2 lots sent to laboratory from Chicago in paper bags.

DOMESTIC SEED

HIGH AND LOW MOISTURE CONTENTS, 1934

An experiment with domestic seed of Chewings fescue was planned to determine the effect of moisture content and of temperature on longevity. The seed was collected in June 1934 from plantings at the Arlington Experiment Farm, Arlington, Va.; sample No. 1a from the 1932 planting and No. 9 from the 1933 planting. The moisture content at the time of harvest was approximately 10 percent. The seed was stored on July 23, 1934, in a cloth bag at room temperature, and in sealed jars in the five controlled temperature chambers. On September 7 the bulk at each temperature was divided, and the moisture of one part was raised to approximately 14 percent. Check moisture tests were made on all samples January 29, 1936. The results of the germination and moisture tests are given in table 8.

At 30° C., seed having the high moisture content lost 25 to 40 percent in germination after 4 months' storage, and after 5 months it had fallen to 6 and 22 percent, whereas the seed with the low moisture showed no loss. The low-moisture seed stored at 30° germinated 24 and 49 percent after 16 months' storage, which is better than the germination of the high-moisture seed after 5 months' storage. Seed stored with the low moisture content at 30° retained its vitality much longer than seed having the high moisture content stored at 20°, but lost its vitality more rapidly than seed having the high moisture content stored at 10°. The low-moisture seed stored at 20° showed a germination above 90 percent after storage for 2 years 2 months, as compared with the germination of 58 and 77 percent of the high-moisture seed stored at 10°. Seed having a moisture content of 12.5 percent retained a high vitality if kept at 2°, and seed having a moisture content of approximately 10 percent and below could be stored at temperatures as high as 20°.

TABLE 8.—*Germination of seed of Chewings fescue grown at Arlington, Va., with moisture contents of approximately 10 and 14 percent, stored at various temperatures*

Sample and date of germination test	Time in storage	Germination with a moisture content [1] of—										
		Approximately 10 percent						Approximately 14 percent				
		Laboratory cloth bag	30° C., sealed storage	20° C., sealed storage	10° C., sealed storage	2° C., sealed storage	−10° C., sealed storage	30° C., sealed storage	20° C., sealed storage	10° C., sealed storage	2° C., sealed storage	−10° C., sealed storage
No. 1a:	*Months*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
July 24, 1934	1	97										
Aug. 24, 1934	2	97	97	93	96	97	94					
Sept. 27, 1934	3	96										
Oct. 23, 1934	4	96	95	95	95	96	96	57	95	96		
Nov. 23, 1934	5	97	94	96	94	96	97	6	98	96	96	
Dec. 21, 1934	6		97					1				
Jan. 24, 1935	7		96	95				0	97			
Feb. 28, 1935	8	95	97	98	96	95	97	0	89	95	96	97
Apr. 23, 1935	10		93	94					74			
May 23, 1935	11		96	96					57			
June 24, 1935	12	94	85	97	95	95	94		31	95	93	94
July 25, 1935	13		81						22	96		
Aug. 30, 1935	14	93	72	94								
Sept. 24, 1935	15		64						3			
Oct. 24, 1935	16	93	54						0			
Nov. 30, 1935	17		49	97					0			
Dec. 21, 1935	18		39									
Jan. 29, 1936	19	89 (7.0)	28 (8.90)	98 (10.21)	95 (10.37)	97 (9.85)	97 (9.98)	— (14.77)	0 (13.52)	79 (12.96)	96 (12.76)	97 (12.47)
Feb. 29, 1936	20	93	27							86		
Mar. 30, 1936	21	92	7							76		
May 27, 1936	23		3							75		
June 27, 1936	24	91	4	95	94	96	96			68	93	92
July 30, 1936	25		4	95						65	93	
Aug. 24, 1936	26	89	1							61		
Sept. 24, 1936	27	90	0	93						58		
No. 9:												
July 25, 1934	1	93										
Aug. 24, 1934	2	95	95	93	96	96	97					
Sept. 29, 1934	3	96										
Oct. 23, 1934	4	96	95	98	95	95	97	67	96	97		
Nov. 23, 1934	5	96	96	97	97	97	97	22	95	97	96	
Dec. 21, 1934	6		97					3				
Jan. 24, 1935	7		95	96				0	87			
Feb. 28, 1935	8	98	94	98	96	95	97	0	77	97	97	97

Apr. 23, 1935	10		94	96					49			
May 23, 1935	11		90	96					38			
June 23, 1935	12	97	87	95	96	93	94		17	97	90	98
July 25, 1935	13		75						12	96		
Aug. 30, 1935	14	94	46	96								
Sept. 24, 1935	15		36						1			
Oct. 24, 1935	16	93	33						1		94	
Nov. 30, 1935	17		24	95					1			
Dec. 21, 1935	18		14						0	90		
Jan. 29, 1936	19	97 (6.91)	11 (9.22)	95 (10.18)	97 (10.17)	96 (10.08)	97 (10.21)		0 (13.22)	91 (13.01)	97 (13.04)	96 (12.69)
Feb. 29, 1936	20		3									
Mar. 30, 1936	21		1							94		
May 27, 1936	23		0							91		
June 27, 1936	24	96	1	97	97		97			86	90	96
July 27, 1936	25		0	97						80	95	
Aug. 24, 1936	26	93	0							79		
Sept. 24, 1936	27	91		95						77		

