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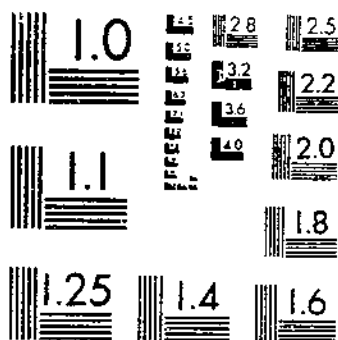
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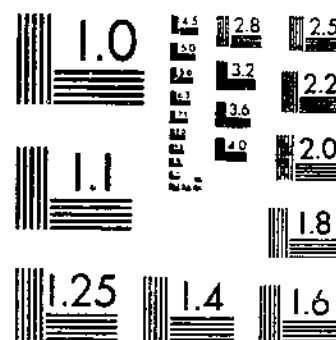
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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

TEMPERATURE AND OTHER FACTORS AFFECTING THE GERMINATION OF FESCUE SEED¹

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INTRODUCTION

A knowledge of the physiology of seed germination is fundamental to an understanding of the growth and development of plants and is essential as a basis of the formulation of the most desirable methods of determining the plant-producing value of seeds. Fescue seed was selected as a favorable subject for a determination of the effect of various factors on the process of germination as well as for a study of the most desirable method of determining the plant-producing ability of seed of differing previous history.

MATERIAL AND METHODS

The species of fescue used were (1) *Festuca rubra* var. *commutata* Gaud. (*F. fallax* Thuill., Chewings or New Zealand fescue), (2) certain mixed commercial strains of *F. rubra* L., (3) a variety or strain of *F. rubra* known commercially as creeping red fescue, (4) *F. capillata*

¹ Submitted for publication July 7, 1938.

DEPOSITORY

Lam. (hair fescue), (5) *F. elatior* var. *arundinacea* (Schreb.) Wimm. (commercially known as reed fescue), and (6) *F. elatior* L. (meadow fescue).

The seed was obtained from seedlings made at the Arlington Experiment Farm, Arlington, Va., in 1932, 1933, and 1934. Seed collected in 1934, 1935, and 1936 gives a series of data from plants 1 to 4 years old and comparative data on three different harvests.

The seed was collected at three different stages of maturity designated as immature, mature, and dead ripe. The immature seed was collected when the lemma and palea were still green and when the seed could be threshed out by hand only with difficulty. The mature seed was collected when the lemma and palea were turning yellow or brownish but before it had reached the shattering stage. The dead-ripe seed was collected when the lemma and palea were very brown and when some of the seed had already fallen. The immature seed was considered greener than a grower would harvest, the mature seed as at the optimum harvesting condition, and the dead-ripe seed as having passed the ideal harvesttime.

The seed was placed for germination on paper toweling saturated with tap water or with a 0.2-percent solution of potassium nitrate in Petri dishes. This substratum was chosen because it had previously been found that this method gave less variable results than other artificial media tried.² This was probably due to the fact that a more uniform moisture condition could be maintained at the various temperatures. Soil tests were not used because it would have been impracticable to handle as many tests in soil as with the described method. The senior writer previously found that the germination of Chewings fescue seed was not affected by the soil type used in the tests except that there was an indication of a decrease in germination at each extreme of the pH value used.² In all tests 4 replicates of 100 seeds each were used.

A series of tests was conducted at the constant temperatures of 10°, 15°, 20°, 25°, and 30° C. and at alternating temperatures including various combinations of these temperatures. The alternation was secured by transferring trays from one germination chamber to another. The temperature of the germination chamber was kept constant within one-half degree of the temperature given. The first temperature listed in an alternation is the one at which the seed was kept for approximately 18 hours daily; the last temperature mentioned was maintained for approximately 6 hours daily.

In the following discussion the optimum temperature for germination is considered as the temperature at which the seed germinated at the fastest rate and which gave the highest results.

The prechilled treatment was secured by placing the test with the seeds on the moistened substrata in Petri dishes at 5° C. for various lengths of time before placing at a higher temperature. The germination counts were dated from the time the test was placed at 5°.

No attempt was made to give the seed definite light exposures. However, all the tests were exposed to light during transfer from one chamber to another, while being counted, and from the electric lamps

² KEARNS, VIVIAN. THE GERMINATION OF *FESTUCA* spp., WITH PARTICULAR REFERENCE TO *FESTUCA RUBRA* FALLAX THUILL. Unpublished thesis, George Washington Univ. 1935

used to heat the chambers above 20° C. The effect of the total exclusion of light on germination was obtained by placing the Petri dish inside a tin box. The counts were then made in a dark chamber under a blue light.

Seeds were considered germinated when the root and shoot both had emerged sufficiently to indicate normal development. It is not safe to count the seed germinated when only the root, which normally comes first, has emerged, because the decline in vitality of fescue seed first shows up in the abnormal sprouts produced. Types of abnormal germination noted in the storage experiment (6)³ were (1) a normal root and a sheath but no plumule; (2) a normal plumule but no root; (3) a sheath only; and (4) a transparent, water-soaked plumule. Counts were made at 7-day intervals with the exception of a count made on the eleventh day.

FESTUCA RUBRA VAR. COMMUTATA

TEMPERATURE

The results of the tests conducted on immature, mature, and dead-ripe seed of *Festuca rubra* var. *commutata* (Chewings fescue) immediately after harvest and comparative tests made at a later date on some of the same samples are given in table 1.

Sample 23a was the only sample placed to germinate on the day collected, and it was the only sample that showed 10° C. to be the optimum constant temperature. This seed showed a decline in the maximum germination as the temperature was raised, giving 80-, 79-, 57-, and 3-percent germination as the temperature was raised from 10° to 15°, 20°, and 30°. When this same sample of seed was tested 2 months later 20° was the optimum constant temperature. With immature or mature seed from a few days to 2 weeks old (Nos. 41a, 21a, and 42a) 15° was the optimum constant temperature. Dead-ripe seed behaved approximately the same when placed to germinate at 10°, 15°, or 20°. Chewings fescue seed a few months after harvest gave practically complete germination at a constant temperature as high as 25°, but a very critical point was reached somewhere between 25° and 30°. Although the seed as it became older was less dormant when tested at 30° it never gave complete germination at this temperature. The indications are that immediately after harvest the optimum constant temperature may be as low as 10°, but as the seed becomes older the optimum temperature rises until 20° and possibly 25° is reached.

³ Italic numbers in parentheses refer to Literature Cited, p. 34.

TABLE 1.—Germination of seed of *Festuca rubra* var. *commutata* at various temperatures

Sample No.	Year seed sown	Year seed harvested	Condition of seed			Time of germination count	Germination at temperature of—										
			Stage of ripeness	Time in straw	Age 1		10° C.	15° C.	20° C.	25° C.	30° C.	10°-25° C.	15°-25° C.	10°-30° C.	25°-30° C.	15°-30° C.	20°-30° C.
							Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1a.....	1932	1934	Mature.....	24	33	7	77	47	0	0	07	45	13	41			
						11	93	72	1	1	04	84	44	87			
						14	94	80	1	1	06	87	73	92			
						21	94	86	2	2	07	95	87	95			
						28	94	90	2	2	07	96	96	95			
						7	0	92	72	7	13	89	73	58			
				24	38	11	29	07	90	16	98	05	92	93	90		
						14	81	07	93	19	98	06	93	97	95		
						21	85	07	95	20	98	06	93	98	96		
						7	0	15	7	15	15	15	15	15	0		
						11	6	69	38	68	80	65	85	90	92		
						14	46	86	93	90	92	92	92	92	92		
22a.....	1932	1935	do.....	0	4	21	54	56	59	56	90	85	80				
						28	56	59	56	90	85	80					
						7	0	71	72	90	85	80					
						11	24	75	81	92	90	85	80				
						14	56	81	82	92	90	85	80				
						21	64	81	82	92	90	85	80				
				0	68	28	67	81	6	0	21	2	2				
						7	0	10	6	0	21	2	2				
						11	51	86	66	94	91	88	58				
						14	51	93	76	97	95	88	85				
						21	75	93	76	97	95	88	85				
						28	75	93	76	97	95	88	85				
41a.....	1932	1936	do.....	14	16	7	0	28	26	2	36	9	9				
						11	84	94	84	95	97	97	70				
						14	84	94	84	95	97	97	70				
						21	90	96	90	97	97	97	70				
						28	91	96	90	98	98	98	98				
						7	0	80	44	0	64	39	29	61			
				6	8	11	94	73	0	0	91	83	79	91			
						14	95	80	1	1	93	90	92	95			
						21	95	87	2	2	93	96	95	95			
						28	95	90	8	8	93	96	95	95			
						7	0	95	83	15	63	93	81	74	79		
						11	97	93	28	07	95	95	95	97	95		
9.....	1933	1934	Mature.....	19-22	95-100	14	84	97	95	32	98	96	96	97	95		
						21	88	97	95	40	98	96	96	97	96		
						7	0	97	93	15	63	93	81	74	79		
						11	97	93	28	07	95	95	95	97	95		
						14	84	97	95	32	98	96	96	97	95		
						21	88	97	95	40	98	96	96	97	96		

21a	(*)	1935	Immature	0	3	7 11 14 21 28	0 50 79 83 83	10 71 88 95 97	7 32 45 67 71	0 3 4 7 10	5 75 89 95 95	12 77 91 90 99	0 21 47 92 95			2 20 34 78 94
21a				0	71	7 11 14 21 28	0 27 79 87 88	0 92 95 96 88	78 91 94 94 95	16 40 50 60 65	0 91 97 97 5	54 94 96 96 11	0 83 97 99 2			84 91 92 93 0
23a	1933	1935	Mature	0	0	7 11 14 21 28	0 45 67 80 80	6 65 73 79 79	6 24 33 52 57	0 0 1 3 3	5 58 84 100 100	11 70 95 99 100	2 14 31 51 95			7 23 61 86 86
23a				0	68	7 11 14 21 28	0 38 59 62 63	12 77 81 82 53	68 83 85 85 79	12 23 30 40 51	0 92 95 95 0	74 94 95 95 51	2 80 94 95 6			76 91 94 95 19
24b	(*)	1935	Dead ripe	0	1	7 11 14 21 28	0 91 92 93 93	0 97 97 97 95	61 84 90 93 95	8 22 34 46 57	2 95 96 96 4	95 97 97 98 70	8 94 95 96 4			93 97 98 98 19
24b				0	50	7 11 14 21 28	0 64 76 78 80	0 90 92 93 40	84 90 95 95 27	22 34 46 57 4	95 96 96 96 93	98 98 98 98 100	8 94 95 96 100			97 98 98 98 86
42a	1933	1936	Mature	14	16	7 11 14 21 28	0 63 65 67 67	40 89 94 94 94	70 72 72 73 73							93 93 96

¹ In this and other tables, age of seed represents period from harvesting to testing.

