GERMINATION STUDIES ON AGED AND INJURED SEEDS [1]

By O. A. STEVENS

Associate botanist, North Dakota Agricultural Experiment Station

INTRODUCTION

From 1909 to 1933, various investigations upon problems of germination were carried on at the North Dakota Seed Laboratory by the writer and his assistants and by advanced students under the writer's supervision. The present paper includes results of some of the experiments that deal with special conditions of seeds.

CLOVER AND ALFALFA

LONGEVITY OF NORMAL SAMPLES

Some of the first studies dealt with the seeding value of "hard" seeds in clovers. Much has been published on this subject since the results of these studies were reported, and only certain features need to be considered here. In one of the first experiments six samples of alfalfa (*Medicago sativa* L.) and two each of sweetclover (*Melilotus alba* Desr.) and red clover (*Trifolium pratense* L.) were tested every 2 months for hard-seed content. These samples, assembled in the early winter of 1913–14, have been continued as a longevity trial, and 20 years' data are now available. The samples were kept in ordinary manila seed envelops, stored in ventilated galvanized boxes which were kept in the laboratory either on or near the floor. Germination tests were made between blotters by standard methods, and 500 seeds were used for each test during the first season.

The samples for the trials were selected with much care. The first three of alfalfa shown in table 1 were grown in western North Dakota in 1913, no. 14497 was grown in Montana, and no. 14469 in South Dakota. No. 14487 was imported Turkestan seed which came from a wholesale seed house and showed the typical color and intermixture of foreign seeds. Both lots of sweetclover were secured from seed houses, the crop being new at that time and no locally grown seed available. No. 14295 was from a St. Louis dealer and no. 15093 was said to be Kansas-grown. No. 14295 was rather immature and contained after recleaning, about 30 percent of greenish-colored seeds. Separate tests showed a germination of 38 percent and 29 hard for these green seeds as compared with 66 and 33 hard for the yellow. The red clovers were grown in Cass and Traill Counties, respectively, in North Dakota. A note in the original entry states: "All lots containing trash and light, shrunken seeds were blown in the vertical air blast separator to grade them evenly." Notwithstanding this, the samples are not quite so carefully prepared as would be desired by present standards.

[1] Received for publication June 11, 1935; issued February 1936. Paper no. 15, Journal Series, North Dakota Agricultural Experiment Station.

TABLE 1.—*Germination and percentage of hard seed in various samples of alfalfa, sweetclover, and red clover seed during the first year of storage*

Sample no.	Percentage of germination and of hard seed in—											
	February		April		June		August		October		December	
	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed
Alfalfa:												
14358	64	33	62	33	77	21	76	21	81	15	89	8
14397	59	38	59	33	57	27	66	28	79	18	81	14
14407	67	32	67	27	78	19	79	20	84	12	84	12
14497	79	16	79	16	83	14	85	13	87	10	91	7
14469	96	3	91	6	94	5	96	3	96	3	96	2
14487	95	4	95	2	93	3	96	2	95	1	94	3
Sweetclover:												
14295	59	35	57	33	58	31	64	23	60	29	63	25
15093	68	27	70	26	69	26	69	26	71	22	69	27
Red clover:												
14446	62	35	57	36	67	29	71	22	69	26	69	28
14448	83	12	83	8	91	7	90	7	91	6	92	4

After the first year, only 200 seeds were used in each test as it was felt that the variations would be somewhat smaller and that these samples would give the significant differences. In general, differences of less than 5 percent are not considered significant unless they appear consistently through a considerable number of tests. The causes and extent of variation have been discussed by the writer in another paper (*8*).[2]

Germination tests, although carried out under standard conditions in standard chambers, are subject to some variations, especially in respect to moisture. It is believed that the common legume seeds are as little sensitive as any kinds of seeds and that this factor is relatively unimportant. The personal factor, however, is important in longevity trials. The actual work on these samples was done by six or more different workers as the laboratory staff changed from year to year, but at all times the tests were under the supervision of the writer. More important than the personal element is the fact that old seeds differ from new both in behavior and appearance. This makes it more difficult in the case of old seeds to determine "normal" germination, "hard" seeds, etc. Even if the work is done by the same person each year, his standards may change unconsciously. Seed laboratory methods, especially the interpretation of germination tests, have been under constant scrutiny in an effort to secure more nearly uniform procedure. Some soil tests of these samples have been made but not regularly, and a field trial of 4 of the alfalfas and 1 sweetclover is reported in connection with other trials (p. 1098). The foregoing discussion applies to the data in tables 1 and 2, and also to other trials to be described in later paragraphs.