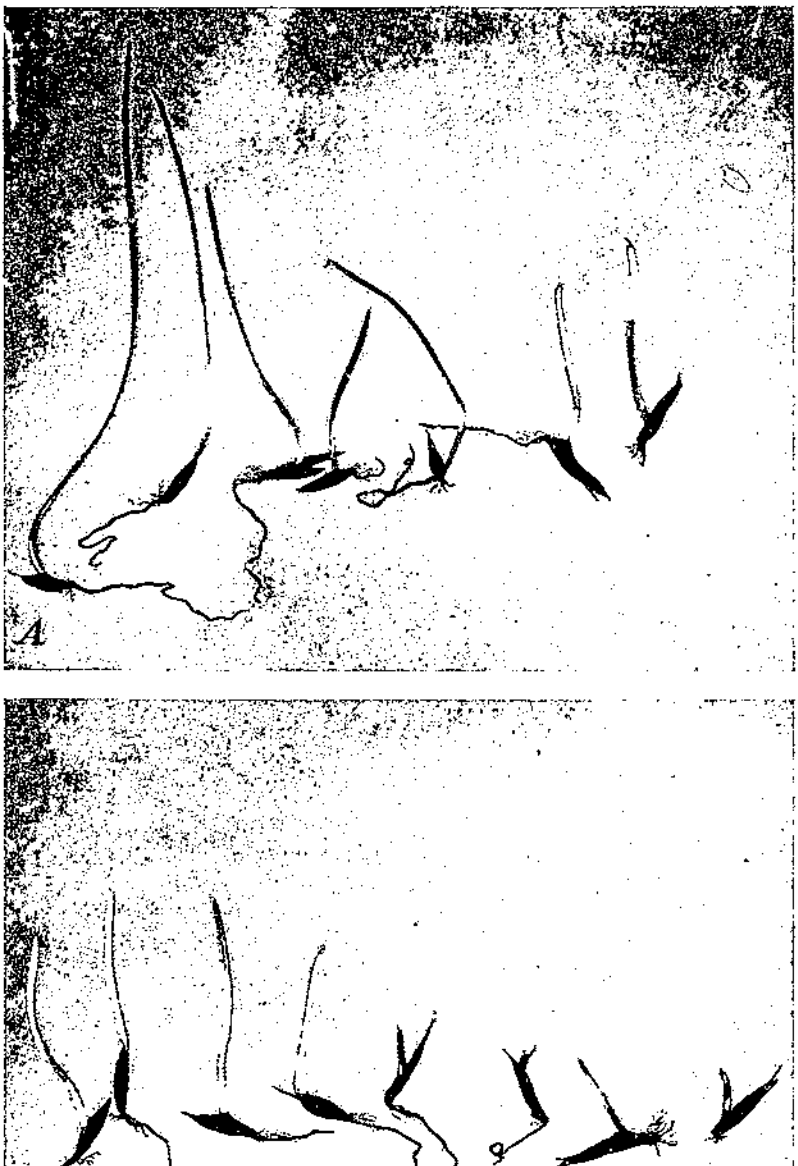
[1] Numbers in parentheses denote check of moisture percentage.

VARIOUS MOISTURE CONTENTS, 1935

A sample (No. 23b) of seed was collected June 20, 1935, from plantings at Arlington. The seed was allowed to dry out in the straw until July 11, 1935, before threshing. The purpose of the experiment was to determine in more detail the effect of moisture content and of temperature on the longevity of fescue seed. The seed was stored at room temperature until December 18, 1935. At this date the seed germinated 96 percent and contained approximately 8 percent of moisture. The moisture content of some of the seed was raised to approximately 10, 12, and 14 percent. The seed was stored in sealed jars at −10°, 2°, 10°, 20°, and 30° C., and the seed with a moisture content of approximately 8 percent was also stored in a cloth bag in the laboratory and in an unheated building at the Arlington Farm. The results of the 30° and 20° storage are given in table 9. On March 11, 1937, after nearly 2 years from time of harvest, the seed of each of the four moisture contents stored at −10°, 2°, and 10° and the seed with a moisture content of approximately 8 percent stored in a cloth bag in the laboratory and at the Arlington Farm showed no loss in germination. There was a decline in germination energy with seed having approximately 14 percent of moisture stored at 10°, but the results show no loss in germination capacity. The rate of fall in germination was directly associated with the percentage of moisture contained in the seed and the temperatures at which the seed was held. A moisture content of 12 percent and above was very detrimental to the life of the seed unless it was stored at a low temperature (2° or −10°). A temperature of 20° was on the border line for the storage of seed with a moisture content above 12 percent. Seed having a moisture content of 10 percent showed serious loss after 1 year's storage at 30°. These results are in agreement with the finding on samples Nos. 1a and 9.

In the loss of vitality of fescue seed, there was first a decrease in germination energy, then the progressive increase of abnormal germination made evident by watery or glassy sprouts, the development of coleoptiles without plumules, and the development of coleoptiles only, and last the persistence of only a few vigorous seed. Vitality of seed having a moisture content of 13 percent and above and stored at 30° C. fell too rapidly for abnormal growth to persist; but seed having a lower moisture content and stored at 30° or having a moisture content of 12 to 13 percent and stored at 20° died more slowly, so that stages in abnormal germination could be detected. Types of abnormal seedlings are shown in plate 1.