² Collected from seedlings made in 1932, 1933, and 1934.

Although a germination of 90 percent and above was often reached at the optimum constant temperature, the maximum germination was more consistently obtained and in a shorter time at an alternation of 15° to 25° C. Seed placed to germinate at the alternations 10° to 25° and 10° to 30° germinated at a much slower rate than at 15° to 25°, but the final percentage was about the same. Fresh seed given a longer period at a warm temperature (25° to 15°), a wider alternation (15° to 30°), or a warmer alternation (20° to 30°) germinated at a slower rate than at 15° to 25°, but this tendency disappeared as the seed became older. The 21-day results at 20° to 30° of samples Nos. 21a, 22a, and 23a show an increase in germination of 15 to 34 percent for the 68- to 71-day-old seed over the seed tested immediately or only a few days after harvest.

Twenty-one days appeared to be sufficient time for the germination of Chewings fescue seed when placed to germinate at 15° to 25° C., and in some cases 11 or 14 days were sufficient.

CHILLING

Chilling the moist seeds and then placing them at the optimum temperature for germination was neither beneficial nor harmful. However, seed given a previous cold treatment germinated at a higher temperature than seed not prechilled. In 1935, prechilling tests (table 2) were not started until the seed was approximately 2 months old and had passed the period of sensitiveness to a warm temperature alternation; therefore chilling showed no benefit when tested at 20° to 30° C. However, tests made in 1936, soon after harvest, the results of which are given in table 3, indicate that fresh seed germinates at a faster rate and in some cases more completely at 20° to 30° if it has been prechilled.

TABLE 2.—Germination of seed of *Festuca rudra* var. *commutata* when prechilled and transferred to a warm temperature, 1935

Sample No.	Condition of seed		Time of germination count	Germination at temperature of—					
	Stage of ripeness	Age		20°-30° C.		30° C.			
				Un-treated	7 days at 5° C.	Un-treated	7 days at 5° C.	14 days at 5° C.	
		Days	Days	Percent	Percent	Percent	Percent	Percent	
21a.....	Immature.....	71	11	91	16	40	18	.....
			14	92	97	50	78	.....
			21	93	97	60	87	.....
23a.....	Mature.....	68	11	91	71	23	38	.....
			14	94	94	30	66	.....
			21	95	94	40	75	83	
24b.....	Dead ripe.....	49	11	97	90	22	70	.....
			14	98	97	34	87	.....
			21	98	97	46	91	82	

TABLE 3.—Germination of seed of *Festuca rubra* var. *commutata* when prechilled and transferred to a warm temperature, 1936

Sample No.	Condition of seed		Time of germination count	Germination at 20°-30° C.	
	Stage of ripeness	Age		Un-treated	7 days at 5° C.
		Days	Days	Percent	Percent
41a.....	Mature.....	16	12	33	46
			14	58	70
			21	85	96
			28	88	96
41b.....	Dead ripe.....	8	12	51	56
			14	76	96
			21	95	96
			28	98	99
42a.....	Mature.....	16	12	64	73
			14	86	92
			21	93	97
			28	96	97

The seed germinated at the high constant temperature of 30° C. (table 2) much better if it had been prechilled. The final percentage of germination was raised from 60 to 87 percent, 40 to 75 percent, and 46 to 91 percent, in samples 21a, 23a, and 24b, by prechilling the seed at 5° for 7 days. A longer period of chilling was not any better. Seed placed to germinate at 30° with no prechilled treatment appeared to be held in a dormant condition, but this seed grew immediately if it was transferred to an optimum temperature for germination, or if it was taken out of 30° and given a cold treatment before placing back at 30°. Sample 21a placed to germinate at 30° germinated 33 percent with potassium nitrate and 10 percent with water in 35 days. This seed was then transferred to 15° to 25°, where the seed germinated an additional 65 and 85 percent, making the total percentage of germination 98 and 95 in 49 days. Sample 23a, which germinated 8 percent in 35 days (with water) at 30°, increased to 92 percent in 49 days when transferred to 15° to 25°. Sample No. 24b germinated 21 percent in 35 days at 30° and was then transferred to 5° for 16 days, then back to 30°, where it germinated an additional 74 percent, making a total of 95 percent. These results are not given in the tables.

POTASSIUM NITRATE

Potassium nitrate was used on seed collected when immature, mature, and dead ripe (samples 21a, 22a, and 24b). The use of potassium nitrate had little effect on the total germination, although it hastened the rate of germination; at 15° to 25° the results with water equaled the results with nitrate by the fourteenth day and at 20° to 30° by the twenty-eighth day (table 4).

TABLE 4.—*Effect of potassium nitrate on germination of seed of Festuca rubra var. commutata*

Sample No.	Condition of seed		Time of germination count	Germination at temperature of—			
	Stage of maturity	Age		15°-25° C.		20°-30° C.	
				With potassium nitrate	With water	With potassium nitrate	With water
		Days	Days	Percent	Percent	Percent	Percent
21a.....	Immature.....	3	11	86	77	29	20
			14	92	91	45	34
			21	97	89	83	78
			28	98	90	94	94
			35			95	95
22a.....	Mature.....	4	11	78	69	18	15
			14	86	86	44	38
			21	93	93	72	68
			28			82	80
			35			86	88
24b.....	Dead ripe.....	1	11	98	95	79	53
			14	98	97	92	78
			21	98	97	95	92
			28	98	97	95	94

LIGHT

Light does not seem to be essential for the germination of Chewings fescue when the seed is placed to germinate at a favorable temperature. Immature seed (21a) was retarded in rate of germination when light was totally excluded, but the final percentage of germination was approximately the same. Mature seed and dead-ripe seed did not show this retarded rate of germination in the dark at an alternation of 15° to 25° C. At 10° when light was totally excluded however, the immature and mature seed germinated at a slower rate, and the final percentage of germination was never as high as when light was not excluded. The results of effect of exclusion of light are given in table 5.

TABLE 5.—*Effect of exclusion of light on germination of seed of Festuca rubra var. commutata*

Sample No.	Condition of seed			Germination at temperature of—							
	Stage of ripeness	Age	Time of germination count	15°-25° C.				10° C.			
				Light excluded		Light not excluded		Light excluded		Light not excluded	
				With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water
		Days	Days	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
21a.....	Immature.	3	14	80	83	92	91	32	35	77	79
			21	83	89	97	99	43	58	86	83
			28	93	96	98	99	46	61	87	83
			35	94	96			52	66	89	84
23a.....	Mature.....	1	14	92	91	93	95			78	67
			21	99	92	99	99	60	54	84	80
			28	100	94	99	100	61	54	85	80
			14	97	100	98	97	93	91	97	92
24b.....	Dead ripe.	1	21	97		98	97	93	91	93	93
			28	97		98	97	93	91	95	93

FESTUCA RUBRA STRAINS

The *Festuca rubra* strains were secured from seed sown from imported commercial lots labeled as red fescue, sheep fescue, and hard fescue. J. R. Swallen, of the Bureau of Plant Industry, identified the plantings as probably *Festuca rubra* L., all being composed of mixed commercial strains. The 1934 harvest was grouped according to the name under which the original seed was imported. They all showed the same response in experiments conducted at various temperatures.⁴ In 1935 and 1936 the three strains were harvested together, but the seed from plantings of different years was kept separate.

The results on the seed from the 1935 harvest of the plantings made in 1932, 1933, and 1934 show that the age of the planting had no effect on the vitality of the seed. However, all the plantings had been cultivated and fertilized. The results are given in table 6.

TABLE 6.—Comparative germination of seed from three different plantings of *Festuca rubra* strains

[Seed harvested and threshed June 18, 1935; germination test begun June 21, 1935]

Sample No.	Year of planting	Germination at temperature of—					
		10° C.		15°-25° C.		20°-30° C.	
		With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water
		Percent	Percent	Percent	Percent	Percent	Percent
17a.....	1932	00	06	00	80	22	13
18a.....	1933	96	96	93	92	38	44
19a.....	1934	96	98	92	90	22	17

TEMPERATURE

The stage of maturity at which the seed was collected affected the germination behavior if the seed was germinated immediately but the after-ripening process was completed in storage (table 7). Immature seed (sample 16a), when germinated immediately, gave equally as good results at 10° C. or 10° to 25° but very low results at 20° to 30°. Owing to the lack of seed supply it was impossible to make further check on this seed. The constant temperature, 10°, was the optimum temperature for the germination of very fresh mature seed (sample 18a). At the constant temperatures the percentage of germination decreased as the temperature was raised. The percentage of germination in 21 days for 10°, 15°, 20°, and 30° was 95, 93, 29, and 0 percent, respectively. The alternating temperatures, 10° to 15°, 10° to 25°, and 15° to 25°, gave final results equal to those at 10°, but the rate of germination was slower. An alternating temperature of 10° to 30° or 20° to 30° was too warm for the germination of very fresh seed. When the seed was 45 days old, 20° gave quicker results than 10°, but the final results were approximately the same.

⁴ KEARNS, VIVIAN. See footnote 2.