A summary of the results of the germination tests with alfalfa, sweetclover, and red clover is given in table 1. It will be noted in table 1 that the alfalfa which began with a fairly high percentage of hard seed showed a well-marked decrease by June, and a still further decrease by late fall. A similar, but less marked effect, appears in the red clover. One sweetclover sample showed practically no change,

[2] Reference is made by number (italic) to Literature Cited, p. 1106.

while the other showed a decrease in hard seeds but without a corresponding increase in germination. A test of all samples in June 1915 following gave practically the same results as the December test. A summary by 5-year periods is shown in table 2.

TABLE 2.—*Germination and percentage of hard seed in various samples of alfalfa, sweetclover, and red clover seed by 5-year [1] intervals over a period of 20 years*

Sample no.	Percentage of germination and of hard seed in—									
	1914		1920		1924		1929		1934	
	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed
Alfalfa:										
14358	64	33	70	1	69	2	55	0	53	2
14397	59	38	72	3	68	3	71	3	64	4
14407	67	32	79	3	72	5	65	3	55	3
14497	79	16	53	1	59	5	53	2	54	1
14469	96	3	81	2	78	2	81	1	82	1
14487	95	4	95	0	86	0	85	0	75	0
Sweetclover:										
14295	59	35	32	30	28	23	22	21	26	18
15093	68	27	71	16	69	15	58	14	48	22
Red clover:										
14446	62	35	56	27	46	14	32	14	16	17
14448	83	12	40	13	39	4	17	3	7	6

[1] No test was made between 1914 and 1920.

Table 2 indicates (1) almost complete loss of hard seed in the alfalfa during the first 5 years, but a long retention of a small percentage; (2) retention of over 50 percent of viability in the same samples at 20 years; (3) retention of 75 to 80 percent of viability in two samples of alfalfa which contained practically no hard seeds at the beginning; (4) a much slower decrease of hard seeds and about equal decrease in germination in the sweetclover, the total loss being greater than in the alfalfa; (5) a still more rapid decline in red clover to a very low germination at 20 years; and (6) a marked difference in the behavior of different samples of the same kind of seed.

The finding of an exceptionally high retention of viability in two samples of alfalfa which had a low content of hard seed at the beginning of the experiment is perhaps surprising, and emphasizes the individuality of samples. Since the hard-seeded condition in alfalfa is rather temporary, there seems little reason to expect that it would affect the longevity. Where this condition is of long duration as in sweetclover, we naturally expect the permeable seeds to lose their vitality first, the hard seeds retaining theirs at least until the coats become permeable.

The first experiment had shown a marked decrease in hard seeds in alfalfa samples during the first year, but more frequent tests seemed desirable. A new series of samples which had been received from November 1914 to April 1915 was assembled and tested in the same way the 1st of each month from April to October. These were fresh seeds all with a high percentage of hard seeds and grown mostly in North Dakota (1 Minnesota, 2 Montana, 1 unknown). The averages of the results are given in table 3.

TABLE 3.—*Germination of and percentage of hard seed in various samples of alfalfa, sweetclover, and red clover seed between April and October*

Seed	Percentage of germination and of hard seed in—									
	April		May		June		July		October	
	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed	Germination	Hard seed
Alfalfa (8 samples)	43	55	59	39	63	35	66	32	72	26
Sweetclover (3 samples)	30	66	36	60	33	63	38	59	33	60
Red clover (3 samples)	60	39	62	36	65	34	64	35	64	35

These results bear out those of the first trial, in showing a sharp decrease in the percentage of hard seeds in the alfalfa in early spring and a continued decrease at a slower rate during the rest of the summer. The sweetclover and red clover showed practically no change during the year. Retained for 15 years longer, the samples have