At the latter moisture contents and temperatures the changes that ultimately lead to death of the seed took place more slowly than with seed held at 30° C. with a high moisture content. Because of this, many stages in loss of vitality leading to various types of abnormalities were found. Some seeds were affected only in the vigor of their germination but produced normal plants. In other seeds one or more tissues had lost their power of development, causing the types of abnormal growth mentioned above which were not capable of continuing growth and forming plants. As may be seen in table 10, the amount of abnormal germination as well as the normal germination (table 9) varied greatly in tests made at weekly intervals and by the



Types of normal and abnormal germination of fescue seed. *A*, Five normal seedlings (at left) and two abnormal seedlings; *B*, additional types of abnormal germination encountered as the seed loses viability.

same methods on seed that loses its vigor slowly (for example, seed stored at 30° C. with a moisture content of 10 percent). It is difficult to interpret the true value of this type of sample. This difficulty leads to variation in results among analysts.

TABLE 9.—*Germination of seed of Chewings fescue (sample 28b), grown at Arlington, Va., and stored with different moisture contents at 30° and 20° C.*

Period of storage before germination tests (weeks)	Germination of seed—							
	Stored at 30° C.				Stored at 20° C.			
	Moisture 14 percent	Moisture 12 percent	Moisture 10 percent	Moisture 8 percent	Moisture 14 percent	Moisture 12 percent	Moisture 10 percent	Moisture 8 percent
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5	73	94	97	97	97	97	95	96
9	20	92	97	97	96			
10	9	93						
11	3							
12	2							
13	0	82	97	97	92			
14	1	89			93			
15		77			93			
16		78			95			
17		75			93			
18		70			92			
19		63			88			
20		57			92			
21		57			93			
22		55			88			
23		48	93		90			
24		41	95		87			
25		36			88			
26		31			81			
27		23			82			
28		25			85			
29		16			80			
30		11			81			
31		11			73			
32		11	94	95	77	96		
33		8			73			
34		6	90		68			
35		6	89		75			
36		4	86		68	94		
37		3	83		65	93		
38		2	88		65	95		
39		2	87		64	94		
40		2	89		62	93		
41		0	80		58	93		
42		1	77		57	94	95	
43		0	83		50	94		
44			81		54	95	96	
45			76		47	96	94	
46			75	92	46	91	97	95
47			74	91	41	93	93	
48			73	92	45	94	96	
49			68	94	42	96	96	
50			67	94	38	91	98	
51			69	95	30	89	96	
52			55	94	36	90	95	
53			55	94	37	89	97	
54			53		39			
55			51	94	33	91	97	
56			42	95	33	90	96	
57			51	96	23	91	96	
58			39	89	27	92	94	
59			32	94	26	85	96	
60			28	91	26	91	93	
61			44	95	27	90	96	
62			32	94	22	91	98	
63			25	92	21	92	95	
64			25	92	20	88	97	

TABLE 10.—*Occurrence of abnormal germination of seed of Chewings fescue (sample 23b) with different moisture contents, stored at 30° and 20° C.*

Period of storage (weeks)	Abnormal germination of seed—					
	Stored at 30° C.				Stored at 20° C.	
	Moisture 14 percent	Moisture 12 percent	Moisture 10 percent	Moisture 8 percent	Moisture 14 percent	Moisture 12 percent
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5	5	1			1	
9	3	1			1	
10	2					
11	3					
13		3	1		1	
14		3			1	
15		4			1	
16		4			0	
17		7			1	
18		6			2	
19		8			2	
20		10			1	
21		8			1	
22		11			1	
23		10	1		2	
24		12	2		1	
25		12			1	
26		10			4	
27		13			2	
28		10			3	
29		12			2	
30		10			5	
31		9			4	
32		8	1	1	4	
33		6			3	
34		3	3		7	
35		5	3		5	
36		2	4		7	
37		6	4		9	
38		4	6		6	1
39		3	6		7	
40		2	3		10	1
41		1	6		7	
42		0	12		6	1
43		1	10		10	1
44		0	10		11	
45			14		0	1
46			15	1	11	2
47			16	2	14	2
48			15	1	9	
49			19	1	11	1
50			22	1	14	1
51			17	1	11	2
52			23	1	14	3
53			29	0	13	3
54			22		6	
55			27	1	12	2
56			34	1	17	1
57			27	1	16	1
58			28	4	11	2
59			47	3	14	3
60			43	1	11	2
61			21	1	12	2
62			56	1	10	1
63			46	1	15	2
64			42	3	10	4