TABLE 7.—Germination of seed of *Festuca rubra* strains at various temperatures

Sample No.	Year seed sown	Year harvested	Condition of seed			Time of germination count	Germination at temperature of—									
			State of ripeness	Time in straw	Age		10° C.		15° C.		20° C.		25° C.		30° C.	
							Pct.	Days	Pct.	Days	Pct.	Days	Pct.	Days	Pct.	Days
16a.....	(1)	1935	Immature.....	0	0	Days	11	68					50			3
						7	11						50			13
						14	21	81					50			28
						28	84						53			30
						35	85						59			30
						7	0	0	0	0	0	0	0	0	0	0
						11	74	25	2	0	59	29	20	3	0	0
16b.....	(1)	1935	.....do.....	12	12	Days	14	92	55	5	0	92	59	37	10	2
						21	97	93	15	0	99	91	82	46	7	7
						28	97	95	40		100	96	95	72	21	21
						35	97	96	57		100	98	97	81	38	38
						7	0		27				4		8	8
						11	14		79				63		49	49
16c.....	(1)	1935	.....do.....	12	56	Days	14	93		92			85		65	65
						21	97		96				96		81	81
						28	97		97				96		80	80
						35	97		97				96		94	94
						7	0		14				2		2	2
						11	2		78				52		26	26
						14	68		59				81		42	42
16c.....	(1)	1935	.....do.....	56	56	Days	21	83		94			90		93	93
						28	91		94				91		77	77
						35	91		94				91		83	83
						7	1	1	0			1	2	0	0	0
						11	64	49	5	0		22	30	2	0	0
18a.....	1933	1935	.....do.....	0	3	Days	14	88	75	9	0	52	51	9	8	8
						21	95	93	20	0		95	81	43	35	35
						28	96	95	19			98	92	75	44	44
						35	96	95	72			99	96	93	50	50
						7	0	0	76	1		64	30	6	36	36
						11	51	94	89	3		88	35	80	69	69
18a.....	1933	1935	.....do.....	0	45	Days	14	92	95	92	3		96	95	80	75
						21	96	95	93	3		96	97	94	85	85
						28	96	95	94	3		97	97	94	89	89
						35			94						92	92
						7	0	34	12			2	21		2	2
						11	80	89	28			78	69		6	6
38.....	1932	1936	.....do.....	12	15	Days	14	91	94	53			91	55		17
						21	94	96	77			95	93		39	39
						7	0	45	9			3	28		4	4
						11	80	93	25			83	70		15	15
39a.....	1933	1936	.....do.....	12	15	Days	14	97	95	54			96	87		30
						21	99	96	77			98	97		55	55
						7	0	33	11			3	24		3	3
						11	88	90	24			83	77		7	7
40.....	1934	1936	.....do.....	14	15	Days	14	96	97	50			95	87		19
						21	98	97	75			98	95		38	38

¹ Collected from seedlings made in 1932, 1933, and 1934.

The same lot of seed at different ages after harvest varied in its temperature response, as illustrated by sample 16b (table 7). At 10° C. the final germination was the same (97 percent in 21 days) for the tests made 12 and 56 days after harvest; but at 20° the fresher seed germinated only 57 percent in 35 days while the older seed germinated 97 percent, the latter result being equal to that at 10° on fresh seed. However, the rate of germination was even more striking. The 12-day-old seed germinated at a faster rate at 10°, while the 56-day-old seed germinated at a faster rate at 20°. The seed (16c) that remained in the straw 56 days gave comparable results with the 56-day-old seed that remained in it only 12 days. Although the final results at 20° to 30° are equally as good as at 15° to 25° for 2-month-

old seed, the seed at 15° to 25° germinated 96 percent in 21 days, while that at 20° to 30° germinated 81 percent, taking an additional 2 weeks to reach 94 percent. The results of the germination test made on mature seed from the 1936 harvest when the seed was approximately 2 weeks old showed a little higher temperature (15°) as the optimum constant temperature and 10° to 25° as the optimum alternating temperature (table 7).

The seed appeared to after-ripen as well when it was collected at a mature stage and threshed out immediately as when the seed was left on the plant until it was dead ripe or when it was collected at a mature stage and allowed to remain in the straw.

CHILLING

To chill the seeds and then place them at an optimum condition for germination was of no benefit, but prechilled seeds were able to withstand a higher germination temperature. The effect of prechilling sample 18a was not tried until the seed was 57 days old (table 8), when the seed had after-ripened sufficiently to germinate 93 percent at 20° to 30° C. without prechilling. However, the seed prechilled for 1 day and transferred to 20° to 30° germinated more rapidly than without prechilling. Although at this age the seed was less sensitive to 25° than when fresh, the germination was increased from 67 percent to 97 percent by prechilling for 7 days. At 30° the germination was increased from 8 percent to 95 percent by prechilling for 6 days and at 35° increased from 1 percent to 73 percent by prechilling for 14 days. Except for the inconsistency for the prechilling 7 days and 14 days to 30°, it might be concluded that the period of prechilling should be lengthened as the germinating temperature is raised.

TABLE 8.—Germination of seed of *Festuca rubra* strains when prechilled and transferred to a warm temperature

(Sample No. 18a tested 57 days after harvest)

Time of germination count (days)	Germination at indicated temperature of—									
	20°-30° C.					35° C.				
	Untreated	1 day at 5° C.	5 days at 5° C.	7 days at 5° C.	14 days at 5° C.	Untreated	1 day at 5° C.	5 days at 5° C.	7 days at 5° C.	14 days at 5° C.
7.....	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
10.....	53	68	0	0	0	0	0	0	0	0
14.....	77	90	78	56	0	0	0	0	0	0
17.....	91	95	94	98	0	1	1	21	43	0
21.....	92	95	95	98	80	1	1	22	47	68
28.....	92	96	95	98	96	1	1	23	47	73
35.....	93	97	95	99	96	1	1	23	47	73
						1	1	23	47	73

TABLE 8.—Germination of seed of *Festuca rubra* strains when prechilled and transferred to a warm temperature—Continued

Time of germination count (days)	Germination at indicated temperature of—													
	30° C.								25° C.					
	Untreated	1 day at 5° C.	2 days at 5° C.	3 days at 5° C.	5 days at 5° C.	6 days at 5° C.	7 days at 5° C.	14 days at 5° C.	Untreated	1 day at 5° C.	5 days at 5° C.	7 days at 5° C.	14 days at 5° C.	
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	
7.....	1	7	23	38	3	0	0	0	17	56	0	0	0	
10.....	2	14	38	70	86	60	41	0	32	72	86	78	0	
14.....	3	15	42	74	80	93	81	0	37	77	92	96	0	
17.....	3	17	43	75	80	95	82	74	41	78	92	96	57	
21.....	3	18	46	75	83	95	83	57	45	80	92	97	95	
25.....	3	19	40	75	83	93	82	60	85	92	97	97	95	
35.....	3	21	40	76	83	95	82	67	86	93	97	97	95	

POTASSIUM NITRATE

Tests were conducted with potassium nitrate on samples 16b and 18a, the results of which are not given in the tables. They showed that potassium nitrate was of no benefit if the seed was placed to germinate at a favorable temperature. On very fresh seed potassium nitrate appeared to overcome to some degree the detrimental effect of unfavorable temperatures. The most striking results were obtained at 20° C., where the germination was increased from 57 percent to 80 percent and from 72 percent to 83 percent by the use of potassium nitrate. No germination was obtained, however, at 30° with or without the use of potassium nitrate.

LIGHT

The exclusion of light had no effect on the final germination either at 15° to 25° C. or at 10°, but it tended to retard the rate of germination at 15° to 25°, as shown by the results with sample 18a given in table 9.

TABLE 9.—Effect of total exclusion of light on germination of seed of *Festuca rubra* strains, sample 18a

Time of germination count (days)	Germination at temperature of—							
	15°-25° C.				10° C.			
	Light excluded		Light not excluded		Light excluded		Light not excluded	
	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
14.....	63	43	62	51			93	83
21.....	83	82	88	81	99	96	96	95
23.....	97	87	93	92	99	95	96	96
35.....	97	91	94	96	99	95	96	96

CREEPING RED FESCUE

TEMPERATURE

In tests of seed of the variety or strain of *Festuca rubra* known commercially as creeping red fescue, mature seed tested when approximately 1 month old (sample 10) and seed collected at a dead-ripe stage and tested immediately (sample 35b) were the only samples that gave practically complete germination at a constant temperature. Immediately after harvest the seed changed rather quickly in its response to temperatures. Sample 31a was tested when the seed was 4 and 5 days old. At 10° C. the 4-day-old seed germinated 54 percent with the use of potassium nitrate and 42 percent with water, and the 5-day-old seed 70 percent with the use of potassium nitrate and 65 percent with water. The change in response at 20° was just as striking as at 10°.

The alternating temperature, 15° to 25° C., was the optimum temperature for germination. Although the final results at 10° to 25° were equal to the results at 15° to 25°, the germination rate was much slower. The results at the higher alternations were very low except with the seed of sample 10, tested when it was approximately 3 months old. At this time practically complete germination was obtained both at 15° to 30° and at 20° to 30°.

All the samples tested soon after harvest showed a germination of approximately 50 to 55 percent at 20° to 30° as compared to approximately 95 percent at 15° to 25°. The results are given in table 10.

TABLE 10.—*Germination of seed of creeping red fescue at various temperatures*

[illegible]

CHILLING

Chilling the seed before placing it at 15° to 25° C. for germination was of no benefit. However, the chilling of fresh seed before placing it at 20° to 30° overcame the sensitiveness to this high temperature, resulting in an increase of germination ranging from 16 to 43 percent (table 11).