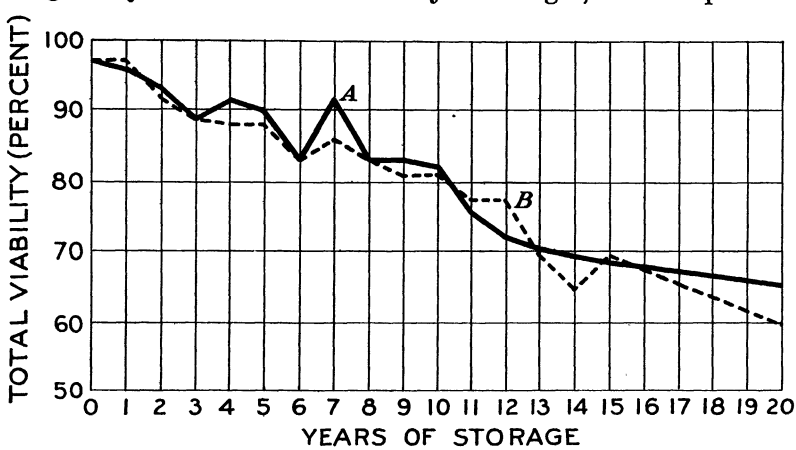


FIGURE 1.—Results of combined germination tests of all samples of alfalfa (*A*) and sweetclover (*B*) after various periods of storage. No data for the years 16 to 19, inclusive.

shown decreases comparable to those in table 2, again with considerable differences between apparently similar samples.

A third similar lot of samples was selected in 1920 for a scarified seed test. The unscarified portions of these samples were tested each year until 1930. By combining all the data available for the different lots of normal alfalfa and sweetclover seed, and considering only total viability (germinating plus hard), the graph shown in figure 1 was secured.

The results agree in general with those found by Sifton (7), but indicate considerably higher retention of viability. Possibly this is due to the fact that samples containing a high percentage of hard seeds were used for the most part. However, the highest germination of all samples at the age of 20 years was from two samples of alfalfa which contained very few hard seeds. Sifton has called attention to the rather sudden loss of vitality in the cereal seeds after about the tenth year, as compared with a gradual decline in the clovers. The

different behavior of clovers is possibly accounted for by the fact that they have a less uniform maturity, are subjected to a greater degree of injury in threshing, and undergo a gradual loss of impermeable seed coat.

LONGEVITY OF SCARIFIED SEEDS

The longevity of scarified sweetclover seed has been discussed quite fully in another paper (*11, p. 13*). The behavior of scarified alfalfa seed is essentially similar. The scarified seeds lose their vitality in the course of 1 to 2 years, probably as a result of increased oxidation permitted by the broken seed coats, and the loss of vitality in the remaining seeds of the sample then proceeds as with unscarified seeds. Different samples may behave quite differently owing to variations in degree of scarification or other abrasions in threshing, or to degree of maturity and other natural influences. The fact that the hard seeds of alfalfa become permeable to a large extent during the spring of the first year, and that they will germinate better in the field than in the laboratory, has practically closed the question of scarification so far as alfalfa is concerned.

GERMINATION OF FROSTED SEEDS

The germination of the immature seeds of sweetclover and of those discolored by frost has already been discussed (*11*). Immature seeds of alfalfa are relatively rare, but a small percentage of brown seed is very commonly present and is an important factor in the commercial value of the seed. The crop of 1925 contained an unusually large amount of seed discolored by frost. The germination of the brown seeds was found to be quite good if they were plump and of good weight, but it seemed desirable to determine whether such seeds would retain their viability. A series of 5 samples of alfalfa and 2 of sweetclover, all North Dakota grown, were assembled. All samples were carefully recleaned and approximately 20 g of each was separated by hand into brown and yellow, and stored in separate packages. The character of the samples is indicated in table 4.