BEHAVIOR OF COLD-STORAGE SEED AT HIGH TEMPERATURES

In order to determine the effect of storage at low temperature on subsequent behavior at a higher temperature, seed (sample 23b) with moisture contents of approximately 8 and 14 percent was stored on December 18, 1935, at 2° C. for periods of 1, 2, and 4, and 6 months, after which it was transferred from the 2° chamber to the 20° and 30° chambers. The results are given in table 11. In a comparison of the two moisture contents the seed having approximately 8 percent moisture showed no loss in germination in 64 weeks from the original storage date when transferred from 2° to either 30° or 20° or when stored constantly at 30° or 20°. However, the seed having a moisture content of 14 percent showed a loss of germination when transferred to 30° or 20° C., but the rate of the fall in germination was much greater at 30° than at 20°. The fall in germination at 30° was equally rapid regardless of whether or not the seed had been previously held in cool storage. The rate of the decline in germination, dated from the time of transfer from 2°, was approximately equal in all samples. This confirms the results obtained on the storage at various conditions after arrival of seed from New Zealand (table 3), part of which was shipped under cool-storage conditions. There is an indication that seed transferred from cool storage to 20° loses more rapidly after transfer to the warm temperature than the seed stored at 20° from the beginning, although this has not been definitely determined. The germination at 30° fell too rapidly to detect a difference in the rate of fall.

DRYING SEED TO CHECK FALL IN GERMINATION

Some of the seed was removed from sealed storage with controlled moisture at various stages in its loss of viability and dried out at room temperature, to test the effect of quick drying on seed that was rapidly falling in germination capacity. Seed stored continuously at 30° C. and seed held in cool storage 1 and 2 months before placing in storage at 30° was transferred to paper bags at room temperature, where it was allowed to dry out. The results of tests of three samples (table 12) show that the seed fell rapidly in germination when held at a high temperature with a high moisture content, but when the seed was dried out at room temperature it maintained for almost 3 months the percentage of germination it showed at time of transfer. Tests were discontinued for a period owing to the small amount of seed, but when testing was resumed there had been some loss during the summer months, followed by a uniform germination for another 3 months. The rapid decline in germination of seed having a high moisture content can be checked if the seed is dried out.

TABLE 11.—*Germination of seed of Chewings fescue (23b) grown at Arlington, Va., having moisture contents of approximately 8 and 14 percent, stored at high temperature for various periods after cold storage for various periods*

Time after transfer to high temperature when germination was tested (weeks)	Germination of seed stored at 2° C. for period shown and then transferred to 30°										Germination of seed stored at 2° C. for period shown and then transferred to 20°									
	Moisture content approximately 14 percent					Moisture content approximately 8 percent					Moisture content approximately 14 percent					Moisture content approximately 8 percent				
	0 month; 13.79 percent moisture	1 month; 13.60 percent moisture	2 months; 13.74 percent moisture	4 months; 13.84 percent moisture	6 months; 12.92 percent moisture	0 month; 7.54 percent moisture	1 month; 7.44 percent moisture	2 months; 7.50 percent moisture	4 months; 8.11 percent moisture	6 months; 8.02 percent moisture	0 month; 13.73 percent moisture	1 month; 13.74 percent moisture	2 months; 13.84 percent moisture	4 months; 13.99 percent moisture	6 months; 12.96 percent moisture	0 month; 7.67 percent moisture	1 month; 7.59 percent moisture	2 months; 7.33 percent moisture	4 months; 8.03 percent moisture	6 months; 7.91 percent moisture
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0		95	99	97	98		97	98	98	99		98	97	96	96		97	97	98	97
1		95		96	97		97					95		97			97			
2		93	94	92	90		98					98					97			
3			87	85	87		97													
4		81	82	82	79			97				95	96				97			
5	73	71	71	66	58	97					97		95			96				
6		58	52	45	42								97							
7		45	35	28	23								94							
8		24	22	21	14		97					97	95							
9	20	14	14		10	97					96	94	94							
10	9	10	6	3	3							94	97							
11	3	3	5	2	2							94								
12	2	3	1	0	1							93								
13	0	0	0	0	0	97					92	94								
14	1	0	0	0	0						93	93								
15		0	0	0	0						93				90					
16		0									95				87					
17											93				85					
18											92				84					
19										98	88				86					
20											92				84					
21											93				83					
22											88				83					
23											90				79					
24											87				75					
25											88			76	78					
26											81			75	73					
27											82	76	67	68	70					
28											85	73	68	69	72					

29									97		80	75	66	64	71					
30											81	72	65	61	65					
31											73	74	65	55	66					
32						95					77	71	60	57	58					
33											73	69	57	49	63					
34											68	66	50	47	58					
35											75	58	55	47	60					
36											68	60	50	49	53					
37								94			65	55	39	43	51					
38											65	52	38	41						
39											64	52	36	35						
40								95			62	53	37	35						
41							96	97			58	45	34	33						
42							94	97			57	43	34	32						
43							93	94			50	44	31	33						
44							93	96			54	43	25	31						
45							93				47	40	27	31						
46						92	95	94			46	37	25	21		95				
47						91	96	96			41	33	19	21						
48						92	97	97			45	33	18							
49						94		96			42	37	22							
50						94	93	95			38	34	22							
51						95	95	96			39	29	17							
52						94	93	91			36	23	17							
53						94	92	95			37	28	15							
54							96	93			39	24	12							
55						94	93	95			33	22	10							
56						95	94				33	20								
57						96	94				23	20								
58						80	94				27	18								
59						94	93				26	21								
60						91					26									
61						95					27									
62						94					22									
63						92					21									
64						92					20									

TABLE 12.—*Germination of seed of Chewings fescue (sample 23b) grown at Arlington, Va., removed from sealed storage with controlled moisture of approximately 14 percent at various stages in its loss of viability, 1936*