TABLE 11.—Germination of seed of creeping red fescue when prechilled and transferred to a warm temperature

Sample No.	Age of seed	Time of germination count	Germination at 20°-30° C.		
			Untreated	7 days at 5° C.	14 days at 5° C.
	Days	Days	Percent	Percent	Percent
35b.....	1	11	34		
		14	55		
		21	73		95
		28	81		97
48.....	8	14	13		
		21	27		77
		28	41		84
		14	16	46	
49.....	2	21	42	70	68
		28	55	84	80

LIGHT

The exclusion of light from seed of creeping red fescue was not detrimental to germination when the seed was placed at the optimum temperature for germination (table 12). At 10° C., with immature seed, the germination was much lower in complete darkness, but the slightly immature and dead-ripe seed did not show this difference.

TABLE 12.—Effect of exclusion of light on germination of seed of creeping red fescue

Sample No.	Condition of seed		Time of germination count	Germination at temperature of—								
	Stage of ripeness	Age		10° C.				15°-25° C.				
				Light excluded		Light not excluded		Light excluded		Light not excluded		
				With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	
				Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
31a.....	Immature.....	5	Days	14	0	1	61	51	68	73	69	78
			Days	21	49	18	70	65	91	89	91	98
			Days	28	51	22	71	68	91	96	97	99
			Days	35	54	26	72	68	91	97	97	99
			Days	14	59	59	62	42	70	88	78	73
31c.....	Slightly immature.	4	Days	21	61	64	69	46	93	92	93	96
			Days	28	65	65	71	48	97	96	94	97
			Days	35	67	66	71	49	97	97	94	97
			Days	7			19	15	61	31	49	36
			Days	14	92	97	98	93	96	93	97	90
35b.....	Dead ripe...	1	Days	21	93	98	98	94	97	90	98	94
			Days	28	93	98	98	94	97	98	99	97

FESTUCA CAPILLATA

TEMPERATURE

In the tests of seed of *Festuca capillata*, at constant temperatures the highest germination was at 10° C., but maximum germination was not obtained at any constant temperature except with samples 43b and 28b, which were dead ripe when harvested. The germination of all samples decreased as the temperature was raised.

An alternation of 20° to 30° C. gave as low germination results as 20° for freshly harvested seed, regardless of the stage of ripeness when collected. Tests conducted at 20° to 30° and at 20° resulted in approximately 15-percent germination. An alternation of 10° to 25° was the optimum temperature for germination. At this alternating temperature, in 35 days sample 25a gave 92-percent germination with potassium nitrate and 73 with water, and sample 27a gave 88 percent with potassium nitrate and 76 with water. The tests with potassium nitrate resulted in practically complete germination, and the results with water were much higher than those at any other temperature. In all cases with freshly harvested seed 10° to 25° produced quicker and more nearly complete germination than 15° to 25°. In the few cases tried it would appear that an alternation of 10° to 30° was more promising than 15° to 25°. Considering the comparatively high germination at 10° constant, it would seem that, for freshly harvested seed, a satisfactory alternation should include 10°. The complete results are given in table 13.

Tests made at a later date on samples 25a, 27a, and 28b showed a decided change in response to the temperatures, especially the constant temperatures and the warm alternating temperature 20° to 30° C. Immature seed (25a) showed a higher germination at 10° 6 months after harvest than when tested immediately after harvest, but maximum germination was not obtained at either time. The greatest change in response to the constant temperatures was at 15° and 20°. At 15° the seed (25a) germinated 16 percent in June and 84 in November; at 20°, 1 percent in June and 78 in November. This seed appeared to be dormant when placed to germinate at 20° to 30° in June, giving only 4-percent germination in 35 days. In November the seed germinated 90 percent at 20° to 30°.

The same change in response to the temperatures applied also to the mature seed (27a) and to a lesser extent to the dead-ripe seed (28b). The results given in table 14 show that the dead-ripe seed, although sensitive in its temperature response, was less sensitive than the immature or mature seed. However, the mature seed in June and the dead-ripe seed in July did not germinate at 30° C. but germinated respectively 31 and 35 percent in 28 days in the November test. In November the best results at constant temperatures were obtained at 15°, the percentage of germination decreasing as the temperature was raised to 30°. The greatest difference in results was between 30° and 25°. But for either of the three stages of maturity, tested immediately after harvest, the highest germination was at 10°, decreasing as the temperature was raised.

TABLE 13.—Germination of *Festuca capillata* at various temperatures

Sample No	Year seed sown	Year harvested	Condition of seed			Time of germination count	Germination at temperature of—															
			Stage of ripeness	Time in straw	Age		10° C.		15° C.		20° C.		30° C.		10°-25° C.		15°-25° C.		10°-30° C.		20°-30° C.	
							With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water
			Days	Days	Days	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		
3a	1932	1934	Mature	25	32	11 14 21 28 35 42	0 31 21 28 35 42	2 15 66 61 64 65					16 28 38 42 43	0 0 0 0 0			0 1 1 18 42 63 82 91	45 66 81 88 88 89			14 28 46 67 81	
26a	1932	1935	do	0	1	11 14 21 28 35 42 49	6 31 21 28 35 42 49	2 15 66 61 64 65 65									0 1 2 18 42 63 82 91	16 45 66 81 88 88 89				
43a	1932	1936	do	14	17	11 14 21 28 35 42	8 50 69 74 74 75	5 28 49 54 55 55	19 37 57 65 65 65	8 25 44 51 52 52	0 3 8 14 23 29	1 1 1 3 3 11			21 55 87 89 89	11 49 78 83 85	16 33 53 68 75	6 20 38 65 75			1 1 1 4 9 18	
43b	1932	1936	Dead ripe	6	10	11 14 21 28 35 42	24 57 87 92 92 92	16 41 70 79 80 80	21 38 59 63 63 63	13 32 51 57 58 58	3 7 10 18 33 33	1 2 4 7 13 13			10 46 86 90 92 12	11 50 76 80 83 80	12 40 68 89 88 10	21 40 69 77 78 5			1 2 5 10 16 22	
44	1933	1936	Mature	14	18	11 14 21 28 35	24 44 48 48 48	14 29 34 43 35	21 39 43 44 34	14 30 33 34 34	0 2 3 5 5	0 0 0 0 0			61 86 87 89	36 65 72 74	22 47 67 76	15 38 52 65			1 3 5 10	

TABLE 13.—Germination of *Festuca capillata* at various temperatures—Continued

Sample No.	Year seed sown	Year harvested	Condition of seed			Time of germination count	Germination at temperature of—															
			Stage of ripeness	Time in straw	Age		10° C.		15° C.		20° C.		30° C.		10°-25° C.		15°-25° C.		10°-30° C.		20°-30° C.	
							With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water
Days	Days	Days	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		
25a	(1)	1935	Immature	4	4	11	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	
						14	5	2	2	0	0	0	0	0	6	3	4	2	0	0	0	0
						21	34	14	7	1	0	0	0	62	48	25	11	5	1	1	1	1
						28	47	21	15	13	1	1	1	0	86	66	60	26	27	3	4	4
						35	56	23	16	16	1	1	0	0	92	73	83	53	57	10	8	8
						42	58	25	17	18	1	1	0	0	95	75	86	58	74	19	13	13
						49	63	26	18	22	1	1	0	0	95	77	90	64	82	25	0	0
						11	5	3	1	0	0	0	0	0	1	0	2	0	0	1	0	0
						14	18	9	4	1	0	1	0	0	9	6	3	1	0	0	1	0
						21	66	43	19	11	1	1	0	0	67	48	22	16	13	10	2	0
27a	1934	1935	Mature	0	1	28	72	54	37	19	6	1	0	0	83	71	44	31	53	38	4	
						35	74	56	41	20	6	1	0	0	88	76	62	41	79	62	8	3
						42	74	57	41	20	7	2	0	0	90	79	77	50	87	77	13	5
						49	75	57	42	20	8	2	0	0	91	80	87	65	90	84	22	9
						11	55	46	25	11	5	0	0	0	0	0	32	27	4	0	0	0
						14	62	50	11	20	10	0	0	0	0	0	43	42	20	5	3	3
						21	85	74	59	30	16	0	0	0	0	0	66	70	38	17	11	11
						28	87	77	60	31	20	0	0	0	0	0	78	82	67	24	19	19
						35	87	77	67	32	20	0	0	0	0	0	80	84	74	27	31	31
						11	7	2	8	7	1	1	0	0	12	11	10	12	0	0	0	0
28b	(1)	1935	Dead ripe	0	1	14	23	15	26	18	2	3	0	0	70	50	31	22	0	2	1	
						21	42	26	42	29	4	4	0	0	88	77	62	39	0	6	2	2
						28	45	29	40	24	8	4	0	0	90	79	74	56	0	18	8	8
						35	48	29	46	25	15	7	0	0	90	81	51	61	28	28	13	13
45a	1934	1936	Mature	14	18	11	7	2	8	7	1	1	0	0	12	11	10	12	0	0	0	
						14	23	15	26	18	2	3	0	0	70	50	31	22	0	2	1	1
						21	42	26	42	29	4	4	0	0	88	77	62	39	0	6	2	2
						28	45	29	40	24	8	4	0	0	90	79	74	56	0	18	8	8
						35	48	29	46	25	15	7	0	0	90	81	51	61	28	28	13	13

1 Collected from seedlings made in 1932, 1933, and 1934.

TABLE 14.—Relation of age to the germination temperature response of seed of *Festuca capillata*