TABLE 4.—*Quality of North Dakota grown alfalfa and sweetclover seed samples as affected by the presence of brown seeds discolored by frost*

Seeds and sample no.	Place grown in North Dakota	Percentage brown (by weight)	Weight of 200 seeds	
			Yellow	Brown
Alfalfa:			*Grams*	*Grams*
47581	Hastings	34.8	0.360	0.340
48248	Washburn	37.4	.420	.380
48770	Arnegard	41.2	.405	.360
48828	Washburn	46.2	.415	.380
49053	Lark	39.4	.415	.395
Sweetclover:				
47450	Christine	51.5	.390	.370
48034	Horace	31.8	.420	.385

The results of these tests were somewhat more difficult to interpret than those of the previous experiments because the condition of "hard" seeds is not so easily recognized in the brown condition. In general it may be said that during 6 years of storage the average actual germination of the yellow seeds in the alfalfa remained constant ta about 57 percent, while the hard seeds decreased from 25 to 12

percent. In the brown seeds, germination decreased from 54 to 30 percent, while the hard seeds remained practically constant at about 13 percent. In the sweetclover, germination decreased from about 70 to 50 percent in both yellow and brown seed, and the hard seeds remained essentially constant at about 30 and 25 percent, respectively.

These results differ from those proviously obtained by the writer and by other workers in indicating a longer retention of the hard-coated condition by frosted seeds. As previously suggested, it was felt that there was some question about the brown seeds recorded as hard at the end of the usual test. In 1935 the hard seeds remaining at the end of the test were carefully reconsidered, but without any material change in the results. All of the remaining hard seeds were then scarified by rubbing with emery cloth and replaced in the germination chamber. In two of the alfalfa samples (nos. 48248 and 48828) about two-thirds of the brown hard seeds softened without producing normal sprouts. In the other samples this result was less marked, though in all samples there were more dead brown seeds than yellow ones. The average additional percentage of dead seeds added to the original result by scarifying the hard seeds was 15 and 3 for the brown and yellow sweetclover and 7.5 and 1 for the alfalfa, respectively. It thus appears that in some of these hard brown seeds the vitality of the seed had been destroyed without rendering the coat permeable. Since no test of this sort had been made previously it is not known whether this occurred in the first instance or during storage.

FIELD GERMINATION OF CLOVERS

Of various field trials, two were quite extensive and of special interest since they included aged and injured seeds. In 1927, Wm. M. Jackson, at the Ellendale (N. Dak.) Normal and Industrial School, carried out a series of tests outlined by the writer. Plantings were made on May 6, May 26, June 22, and July 13. The first two were the most successful. In the latter two germination was poorer and weeds were more troublesome. A total of 45 carefully selected samples was used in the following groups: (1) Check—1 alfalfa, 3 sweetclover; (2) hard seeds—4 alfalfa, 3 sweetclover; (3) broken (chipped and cracked) producing broken sprouts—5 alfalfa, 4 sweetclover; (4) immature—5 alfalfa, 4 sweetclover; (5) frosted—3 alfalfa, 2 sweetclover; (6) old—4 alfalfa, 1 sweetclover.

For each planting 200 seeds were used. The old seeds were from the same samples shown in table 1, and therefore were 14 years old. The frosted seeds were from the samples listed in table 4, and were only 1 year old. The average weight of the seeds in the immature lots was 60 to 70 percent of that of normal seeds. The samples with broken seeds produced from 18 to 59 percent of broken sprouts in the blotter tests. While these are not counted as germinated, it was suspected that there were other sprouts which would not succeed in producing plants. Expressing the results in terms of percentage of plants in the field to germination in blotters the averages for all four plantings were:

(1) Checks—alfalfa 64, sweetclover 51.
(2) Hard seeds—alfalfa 123, sweetclover 48.
(3) Broken seeds—alfalfa 42, sweetclover 24.
(4) Immature—alfafa 23, sweetclover 23.
(5) Frosted—alfalfa, yellow 59, brown 38; sweetclover, yellow 53, brown 40.
(6) Old—alfalfa 41, sweetclover 37.

The check sample of alfalfa showed about 15 percent of hard seed in the blotter test, the sweetclovers less than 10 percent. In series 2 about 65 percent of hard seeds were present in both alfalfa and sweetclover, and here the alfalfa produced more than twice as many plants as the sweetclover; that is, a large number of the hard seeds of the alfalfa produced plants and apparently none or few of the sweetclover. In the other lots, normal seeds produced about half as many plants as in the blotter test, the old and discolored seeds 10 to 15 percent less, and the immature and broken seeds about one-fourth as many. The marked difference between the alfalfa and sweetclover in the broken seeds is probably due to the difference in behavior of the hard seeds (35 percent present).