Date of germination test	Seed stored at 30° C.		Seed stored at 2° C. 1 month, then at 30°				Seed stored at 2° C. 2 months, then at 30°			
	Check	Transferred to room Feb. 26	Check	Transferred to room			Check	Transferred to room		
				Feb. 26	Mar. 10	Mar. 18		Mar. 10	Mar. 17	Mar. 31
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Jan. 21	73		95							
Jan. 28			95							
Feb. 4			93							
Feb. 18	20		81				99			
Feb. 26	9		71							
Mar. 3	3	9	58	74			94			
Mar. 10	2	9	45	68			87			
Mar. 17	0	8	24	70	43		82	87		
Mar. 24	1	7	14	70	41	20	71	90	81	
Mar. 31		10	10	70	40	26	52	89	81	
Apr. 7		10	3	70	43	26	35	84	79	57
Apr. 14		8	3	71	45	25	22	92	81	61
Apr. 21		9	0	70	39	21	14	88	81	53
Apr. 29		6	0	65	42	23	6	85	83	56
May 5		8	0	69	39	23	5	90	78	59
May 12		10	0	70	48	23	1	90	85	55
May 19		11		72	47	27	0	87	85	55
May 26		10		72	40	29	0	86	81	53
June 2		9		68	41	28	0	90	83	64
Oct. 6		2		38	10	6		67	60	21
Nov. 5		3		40	16	9		66		21
Dec. 2		2		33	14	6		65		23

CONDITIONS APPROXIMATING COMMERCIAL STORAGE

In order to follow changes in viability and moisture content of seed stored more nearly as in commercial practice, Chewings fescue seed was obtained from the 1935 crop grown in Oregon. One peck was sent to each of the following places in September 1935: Hermiston and Corvallis, Oreg., Geneva, N. Y., and Arlington, Va.[1] The seed was stored in cloth bags in unheated buildings except at Corvallis, Oreg., where it was stored in a partially heated building until September 1936, when it was transferred to an unheated building.

A moisture determination and a germination test were made monthly on the four 1-peck lots. The results are given in table 13. From the results of March 1937, it would appear that all four samples were still of high germination value, but the samples stored at Geneva and at Arlington had lost considerably in germination energy. The 7-day readings for the October 1935 test and the January 1937 test, shown in table 14, may be taken as an index of the change of germination energy, since the rate at which the seed germinates is a measure of its vigor or germination energy.

The sample stored at Geneva had maintained a higher moisture content than the sample stored at Arlington, but the temperature was higher at Arlington.

[1] Acknowledgment is made to H. K. Dean, of the U. S. Umatilla Field Station, Hermiston, Oreg., Mrs. Grace Cole Fleischman, Oregon Agricultural College, Corvallis, Oreg.; and M. T. Munn, Division of Seed Investigations, New York State Agricultural Experiment Station, Geneva, N. Y., for providing storage and forwarding samples monthly.

TABLE 13.—*Germination and moisture content of 1935 crop of Oregon-grown seed of Chewings fescue stored in different States*

Date of test	Sample 758466 stored at Geneva, N. Y.		Sample 758463 stored at Hermiston, Oreg.		Sample 758464 stored at Corvallis, Oreg.		Sample 758465 stored at Arlington, Va.	
	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
September 1935			8.96	93	11.05	94		
October 1935	10.80	97	8.66	95	11.22	95	11.50	98
November 1935	12.40	95	8.75	96	9.22	96	11.48	96
December 1935	14.17	97	9.56	96	8.99	94	11.46	96
January 1936	15.22	96	9.59	95	9.36	95	12.30	97
February 1936	15.00	92	9.25	95	8.98	95	11.37	96
March 1936	14.29	97	13.64	96			11.21	97
April 1936	14.48	94	11.40	95	8.46	98	11.22	97
May 1936	13.65	93	9.61	94	11.73	97	10.53	96
June 1936	11.14	94	9.49	96	11.59	94	10.34	97
July 1936	10.51	80	7.18	88	11.60	80	10.78	95
August 1936	9.43	91	6.63	91	10.70	94	8.79	95
September 1936	11.27	91				94	10.54	96
October 1936	12.19	94	7.58	93	11.63	92	11.20	96
November 1936	13.24	90	7.73	94	12.34	92	10.80	96
December 1936	12.69	92	11.28	96	12.51	93	9.83	93
January 1937	13.30	91	12.63	94	15.53	92	11.27	94
February 1937	14.42	94	13.15	95	15.88	94	10.63	93
March 1937	13.75	91	12.05	95	17.31	94	10.25	92

TABLE 14.—*Germination in 7 days (indicating germination energy) of Chewings fescue seed stored under conditions approximating commercial practice*

Sample No.	Place of storage	Germination	
		October 1935	January 1937
		Percent	*Percent*
758463	Hermiston, Oreg	80	84
758464	Corvallis, Oreg	85	63
758465	Arlington, Va	73	26
758466	Geneva, N. Y	91	23