Sample No.	Condition of seed				Time of germination count	Date of germination test	Germination at temperature of—																	
	Stage of ripeness	Time in straw		Time of germination count			10° C.		15° C.		20° C.		25° C.		30° C.		10°-25° C.		15-25° C.		10°-30° C.		20°-30° C.	
		Days	Age				With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water
		Days	Days	Days		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		
25a	Immature	4	4	11	June 21, 1935	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0		
				14		5	2	2	7	0	0	0	0	0	0	6	3	4	1	0	0	0		
				21		34	14	14	0	0	0	0	0	0	0	62	48	25	11	0	0	1		
				28		47	21	15	1	1	0	0	0	0	0	86	60	60	26	27	5	4		
				35		50	23	16	1	1	0	0	0	0	0	93	73	83	53	57	0	1		
				11		5	6	77	65	77	66	0	0	0	0	62	52	88	85	24	14	79	70	
27a	Mature	0	144	21	Nov. 8, 1935	60	48	91	82	84	78	0	0	0	0	95	94	94	92	96	93	91		
				28		63	52	91	83	85	78	0	0	0	0	98	94	95	92	97	96	91		
				35		65	52	91	84	85	75	0	0	0	0	96	95	95	92	97	97	91		
				11		5	3	1	0	0	0	0	0	0	1	0	2	0	0	0	1	0		
				14		18	9	4	1	1	1	0	0	0	0	0	0	3	1	0	0	1	0	
				21		66	43	10	11	1	1	0	0	0	0	67	48	22	16	13	10	2	0	
28b	Dead ripe	0	1	28	July 10, 1935	72	54	37	19	6	1	0	0	0	0	83	71	44	31	53	38	4		
				35		74	56	41	20	6	1	0	0	0	88	76	62	41	79	62	8	3		
				11		11	14	88	79	78	77	00	59	30	26	84	80	91	83	71	54	82	78	
				14		57	39	89	82	81	79	70	05	32	28	93	84	91	84	84	81	84	81	
				21		66	44	89	82	81	80	70	08	35	31	94	80	92	85	88	86	87	82	
				28		68	45	90	82	81	80	71	08	35	31	94	86	94	86	88	88	87	83	
28b	Dead ripe	0	123	35	Nov. 9, 1935	69	46	90	82	81	80	71	08	36	32	94	86	94	86	88	88	87		
				11		55	46	25	11	5	0	0	0	0	0	0	32	27	4	0	0	0		
				14		62	56	41	20	10	0	0	0	0	0	0	43	42	20	5	3	3		
				21		85	74	50	30	16	0	0	0	0	0	0	66	70	38	17	11	11		
				28		87	77	60	31	20	0	0	0	0	0	0	78	82	67	24	19	19		
				35		87	77	67	32	20	0	0	0	0	0	0	80	84	74	27	31	31		
28b	Dead ripe	0	123	11	Nov. 9, 1935	62	72	81	83	78	81	02	52	39	16	83	79	83	81	74	71	77		
				14		75	73	82	84	79	81	06	58	42	22	83	79	83	81	78	70	79	78	
				21		77	76	84	84	79	81	08	61	50	32	81	79	85	81	81	78	80	77	
				28		78	75	84	84	79	81	08	65	50	35	84	82	85	81	81	78	80	77	
				35		79	76	84	84	79	81	08	68	50	36	84	82	85	81	81	78	80	77	
				11		62	72	81	83	78	81	02	52	39	16	83	79	83	81	74	71	77	75	

With seed approximately 5 months old, maximum germination was obtained at a wider range of alternating temperatures, and with the older seed either 10° to 25° or 15° to 25° may be considered to be the optimum temperature for the germination of *Festuca capillata*.

The seed of this species germinated more slowly than that of the other species under consideration. A period of 28 days was required for practically complete germination of after-ripened seed and a longer period when the seed was fresh.

EFFECT OF STORAGE TEMPERATURE ON GERMINATION TEMPERATURE

Seed kept in cold storage appeared to be held in a dormant condition. Table 15 gives the results of a temperature series made in November 1935 on *Festuca capillata* after the seed had been stored for 17 months in the laboratory in a cloth bag and in sealed jars at 30°, 20°, 10°, 2°, and -10° C. The July and September (1934) tests on the laboratory-stored seed are given for comparison. The July test (the first after harvest) was made when the seed was approximately 1 month old. The September test was made when the seed was approximately 3 months old.

As shown in the previous experiment, the seed is more tolerant of a high constant temperature as it becomes older. Also, in this experiment the germination of the laboratory-stored seed (3a) when tested at 30° C., increased from 0 percent for 1-month-old seed to 69 percent for 17-month-old seed. Seed stored at 30° germinated approximately the same as the laboratory-stored seed, 63 percent, and it is striking that this seed showed a higher germination when placed to germinate at 30° than any of the seed stored at a lower temperature. The lower the temperature at which the seed was stored the larger the percentage of seed remaining dormant when placed to germinate at 30°. Seed stored at -10° and 2° showed no germination in 28 days at 30°, but seed stored at 10° germinated 26 percent and that stored at 20°, 57 percent in the same number of days. The test carried on at 30° for 35 days was then transferred to the 15° to 25° alternation, where the greater part of the remaining seeds germinated, showing that they had been held dormant and not killed by the high temperature. The same dormancy response was shown when the seed was placed to germinate at 20° and 25°, although to a lesser degree. The results from the November test of the -10° and 2° storage seed were more comparable to the June test of the laboratory-stored seed, made when the seed was comparatively fresh, than to the November test. In November the -10° seed germinated 2 and 34 percent at 25° and 20°, which checks closely with the 8 and 42 percent obtained in the June test, but not with the 80 and 81 percent of the November test of the laboratory-stored seed. The 2° storage showed the same response to 25° and 20°, but to a lesser extent. It is interesting to note that within a storage condition the seed showed about the same percentage of germination at the alternating temperatures with the exceptions of 5° to 15° and 20° to 30°. The 5° to 15° was apparently too cool an alternation for the germination of any of the seed, regardless of where it had been stored, and 20° to 30° was too warm for seed that had been held in storage at a temperature as low as 2° or -10°.

TABLE 15.—Relation of storage temperature to germination temperature of seed of *Festuca capillata* (sample 3a)

Storage conditions	Date of germination test	Time of germination count	Germination at temperatures of—																			
			10° C.		15° C.		20° C.		25° C.		30° C.		5°-15° C.		10°-25° C.		15°-25° C.		10°-30° C.		20°-30° C.	
			With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water
		Days	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Fresh.....	July 23, 1934	14					28		4		0						66				28	
		28					42		8		0						88				67	
Laboratory, cloth bag.....	Sept. 27, 1934	14		34			82		38		2					88		90			74	
		28		81			85		51		12					92		91			84	
Do.....	Nov. 12, 1935	14	62	55	80	79	81	80	78	80	71	65			81	76	85	85	81	75	85	87
		28	81	80	83	84	83	81	78	80	74	69	51	42	88	84	86	87	86	81	85	88
Sealed jar, 30° C.....	do.....	14	26	23	57	59	73	67	69	71	59	58			63	54	70	72	63	55	71	
		28	74	76	72	70	76	73	71	72	61	63	24	24	79	65	76	78	80	77	76	77
Sealed jar, 20° C.....	do.....	14	31	35	83	78	90	87	85	86	44	50			89	87	97	89	92	90	93	80
		28	74	69	84	83	92	80	88	87	49	57	53	57	91	92	98	91	96	91	93	90
Sealed jar, 10° C.....	do.....	14	65	51	84	85	85	87	79	64	26	18			91	88	96	80	88	82	93	89
		28	79	67	86	86	86	89	83	71	33	26		61	46	94	92	97	90	91	94	95
Sealed jar, 2° C.....	do.....	14	62	38	75	74	59	52	13	10	1	0			90	80	92	92	92	82	80	82
		28	67	50	77	76	62	54	27	14	2	0		58	42	93	92	93	94	94	95	90
Sealed jar, -10° C.....	do.....	14	40	34	74	63	48	30	5	1	0	0				88	86	89	84	78	70	62
		28	63	53	80	67	54	34	8	2	0	0		53	34	96	96	93	94	97	93	86

CHILLING

When tested at a warm temperature, the percentage of germination of fresh seed can be raised if the seed is prechilled, but such treatment never gives complete germination. The germination on 10- to 18-day-old seed was increased by 40 to 50 percent at the alternation 20° to 30° C. by prechilling 7 to 14 days. At this temperature after-ripened seed did not show this benefit of chilling (samples 27a and 28b, table 16). However, at the high constant temperature 30° the percentage of germination of this same after-ripened seed was increased by approximately 40 to 45 percent by prechilling.

TABLE 16.—Germination of seed of *Festuca capillata* when prechilled and transferred to a warm temperature

Sample No.	Age of seed	Germination at temperature of—																			
		20°-30° C.								10°-25° C.		25° C.					30° C.				
		Untreated		1 day		7 days		14 days		Untreated		Untreated		7 days	14 days	21 days	Untreated		7 days	14 days	21 days
		With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With water	With water	With water	With potassium nitrate	With water	With water	With water	With water
		Days	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
43a.....	17	9	5	20	12	61	48	76	66	89	83	.....	.....	.....	.....	.....	.....	.....	.....	.....
44.....	18	5	1	8	4	63	47	60	40	87	72	.....	.....	.....	.....	.....	.....	.....	.....	.....
45a.....	18	18	8	10	9	74	56	69	43	90	70	.....	.....	.....	.....	.....	.....	.....	.....	.....
43b.....	10	10	10	24	16	74	66	77	68	90	80	.....	.....	.....	.....	.....	.....	.....	.....	.....
27a.....	141	87	83	.....	.....	.....	85	.....	86	94	86	71	68	74	75	71	35	31	75	75
28b.....	123	80	77	.....	.....	.....	83	.....	88	84	82	68	65	84	90	80	50	35	78	80

The dormant reaction of cold-storage seed to a high constant germination temperature has already been discussed. The germination of this seed, as with the fresh seed, can be increased by prechilling for at least 7 days. Seed stored at -10° , 2° , and 10° gave maximum germination if prechilled before germinating at 25° . Although the germination was increased by prechilling before germinating at 30° , maximum germination was not obtained. Seed stored at 20° showed no great need of a prechilling treatment before germinating at 25° , but germination was increased by this treatment before placing it at 30° . Seed stored at warmer temperatures showed no dormant reaction as a result of such storage when germinated at the high constant temperatures. The results obtained in tests at 20° to 30° are given for comparison. Maximum germination was obtained at 20° to 30° without prechilling with the exception of the -10° storage and the test with water at the 2° storage. The results are given in table 17. The 28-day results of tests at this temperature and at the optimum temperature 10° to 25° are given in table 15.