In order to have a laboratory check on the bulk storage, smaller quantities of the seed from Oregon were stored in a cloth bag and in a sealed jar at the controlled temperatures of 30°, 20°, and 2° C. and in the laboratory. The sample stored in a cloth bag in the laboratory had dried out to approximately 9-percent moisture and still showed a high germination in November 1936, but the germination of the seed stored in a sealed jar where the moisture was held practically constant at approximately 12 percent fell rapidly until it showed only 7-percent germination after 14 months of storage. At 30° C. the seed in a sealed jar held at the original moisture showed no germination after 5 months' storage, and after 14 months at 20° the germination had fallen 14 percent. Only at 2° did the seed stored in a sealed jar show practically no loss in germination. The seed stored in a cloth bag showed a loss of 31 percent at 30° and of 71 percent at 20° after 14 months. The greater loss at 20° was probably due to the higher humidity in this chamber. A check on the humidity of these two chambers over a period of a week during May 1936 showed for the 20° chamber a relative humidity of from 62 to 73 percent and for the 30° chamber a relative humidity of from 41 to 61 percent. The

TABLE 15.—*Germination and moisture content of 1935 crop of Oregon-grown seed of Chewings fescue (sample 758465), after storage under various conditions*

Date of test	Results under indicated conditions of storage															
	Laboratory				30° C.				20° C.				2° C.			
	In cloth bag		In sealed jar		In cloth bag		In sealed jar		In cloth bag		In sealed jar		In cloth bag		In sealed jar	
	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination	Moisture content	Germination
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
September 1935	11.26	97														
November 1935						95		90		96		96		98		97
December 1935		97		97		97		80		95		97		96		96
January 1936								15						98		
February 1936						95		1				95				
March 1936								0				96				
April 1936		96		88		93		0		91		92		97		98
May 1936				84		91				90		92				
June 1936				76		96				89		92				
July 1936																
August 1936																
September 1936		93		46						49		85				
October 1936		95		18		76		0		39		86		97		96
November 1936	9.27	93	12.00	7	8.11	66	12.71		12.82	25	12.22	82	10.07	95	12.12	95
December 1936										22		69				
January 1937				1		54										
February 1937									11.07		12.43					

moisture content of the seed stored in a cloth bag was not checked frequently, therefore it is difficult to compare these results with those from sealed storage. The loss at 30° was greater than would be expected from previous results, but it is probable that during part of the time the moisture of the seed was greater than 8.11 percent as indicated by the one test made. The results are given in table 15.

This experiment indicates that the artificial method of storage in sealed containers does not cause a more rapid deterioration of the seed than would be expected of seed under ordinary conditions at the same temperature and having the same moisture content. Sealed jars afford the only practicable means of maintaining a constant moisture content. The moisture content of the seed appears to be the critical factor in the longevity of Chewings fescue seed.

STORAGE OF FESTUCA RUBRA STRAINS

Seed of certain mixed commercial strains of *Festuca rubra* [10] was also tested. This seed was harvested at the same time Nos. 1a and 9 Chewings fescue were harvested. Germination tests were made monthly, and a check on the moisture content was made in January 1936. The results (table 16) show that this seed responded to the different storage conditions in the same way as Chewings fescue.

[10] KEARNS, VIVIAN, and TOOLE, E. H. See footnote 7.

TABLE 16.—*Germination of seed of Festuca rubra strains with moisture content of approximately 10 and 14 percent stored at various temperatures*

Sample No.	Date of germination test	Germination with indicated moisture content[1] and storage conditions									
		Laboratory, cloth bag	Moisture approximately 10 percent					Moisture approximately 14 percent			
			Sealed storage					Sealed storage			
			30° C.	20° C.	10° C.	2° C.	−10° C.	30° C.	20° C.	10° C.	2° C.	−10° C.
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
4a	July 24, 1934	96										
	Aug. 24, 1934	96	95	93	93	95	98					
	Sept. 27, 1934	97										
	Oct. 23, 1934	93	95	95	97	97	97	38	94	96		
	Nov. 23, 1934	98	95	95	95	94	96	0	93	95	97	
	Dec. 21, 1934		98					0				
	Jan. 24, 1935		96	96				0	89			
	Feb. 28, 1935	95	94	96	97	94	95	0	80	96	97	95
	Apr. 23, 1935		93	97					56			
	May 23, 1935		87	93					36			
	June 23, 1935	93	81	95	97	96	93		21	93	96	98
	July 25, 1935		76						12	95		
	Aug. 30, 1935	89	60	95								
	Sept. 24, 1935		49						1			
	Oct. 24, 1935	91	36						0			
	Nov. 30, 1935		32	96					0			
	Dec. 21, 1935		26									
	Jan. 29, 1936	93 (7.06)	19 (9.28)	94 (9.83)	95 (10.02)	93 (9.5)	95 (10.03)		0 (13.25)	89 (12.5)	98 (13.1)	94 (10.72)
	Feb. 29, 1936		13							88		
	Mar. 30, 1936		2							86		
	May 27, 1936		10							86		
	June 27, 1936	90	1	94	95	94	95			81	94	96
	July 30, 1936		2	96						80	94	
	Aug. 24, 1936	87	0							75		
	Sept. 24, 1936	88	1							73		
	Dec 2, 1936	83	0							67		
	July 25, 1934	96										
	Aug. 23, 1934	96	96	96	97	97	96					
	Sept. 28, 1934	97										
	Oct. 23, 1934	96	98	96	94	97	95	40	95	96		
	Nov. 23, 1934	98	96	97	97	95	95	0	96	97	98	
	Dec. 21, 1934		96					0				
	Jan. 24, 1935		97	98				0	85			

	Feb. 28, 1935	95	98	98	97	97	97	0	72	95	96	96
	Apr. 23, 1935		95	94					45			
	May 23, 1935		94	98					28			
	June 23, 1935	91	94	97	93	99	97		13	94	94	95
	July 25, 1935		92						11	96		
5a	Aug. 30, 1935	91	94	94								
	Sept. 24, 1935		91						2			
	Oct. 24, 1935	92	89						0			
	Nov. 30, 1935		90	95					4			
	Dec. 21, 1935		86									
	Jan. 30, 1936	93 (6.81)	84 (8.01)	95 (11.0)	98 (10.36)	97 (9.38)	96 (9.62)		[2] 0 (13.66)	94 (12.45)	98 (12.07)	97 (11.64)
	Feb. 29, 1936		83									
	Mar. 30, 1936		70									
	May 27, 1936		59									
	June 27, 1936	88	46	87	96	98	97			92	94	96
	July 27, 1936	87	43	87						89	94	
	Aug. 24, 1936	86	36	86						88		
	Sept. 24, 1936	85	36	78						91		
	Dec. 2, 1936	79	19	52	97					88		
	July 25, 1934	96										
	Aug. 24, 1934	95	93	96	93	94	95					
	Sept. 28, 1934	96										
	Oct. 23, 1934	89	94	95	92	94	95	87	97	94		
	Nov. 23, 1934	95	97	96	94	95	95	84	95	97	96	
	Dec. 21, 1934		98					77				
	Jan. 24, 1935		93	97				69	95			
	Feb. 28, 1935	92	93	96	95	95	96	66	92	97	93	95
	Apr. 23, 1935		91	98				58	90			
	May 23, 1935	88	95					54	84			
	June 23, 1935	93	86	97	99	95	94	41	87	93	97	95
	July 25, 1935		84						85	92		
6a	Aug. 30, 1935	89	76	94				29				
	Sept. 24, 1935		75					31	75			
	Oct. 24, 1935	91	61					25	68			
	Nov. 30, 1935		65	94				21	60			
	Dec. 21, 1935		49					28	63	90		
	Jan. 30, 1936	91 (6.73)	54 (8.44)	96 (10.03)	92 (9.92)	95 (9.96)	96 (9.59)	[2] 18 (8.60)	55 (11.09)	92 (11.89)	97 (11.98)	95 (10.75)
	Feb. 29, 1936		36						58			
	Mar. 30, 1936		22						51			
	May 27, 1936		12						37	91		
	June 27, 1936	86	13	91	94	94	97			82	94	95
	July 30, 1936	87	22	94						91	93	
	Aug. 24, 1936	83	3							92		
	Sept. 24, 1936	86	6							93		
	Dec. 2, 1936	83	4	96						88		

[1] Numbers in parentheses denote check of moisture percentage.
[2] No seed left for further test.

DISCUSSION

Loss of viability of fescue seed is directly associated with a high moisture content of the seed and a high temperature. It may be assumed that this general statement will hold for other kinds of seeds. Although the critical moisture and temperature conditions may vary somewhat for different kinds of seeds, it is believed that these results may serve as a general guide in determining suitable storage conditions for most kinds of seeds, until the detailed behavior of other kinds are determined.

The advantage of shipping seed under cool storage in oversea transit is lost a few months after entry into this country unless the seed is held in subsequent storage at a temperature as low as 2° C. or unless the seed is dried to a moisture content not exceeding 10 percent. Experiments on domestic seed having a moisture content of approximately 8 percent and 14 percent stored at 20° and 30°, and also at 2° for 1 to 6 months and then transferred to 20° and 30°, demonstrate this fact. The seed having a moisture content of approximately 8 percent showed no loss after 14 months of storage continuously at 20° or 30° or held in cold storage for various periods before subsequent storage at the higher temperatures. The seed having a moisture content of approximately 14 percent lost just as rapidly when transferred from cool storage to a higher temperature as when the seed was held constantly at a high temperature, but the rate of the fall was much greater when the seed was transferred to 30° than when transferred to 20°. Seed samples with a moisture content of approximately 14 percent stored at 2° for 1, 2, 4, and 6 months showed a germination of 95, 99, 97, and 98 percent on the day they were transferred to 30°; but 5 weeks from the date of transfer these samples showed a germination of 71, 71, 66, and 58 percent, respectively, a germination as low as or lower than the 73 percent shown at the end of 5 weeks by the seed held continuously at 30°. There is a slight indication that the seed held in cool storage and then transferred to 20° lost vitality in a shorter period, counting from the date of transfer, than the seed held constantly at 20°.