TABLE 17.—Germination of seed of *Festuca capillata* previously held in storage, when prechilled and transferred to a warm temperature

Storage conditions	Germination ¹ at temperature of—														
	25° C.					30° C.					20°-30° C.				
	Untreated		7 days at 5° C.	14 days at 5° C.	21 days at 5° C.	Untreated		7 days at 5° C.	14 days at 5° C.	21 days at 5° C.	Untreated		7 days at 5° C.	14 days at 5° C.	21 days at 5° C.
	With potassium nitrate	With water	With water	With water	With water	With potassium nitrate	With water	With water	With water	With water	With potassium nitrate	With water	With water	With water	With water
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Hall, cloth bag.....	80	78	78	80	80	74	69	72	71	66	85	88	82	78	80
Sealed jar, 30° C.....	71	72	74	70	65	61	65	65	58	66	76	77	75	72	67
Sealed jar, 20° C.....	88	83	93	89	87	49	57	84	81	82	93	89	94	91	90
Sealed jar, 10° C.....	83	72	94	88	87	34	28	78	75	70	94	91	89	84	95
Sealed jar, 2° C.....	32	15	88	87	83	2	0	50	57	43	91	79	87	84	86
Sealed jar, -10° C.....	8	2	63	79	70	0	0	41	41	40	88	85	85	88	79

¹ Results after 35 days.

POTASSIUM NITRATE

Freshly harvested seed of *Festuca capillata* was benefited by the use of potassium nitrate. At 10° to 25° C. immature seed (25a) germinated 20 percent and mature seed (27a) over 10 percent more with the use of potassium nitrate than with water. At the unfavorable temperatures for germination an increase of 10 percent and above was observed when the substratum was moistened with potassium nitrate. Tests made when the seed was approximately 6 months old did not show as significant an increase with the use of potassium nitrate. Since the use of potassium nitrate has such a decided effect on the germination of the seed of *Festuca capillata*, the results obtained with it are given in all the tables for this seed.

LIGHT

The effect of the exclusion of light on the germination of seed of *Festuca capillata* is shown in table 18. The seed of this species was sensitive to light at the three temperature conditions tested, both when freshly harvested and approximately 5 months later. The immature and mature seed were more light-sensitive than the dead-ripe seed. The use of potassium nitrate did not entirely replace the lack of light, although it increased the germination even when light was not excluded.

TABLE 18.—Effect of exclusion of light on germination of seed of *Festuca capillata*

Sample No.	Stage of ripeness	Month seed tested	Germination at temperature of -											
			10° C.				15°-25° C.				10°-25° C.			
			Light excluded		Light not excluded		Light excluded		Light not excluded		Light excluded		Light not excluded	
			With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water	With potas- sium nitrate	With water
			Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
25a	Immature	June	9	3	47	21	42	7	60	26	..	..	..	..
		November	45	20	83	52	..	..	..	..	..	..	..	..
27a	Mature	June	11	10	72	54	27	12	44	31	..	..	..	..
		November	39	26	68	45	..	..	..	..	77	74	94	86
28b	Dead ripe	June	81	64	87	77	72	34	78	52	..	..	..	..
		November	72	66	78	76	78	77	85	81	84	77	84	82

FESTUCA ELATIOR VAR. ARUNDINACEA

TEMPERATURE

The temperature requirement for germination of seed of *Festuca elatior* var. *arundinacea* was shown to be affected by the stage of ripeness at which the seed was harvested and also by the length of time and type of storage intervening before the seed was placed to germinate. The seed collected in 1934 (samples 7a and 15) had a rather high germination percentage at 20° C., decreasing at 25° and 30°. However, in 1935 and 1936 the seed was placed to germinate sooner after harvest, and 15° had the highest germination, with lower germination at 20° and 10°. In no case did a constant temperature give a high germination except in the 1934 collections, tested when the seed was approximately a month old.

Results of tests conducted in 1934 on 3-to-4-week-old seed indicate that *Festuca elatior* var. *arundinacea* germinates equally well at temperatures of 15° to 25° and 20° to 30° C. Seed given a longer period at the higher temperature (25° to 15°) and a wider alternation (15° to 30°) germinated at a strikingly slower rate than seed placed to germinate at 15° to 25° or 20° to 30°, although the final results were approximately the same.

Seed collected in 1935 and 1936 and put to germinate immediately showed 15° to 25° C. to be the optimum temperature for the germination of very fresh seed. The slightly immature seed (30a) showed

the greatest difference between the 15° to 25° and the 20° to 30° alternations, having a germination in 28 days of 98 percent at 15° to 25° and 76 percent at 20° to 30°. The mature seed (30b) germinated 94 percent at 15° to 25° and 86 at 20° to 30°, and the dead-ripe seed (30e) 94 at 15° to 25° and 89 at 20° to 30°. The 15° to 25° alternation gave practically complete germination in 21 days, while the 20° to 30° did not. When one compares the results for the two alternations at 21 days of samples 30a, 30b, and 30e, the differences are still more striking. The results are given in table 19.

The effect of age of the seed in respect to its sensitiveness to temperature requirements for germination is shown in comparing results of germination tests made on samples 30a and 30b in December 1935, when the seed was 6 months old, with the tests made in June, immediately after harvest. The results are given in table 20. The 6-month-old seed was much less sensitive to differences of temperature. There was a greater tolerance by the 6-month-old seed for the higher constant temperatures, 25° and 30° C. Also, these results support the opinion that for very fresh seed 15° is the best constant temperature, but that as the seed becomes older the favorable constant temperature is raised to 20°. It appears, however, that an alternation of temperatures furnishes the optimum condition for germination. In very fresh seed the optimum alternation was 15° to 25°, but, as will be noted from a study of the results, with the 6-month-old seed the range of alternation of temperatures giving satisfactory germination is widened to include 10° to 25°, 15° to 25°, 10° to 30°, and 20° to 30°.

The length of time required for maximum germination should also be noted. The tests reported in table 21, as well as numerous other tests that have been made, show that 21 days is required on very fresh seed. At 15° to 25° C., samples 30a and 30b germinated respectively 97 and 94 percent in 21 days in June. In December the germination of these samples in 11 days was 99 and 97 percent; in the 11-day test in June it was 62 and 52 percent.

TABLE 19.—Germination of seed of *Festuca elatior* var. *arundinacea* at various temperatures

Sample No.	Year seed sown	Year har- vested	Condition of seed			Time of ger- mina- tion count	Germination at temperature of—											
			Stage of ripeness	Time in straw	Age		10° C.	15° C.	20° C.	25° C.	30° C.	10°-25° C.	15°-25° C.	25°-30° C.	10°-30° C.	15°-30° C.	20°-30° C.	
							Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
7a	1932	1934	Mature	13-20	21-28	Days	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
						7			82	46	3		81	37		37	83	
						11			85	54	7		91	80		65	90	
						14			87	55	10		92	85		84	91	
						21			87	57	13		92	95		87	91	
						28			87	58	15		92	95		87	91	
						7		16	3			1	35				18	
46a	1932	1936	do	6	7	11						42						
						14	26	63	11			70	90				90	
						21	65	88	41			88	94				97	
						28	70	88	41			88	94				97	
						7		5	1				16				6	
46b	1932	1936	Dead ripe	0	1	11						33						
						14	18	61	9			69	93				73	
						21	51	81	33			86	96				85	
						28		57	82	33		86	96				88	
						7			93	30	1		93	42		56	94	
15	1933	1934	Mature	13-20	21-28	11			94	41	3		97	89		91	98	
						14			95	43	3		97	90		95	98	
						21			96	45	6		97	93		99	98	
						28			96	45	9		97	99		99	98	
						7	0	8	0			3	0		0		2	
30a	1933	1935	Slightly immature	0	0	11	9	20	1			49	62		17		10	
						14	10	23	1			75	90		30		33	
						21	16	43	2			93	97		75		65	
						28	22	45	3			93	98		88		76	
						7	0	8	0			4	16		0		0	
30b	1933	1935	Mature	0	1	11	1	13	2			0	31	52		14	40	
						14	4	16	2			0	57	82		38	68	
						21	4	19	2			0	82	94		77	81	
						28	4	21	2			0	83	94		86	86	
						7	17	70	67			1	78		13		63	
30c	1933	1935	Dead ripe	0	1	11	85					1	94				81	
						14	87	90	75			2	94		89		85	
						21	87	90	77			4	94		92		89	
						28	87	91	77			6	94		92		89	
						7		16	1				45				20	
47	1933	1936	do	0	1	11						31	83					
						14	10	56	3			59	91				60	
						21	11	60	4			82	96				84	
						28	11	60	4			84	96				90	

TABLE 20.—Relation of age to germination temperature response of seed of *Festuca elatior* var. *arundinacea*

Sample No.	Stage of ripeness	Date of germination test	Time of germination count	Germination at temperature of—									
				10° C.	15° C.	20° C.	25° C.	30° C.	10°-25° C.	15°-25° C.	10°-30° C.	20°-30° C.	
				Days	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
30a	Slightly immature	June 22, 1935	7	0	8	1	—	0	0	0	0	2	
			11	9	20	1	—	0	49	62	17	10	
			14	10	23	1	—	0	75	90	30	33	
			21	16	43	2	—	0	93	97	75	65	
			28	22	45	3	—	0	93	98	88	76	
		Dec. 17, 1935	7	0	67	87	67	15	8	97	23	95	
			11	44	92	91	76	25	97	99	96	97	
			14	86	92	92	80	31	99	—	98	98	
			21	92	93	92	82	35	99	—	99	98	
			28	92	93	92	82	37	—	—	99	—	
		June 25, 1935	7	0	8	0	—	0	4	16	0	0	
			11	1	13	2	—	0	31	52	14	40	
			14	4	16	2	—	0	57	82	38	68	
			21	4	19	2	—	0	82	94	77	81	
			28	4	21	2	—	0	83	94	86	88	
30b	Mature	June 25, 1935	7	0	83	92	78	35	23	94	45	97	
			11	61	89	93	85	60	97	97	97	97	
			14	86	89	93	88	55	98	98	98	97	
			21	86	90	93	88	58	98	98	98	97	
			28	86	90	93	88	58	98	98	98	—	
		Dec. 17, 1935	7	0	83	92	78	35	23	94	45	97	
			11	61	89	93	85	60	97	97	97	97	
			14	86	89	93	88	55	98	98	98	97	
			21	86	90	93	88	58	98	98	98	97	
			28	86	90	93	88	58	98	98	98	—	

EFFECT OF STORAGE TEMPERATURE ON GERMINATION TEMPERATURE

Seed stored for some time at a low temperature (2° C.) behaved much the same as fresh seed in the temperature requirements for germination, as shown in the results given in table 21. Sample 15 was divided in July and part placed in a cloth bag stored in the laboratory and part placed in a sealed jar stored at 2°. Both lots were tested later.

The results from successive tests indicated a progressive increase in the germination at the higher constant temperatures of the laboratory-stored seed. However, the seed stored for approximately 17 months in a sealed jar at 2° showed a dormant reaction to the high constant temperatures, germinating comparably with fresh seed. Tests made at alternating temperatures did not show this difference.

TABLE 21.—Germination of seed of *Festuca elatior* var. *arundinacea* stored at different temperatures

[Sample 15]

Place of storage	Date of germination test	Time of germination count	Germination at temperature of—							
			10° C.	15° C.	20° C.	25° C.	30° C.	15°-25° C.	20°-30° C.	
			Days	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Laboratory	July 26, 1934	7	-----	-----	93	30	1	93	94	
		11	-----	-----	94	41	3	97	98	
		21	-----	-----	96	45	6	97	98	
Do.	Sept. 29, 1934	7	-----	-----	96	81	15	98	92	
		11	52	-----	98	94	26	99	97	
		21	88	-----	98	95	30	99	98	
Do.	Dec. 20, 1935	7	-----	43	89	85	32	82	97	
		11	4	96	93	91	58	99	99	
		21	95	96	94	93	73	100	100	
2° C.	do.	7	-----	-----	85	93	27	2	97	
		11	53	95	94	49	4	98	97	
		21	88	95	95	52	11	99	98	

CHILLING

Seed given a prechilled treatment can stand a higher temperature for germination than seed not prechilled. In table 22 the seed stored at 2° C. had only 11-percent germination in 21 days at 30° C. But this same seed, prechilled at 5° C. for 1 week and then placed at 30°, germinated 92 percent in 21 days. A longer period at 5° was not found to be necessary. The 25° test of this seed resulted in 52-percent germination in 21 days, whereas seed prechilled for 1 week before placing at 25° germinated 94 percent in 11 days.

TABLE 22.—Germination of seed of *Festuca elatior* var. *arundinacea* when prechilled and transferred to a warm temperature

(Sample 15 in mature stage at age of approximately 17 months)

Place of storage	Time of germination count	Germination at temperature of—									
		25° C.			30° C.				20°-30° C.		
		Un-treated	7 days at 5° C.	14 days at 5° C.	Un-treated	7 days at 5° C.	14 days at 5° C.	21 days at 5° C.	Un-treated	7 days at 5° C.	14 days at 5° C.
	Days	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	
Storage chamber at 2° C.	7	27			2				94		
	11	49	94		4	70			97	92	
	14	51	97		8	87			98	100	
	21	52	97	96	11	92	80		98		99
	28	52	97	96	18	93	92	86			99
	35	52			23	94	92	81			
Laboratory	7	85			32				97		
	11	91	80		58	76			99	66	
	14	92	99		67	95			100	99	99
	21	93	99	97	73	95	97			100	99
	28	94	99	98	82	95	99				
	35				87						

POTASSIUM NITRATE AND LIGHT

Only the slightly immature and mature seed showed a lower germination with the total exclusion of light. Potassium nitrate benefited these same samples when light was excluded. However, the use of potassium nitrate did not completely replace the effect of light. This light effect was lost after 6 months. The results are given in table 23.

TABLE 23.—Effect of potassium nitrate and of the exclusion of light on germination of seed of *Festuca elatior* var. *arundinacea* at 15° to 25° C.

Sample No.	Condition of seed		Time of germination count	Germination at 15° to 25° C.			
	Stage of ripeness	Age		Light excluded		Light not excluded	
				With potassium nitrate	With water	With potassium nitrate	With water
		Days	Days	Percent	Percent	Percent	Percent
30a.	Slightly immature	1	21	86	70	95	97
		179	7		95		97
30b.	Mature	1	21	88	75	97	94
		177	7	95	96	96	94
30c.	Dead ripe	1	21	91	95	94	94

FESTUCA ELATIOR

TEMPERATURE

Of all the species tried, *Festuca elatior* was the least sensitive in temperature response. Results of the tests of seed collected and threshed out immediately and put to germinate when 1 day old are given in table 24. The seed germinated at a faster rate at 15° C. than at any other constant temperature, although the final results at 20° were equally as high. At 10° germination was lower than at 15°. At the constant temperature of 30° this sample germinated 79 percent in 35 days, which is much higher than the germination at this temperature of any of the other species even 2 months after harvest. With alternating temperatures the optimum was 15° to 25°, although at 20° to 30° a germination of 87 percent was obtained with fresh seed and 94 percent with seed 3 to 4 weeks old.

TABLE 24.—Germination of seed of *Festuca elatior* at various temperatures

[Seed in mature stage]

Sample No.	Age of seed	Time of germination count	Germination at temperatures of—									
			10° C.	15° C.	20° C.	25° C.	30° C.	5°-15° C.	15°-25° C.	10°-30° C.	20°-30° C.	
37	1	Days	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
		7	77	58	11	0	90	59	8			
		12	77	93	91	0	97	93	8			
		14	77	93	91	0	97	95	8			
		21	83	94	94	63	97	96	8			
		28	85	94	94	68	97	96	8			
8a	21-28	35				79	75					
		7		88	83	34		92		9		
		11		90	88	43		93		9		
		14		91	89	47		93		9		
		21		92	89	58		93		9		
		28		92	91	74		94		9		

POTASSIUM NITRATE AND LIGHT

The only temperature at which the use of potassium nitrate showed any effect was at 5° to 15° C., where the nitrate test produced 19 percent higher germination than the test with water (table 25).

Seed that had light excluded at 15° to 25° C. gave results equal to the test at 15° to 25° that received some light.

TABLE 25.—Effect of nitrate on germination of seed of *Festuca elatior*

[Sample 37]

Time of germination count (days)	Germination at temperature of—									
	10° C.		20° C.		5°-15° C.		15°-25° C.		20°-30° C.	
	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water	With potassium nitrate	With water
7	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
12	92	77	96	91	0	0	89	90	87	84
14	93	77	96	91	0	0	93	97	88	86
21	95	83	96	94	62	63	94	97	88	86
28	96	85	96	94	81	88	-----	-----	88	87
35	-----	-----	-----	-----	94	75	-----	-----	-----	-----

DISCUSSION

The seeds of all the species of *Festuca* used in this experiment, when tested immediately after harvest, were dormant at high germination temperatures, either constant or alternating. The degree of dormancy was determined by the stage of maturity at which the seed was harvested and the number of days intervening before testing. Seed placed to germinate immediately after harvest required a relatively low temperature for germination.

Harrington (4) found that a temperature considerably lower than 20° C. (12° to 16°) was favorable for the germination of dormant wheat. Toole (11) found that dormant wheat was very sensitive to the temperature of 26°, and some samples to 20°, and that it gave complete germination if prechilled at 5° for 3 to 5 days before placing at 26°. He states:

There is no question but that freshly harvested wheat and other grains are very sensitive to temperature conditions for germination. The degree of this sensitiveness, which is called dormancy, varies very greatly with the source of the seed, the seasonal conditions, and the age of the seed from time of harvest.

The need of a low temperature for germination found in freshly harvested *Festuca* seed was more pronounced in seed collected when immature or mature than when collected when the seed was dead ripe.

In general, a cool alternating temperature was best, except in *Festuca rubra* strains, for which the germination was slightly better at 10° C. *F. elatior* germinated equally well at constant and alternating temperatures. The alternating temperature of 15° to 25° was the optimum temperature for all the fescues except *F. capillata*, which germinated better when fresh at the lower alternation of 10° to 25°.

Harrington (5), in discussing the variation in behavior of different lots of the same kind of seed, says:

It may therefore be that some kinds which are usually constant temperature germinators may, under certain conditions, germinate better with an alternation of temperatures. Incomplete after-ripening might have this effect.

It appears that the seeds of *Festuca* are usually alternating-temperature germinators (except *F. rubra* strains and *F. elatior*) but may become tolerant of constant temperatures as they become older. This alternating temperature for *Festuca* seed that has not been after-ripened must include cool temperatures as low as 10° or 15° C. and not higher than 25°, and as the seed becomes older this cool temperature might still be considered as the optimum condition for germination, although the seed becomes more tolerant of warm temperature alternations and also of constant temperatures.

At constant temperatures, 10° C. was best for very fresh seed, with the exception that creeping red fescue and *Festuca elatior* var. *arundinacea* gave better results at 15° than at any other constant temperature. Fresh seed of *F. rubra* var. *commutata* gave the fastest and highest germination at 10°, but with increase in age the seed of this species dropped in rate and final germination at 10° and the optimum condition was raised to 15° and 20°. Seed of *F. capillata* behaved like seed of *F. rubra* var. *commutata* at constant temperatures except that it did not show a slower rate and lower results at 10° with increase in age. The *F. rubra* strains, the only fescue that germinated better at a constant temperature (10°) than at an alternating temperature, responded like *F. capillata* seed to the constant temperatures

as it increased in age. Therefore it might be concluded for the three species mentioned above that the optimum constant temperature is as low as 10°, with a rise in the optimum to 15° and 20° as the seed becomes older. Whether an optimum temperature of 25° is ever reached, the seed certainly becomes more tolerant of this temperature with increase in age. The seed also becomes more tolerant of 30°, but none of the species tried except *F. elatior* ever gave a high germination at this constant temperature.