Checking the fall of germination by drying out on arrival of the seed shipped under cool storage found in the experiment on samples 751444–751446 was supported by the experiments on sample 23b. The seed with a high moisture content stored at a high temperature deteriorated rapidly, but if the seed was taken out and dried at room temperature it maintained a constant germination for approximately 3 months. Subsequent storage of samples shipped under cool storage conditions and of samples dried before shipment showed that seed dried before shipment arrived in as good condition as seed shipped in cool storage and that it had a longer life after receipt in this country. For example, samples 751444 and 751445 shipped under cool-storage conditions showed on arrival a germination of 81 percent, but after 4 months' storage in the laboratory with the original moisture content the seed was dead. Samples in the series 750945–750974, dried to 7.3 percent before shipment, showed on arrival a germination of from 72 to 96 percent, and after 2 years 2 months' storage in the laboratory with the original moisture content the seed still showed a germination of from 34 to 74 percent. Or, to compare within the same shipment, samples 750945–750974, the seed dried before shipment and kept dry

showed after 2 years 2 months' storage in the laboratory a germination about equal to the nondried seed on arrival.

The results of the test of domestic seed with moisture content varying from approximately 8 to 14 percent stored in sealed jars at temperatures of −10°, 2°, 10°, 20°, and 30° C. show the direct association of the moisture content of the seed and the storage temperature on the life of fescue seed. Fescue seed lost its vitality very rapidly at 30° if the moisture content was high. At this temperature the seed fell approximately 20 percent in germination in 5 weeks, 4 months, and 12 months at moisture contents of 14, 12, and 10 percent, respectively; the seed was practically dead in 3 to 5 months when the moisture was 14 percent and in 8 months at 12-percent moisture.

Fescue seed stored at 30° with a moisture content of approximately 10 percent retained its vitality much longer than seed having a moisture content of approximately 14 percent stored at 20°, but not as long as the seed having a moisture content of approximately 14 percent stored at 10°. However, seed having a moisture content of approximately 10 percent stored at 20° showed a germination above 90 percent after 2 years 2 months' storage, as compared with the germination of 58 and 77 percent for the seed having a moisture content of approximately 14 percent stored at 10°.

The moisture content of fescue seed stored at 30° should not exceed 8 percent, stored at 20° should not exceed 10 percent, and stored at 10° should not exceed 12 percent for long-time storage. Therefore, it is of no benefit to ship seed containing a high percentage of moisture under cool-storage conditions, because it will lose its vitality on arrival in this country as rapidly as the seed not shipped under cool storage, and the initial germination of such seed on arrival would only serve to mislead the trade. Seed that dies slowly goes through a period when a large percentage of sprouts develop abnormally during germination. These abnormal sprouts are worthless, since they would never develop to maturity. Their true value is very difficult to interpret, and they are of the type that cause controversy concerning the lack of uniformity of germination results among analysts.

SUMMARY

Chewings fescue (*Festuca rubra* var. *commutata*) seed shipped from New Zealand under different conditions and domestic seed of high viability were stored at different moisture contents and at a series of temperatures. The germination of the seed was determined at intervals. Domestic seed of commercial strains of *Festuca rubra* was tested in comparison with the seed of Chewings fescue.

The advantage of shipping seed under cool storage conditions in oversea transit was lost a few months after arrival in the United States unless the seed was held in subsequent storage at a temperature as low as 2° C. or unless it was dried out after arrival to a moisture content not exceeding 10 percent.

Seed dried before shipment overseas and kept dry showed after 18 to 26 months' storage in the laboratory at room temperature a germination equal to that shown by the nondried seed on arrival in this country.

Domestic seed in sealed containers stored at 30° C. with approximately 14-percent moisture lost 20- to 30-percent germination in 4 to 5 weeks; with 12-percent moisture this loss occurred in 4 to 5 months, and with 10-percent moisture in approximately 12 months.

With 8-percent moisture there was no appreciable loss in 1 year and 3 months.

Seed stored at 20° C. with approximately 14-percent moisture lost approximately 20 percent in 8 to 10 months; with 12-percent moisture the loss was less than 10 percent in 1 year 3 months, and with 10-percent moisture there was no appreciable loss in 2 years.

Seed stored at 10° C. with approximately 14-percent moisture showed 15 to 30 percent loss in germination in 2 years; with approximately 10-percent moisture the seed had shown no loss in the final germination in 2 years, but the rate of germination was slower.

The moisture content of fescue seed stored at 30° C. should not exceed 8 percent; at 20° it should not exceed 10 percent; and at 10° it should not exceed 12 percent for long-time storage. If the moisture content of the seed exceeds 10 percent it should be stored at a temperature below 20°, but if the moisture content of the seed is below 8 percent it may be stored safely at a temperature as high as 30°.

Seed that dies slowly showed at certain stages in its fall of germination a large percentage of sprouts which develop abnormally and are not capable of further development.

Seed having a moisture content of approximately 8 percent held in cold storage from 1 to 6 months before transferring to 20° and 30° C. showed no significant loss in germination after 14 months.

Seed having a moisture content of approximately 14 percent held in cold storage from 1 to 6 months lost in germination when transferred to 20° and 30° C. The fall in germination was much faster when the seed was transferred to 30° than when transferred to 20°. Seed having a moisture content of approximately 14 percent and stored at 30° fell rapidly in germination regardless of whether the seed had been held at 30° from the beginning or had been previously in cool storage. There is a slight indication that seed having a moisture content of approximately 14 percent and transferred from cool storage to 20° lost more rapidly than the seed stored at 20° from the beginning.

The rapid decline in germination of seed having a high moisture content was checked if the seed was dried out.

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