However, if the seed is chilled for a period of 7 days at 5° C. it will then give practically complete germination at a high temperature. A longer period of prechilling is not necessary. Tests made on *Festuca rubra* var. *commutata* showed that seed placed to germinate at 30° was held in a dormant condition, but if this same seed was taken out and given a cold treatment before placing back at 30° this dormancy was overcome. Also, seed held in a dormant condition at a warm temperature unfavorable for germination grew immediately if transferred to the optimum temperature for germination. Thus it would appear that prechilling was not in itself beneficial but that it compensated for an unfavorable temperature. The temperature 20° to 30°, given as the optimum temperature in the Rules for Seed Testing (1), gave very poor results with fresh seed of all the species tried. This tendency toward dormancy at 20° to 30° was overcome in all species after 1 month or longer of storage. The lower the temperature required for the germination of fresh seed the longer was the interval after harvest necessary to overcome the dormancy shown when germinated at 20° to 30°. For example, *F. rubra* var. *commutata* germinated well at 20° to 30° approximately 1 month after harvest, but it took several months for *F. capillata* to give a complete germination at that temperature.

Experiments with *Festuca capillata* and *F. elatior* var. *arundinacea* indicate that seed kept in cold storage is held in a dormant condition in respect to high constant germination temperatures. Results of tests made on *F. elatior* var. *arundinacea* stored in a sealed jar at 2° C. for approximately 17 months were comparable to the results when the seed was fresh. Results of tests made on *F. capillata* seed stored in sealed jars at -10°, 2°, 10°, 20°, and 30°, and in a cloth bag in the laboratory, showed that the lower the temperature at which the seed was stored the more dormant was its reaction when germinated at high temperatures.

The effect of dry storage at a low temperature, resulting in maintaining a dormant reaction toward high temperatures, is in striking contrast to the effect of prechilling the moistened seed, which tends to overcome dormancy. Prechilling the moistened seed even broke the dormancy of seed stored dry at a low temperature.

Fresh seed of meadow fescue (*Festuca elatior*) proved to be the least sensitive to the warm germination temperatures. For this reason very little work was done on this species. Mature seed, 1 day after harvest, germinated above 90 percent in 12 days at the constant temperatures 15° and 20° C. and at the alternating temperatures 15° to 25° and 10° to 30°. Fresh seed of this species also showed the highest percentage of germination on any species at 30° or 20° to 30°, 79 and 87 percent respectively, in 35 days. Seed 1 month old showed practically complete germination over a still wider range of

temperatures. Kreysing (8), in his work on the germination of meadow fescue, gives 4.75° as the minimum, 19° to 24° as the optimum, and 38° as the maximum temperature for germination. He found alternating temperatures to be favorable for the germination of meadow fescue, especially freshly harvested seed, and light to be beneficial for the germination of freshly harvested seed but unfavorable for older seed. Kling (7) reports the strongest germination energy at 20° , with beneficial influence of light for this species. He also states that good germination was obtained at 30° . According to Reiling (10), 4-month-old seed of meadow fescue will germinate without alternating temperatures, but alternating temperature and light are essential for fresh seed. Harrington (5) says that meadow fescue will germinate as well at favorable constant temperatures as with an alternating temperature. The writers' results agree with Harrington but did not give as definite temperature limits for good germination nor the need of light and alternating temperature for fresh seed as is implied by the other workers mentioned above.

Kling (7) also reports for sheep fescue (*Festuca ovina* L.) the strongest germinating energy at 20° C. with influence of light. Bär (2) gives 18° as the optimum temperature for the germination of *F. rubra* (red fescue) and *F. ovina* (sheep fescue), and 30° as injurious to germination. If this seed corresponds with the *F. rubra* strains reported on in this bulletin, the optimum temperatures given by the above-mentioned writers do not agree with the present results for fresh seed. Results obtained here show that 10° is the optimum temperature for the germination of very fresh seed. At constant temperatures the percentage of germination decreased as the temperature was raised. The results of Kling and of Bär agree more with the results obtained on approximately 2-month-old seed. Kling states that sheep fescue does not germinate well at an alternating temperature nor at a constant temperature of 30° . The writers found with the *F. rubra* strains that the rate of germination was slower at the alternating temperature 10° to 15° , 10° to 25° , and 15° to 25° , but that the final results were equal to those obtained at 10° . The results at 30° agree with those found by other writers. Kling (7) also states that seed frozen at -10° for 18 hours is greatly injured if placed to germinate at 30° but shows no difference at 10° , 18° , and 24° . The writers found that prechilling at 5° before placing at temperatures otherwise too high for complete germination greatly increased germination. The number of days of prechilling required depends on how high the germination temperature is to be. Freezing the test at -10° was not tried, but the writers found with *F. capillata* that dry seed stored at -10° gave very poor results when germinated at 30° .

The behavior of *Festuca capillata* is more comparable to that of the *Poa* species than to the other fescues. Toole (12) found that light, nitrate, and an alternation of temperatures were necessary for the complete germination of Canada bluegrass (*Poa compressa* L.). Gassner (3) found an alternation of 10° to 22° C. to be the optimum temperature for the germination of *P. pratensis* L. Maier (9) also states that *P. pratensis* and especially *P. nemoralis* L. are sensitive to light. Maier gave the constant temperature 12° C. as being more favorable for the four *Poa* species tested than 22° or 30° . An alternating temperature, nitrate, and light are necessary for maximum

germination of *F. capillata*. Although no definite light exposures were made, the total exclusion of light from tests of *F. capillata* gave much lower results even when the seed was placed to germinate at a favorable temperature and moistened with nitrate. The optimum temperature is 10° to 25° for fresh seed. Older seed becomes more tolerant of constant temperatures and warm-temperature alternations, but the low-temperature alternations 10° to 25° and 15° to 25° give the best germination and the seed remains sensitive to light and nitrate. The results with fresh seed at the constant temperatures are in accordance with those found by Maier for *Poa*. For fresh seed of *F. capillata*, the best germination was obtained at 10°, with a decrease in germination as the temperature was raised; but for 5-month-old seed the optimum temperature was raised to 15° and 20°. *F. capillata* is the only species that showed a beneficial light and nitrate effect. The other species of fescue were benefited by the use of nitrate or retarded by the exclusion of light at temperatures unfavorable for complete germination. At the optimum temperature nitrate was not needed. Therefore, only at temperatures not conducive to complete germination did the nitrate and light effect have an opportunity to show up.

The seeds of the different species of fescues studied show some differences in their responses to the various factors influencing germination, but the progressive changes with the aging of the seed are in general similar. These studies show the importance of a knowledge of the previous history of the seed in any investigation of germination requirements. A more complete understanding of the physiological processes concerned in germination must be based on detailed studies of the germination behavior of many kinds of seeds.

SUMMARY

The species of *Festuca* studied were (1) *Festuca rubra* var. *commutata* Gaud. (*F. fallax* Thuill., Chewings or New Zealand fescue), (2) strains of *F. rubra* L., (3) a variety or strain of *F. rubra* known commercially as creeping red fescue, (4) *F. capillata* Lam. (hair fescue), (5) *F. elatior* var. *arundinacea* (Schreb.) Wimm. (commercially known as reed fescue), and (6) *F. elatior* L. (meadow fescue).

The temperature at which the seed germinated at the fastest rate and which gave the highest results is considered as the optimum temperature for germination.

Fescue seed placed to germinate immediately after harvest required a relatively low temperature for germination.

The need of a low temperature for germination was more pronounced in seed collected when immature or mature than in seed collected when it was dead ripe.

With fresh seed, the optimum temperature for germination was 10° C. for *Festuca rubra* strains; 15° to 25° for *F. rubra* var. *commutata*, creeping red fescue, and *F. elatior* var. *arundinacea*; 10° to 25° for *F. capillata*; and 15°, 20°, or 15° to 25° for *F. elatior*.

As the seed increases in age it will germinate over a wider range of temperatures. A few months after harvest fescue seed produced maximum germination at the warm alternation, 20° to 30° C., although the rate was slower than at lower temperatures.

The best constant temperature for fresh seed of *Festuca rubra* var. *commutata* was 10° C., but for older seed both the rate and the final percentage of germination was lower at 10° and the best constant temperature was raised to 15° and 20°. *F. capillata* and *F. rubra* strains showed the same change in response to temperature as the seed increased in age but did not show the decrease in germination at 10°.

Fresh seed of *Festuca capillata*, *F. elatior* var. *arundinacea*, and creeping red fescue showed a low germination at constant temperatures. The best constant temperature was 10° C. for *F. capillata* and 15° for the other two species.

Festuca capillata, which required a very low temperature alternation when fresh, required a longer period after harvest before it would give a maximum germination at 20° to 30° than the species that showed 15° to 25° as the optimum temperature for fresh seed.

Seed of all species prechilled at 5° C. for approximately 7 days showed an increase in germination at temperatures ordinarily too high for complete germination of fresh seed or that not after-ripened.

Seed of *Festuca elatior* var. *arundinacea* and *F. capillata* kept in dry storage at low temperatures showed a temperature response at high constant temperatures comparable to seed that had not been after-ripened.

Festuca capillata was the only species that responded to the use of light and nitrate in addition to an optimum temperature. Light and nitrate were beneficial to the other species only at temperatures unfavorable for complete germination.

The duration of the test necessary for maximum germination at the optimum temperature was 14 days for *Festuca elatior*, 21 days for *F. rubra* var. *commutata*, creeping red fescue, *F. elatior* var. *arundinacea*, and *F. rubra* strains, and 28 days for *F. capillata*. Some individual tests of all species showed complete germination in less time than that given above.

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END