A second and similar trial was carried out at Fargo, N. Dak., in 1928 by W. A. Davidson. The same samples were used for the old and discolored seeds, but for the other lots new samples were employed similar to those used in the previous trial. Plantings were made on May 22 and July 9. The first gave better results. The soil was very dry at the time of planting, but rain fell on June 7 and the soil was in good condition at the time of the second planting. The results were similar to those at Ellendale and calculated on the same basis were:

(1) Checks—alfalfa 48, sweetclover 62.
(2) Hard seeds—alfalfa 146, sweetclover 61.
(3) Broken seeds—alfalfa 22, sweetclover 32.
(4) Immature—alfalfa 24, sweetclover 27.
(5) Frosted—alfalfa, yellow 70, brown 40; sweetclover, yellow 63, brown 36.
(6) Old—alfalfa 46, sweetclover 33.

A field planting was made May 8, 1920, of machine-scarified and of unscarified samples from identical lots of fresh seed. Calculated as in the preceding paragraph, the results were:

Alfalfa, 5 samples—unscarified, in field, 147; scarified, germinated between blotters, 198, in field 181.

Sweetclover, 3 samples—unscarified, in field, 82; scarified, germinated between blotters, 148, in field 104.

Red clover, 1 sample—unscarified, in field, 73; scarified, germinated between blotters, 102, in field 67.

In the 1920 planting, the seedlings were removed as they appeared and the experiment was carried on for only 1 month. In the other two plantings, the plants were left during the summer. On the whole, the results are in fair accord with those of other workers, although they do not indicate the germination of hard seeds later in the season as reported by Leggatt (*3*) and Whitcomb (*13*), nor their better germination at higher temperatures as reported by Lute (*4*). The influence of the variable factors of soil and weather are obviously very great. The writer wishes to stress particularly the variability in condition of samples. A classification into "scarified" and "unscarified" often is meaningless because of the variable effects of the scarifying process. This has been shown by the writer (*11, p. 15*) in a study of sweetclover.

LONGEVITY OF SOYBEANS

A collection of 23 samples of soybeans (*Soja max* (L.) Piper) tested for the Department of Agronomy of the North Dakota Experiment Station in 1924, was again tested in 1926 and 1928, and a few were tested in 1929–31. One hundred seeds were used for each test. The crop years of 1921, 1922, and 1923 and seven varieties were represented. The combined results are presented in table 5.

TABLE 5.—*Viability of soybeans of the crops of 1921–23 after storage in laboratory, 100 seeds being used per test*

Item	Results after storage for indicated number of years								
	1	2	3	4	5	6	7	8	9
Samples.....number..	13	4	17	4	17	8	8	4	3
Average germination.....percent..	92	91	83	84	67	65	51	47	30

Four of these samples gave 80 percent or more germination in 5 years, while only two had dropped below 50 percent. One sample of the Chestnut variety gave 90 percent the eighth year, but fell to 47 percent the tenth year (the only record for the tenth year). One sample of Manchuria gave 90 percent the seventh year but dropped to 66 percent the eighth year. The Wisconsin Black variety usually has shown considerable hard seed in fresh samples, but the two lots of it in this series did not hold their viability as well as some other varieties. In 1931, three of the best and three of the poorest samples were planted in the garden. The results are shown in table 6.

TABLE 6.—*Comparison of laboratory and field germination of old samples of soybeans of different varieties*

Variety	Age	Germination in laboratory	Germination in field
	Years	*Percent*	*Percent*
Chestnut	10	47	39
Manchu	9	33	5
Manchuria	8	66	44
Mandarin	9	21	22
Manchuria	--	14	4
Minsoy	8	16	10

The results of these tests are in fair agreement, considering the small number of trials, and are sufficient to show that the samples were all capable of producing plants in the field. It may be mentioned that some of them are still continuing (1935) to produce volunteer growth each year as a result of spontaneous reseeding.

GERMINATION OF BROKEN SEEDS IN FLAX

The broken seeds of flax (*Linum usitatissimum* L.) present a considerable problem, as may be seen from the fact that all samples examined at the seed laboratory from the crop years 1931 and 1932 contained an average of 4.5 percent by weight of pieces comprising not more than one-half of a seed. This includes samples of all kinds, cleaned and uncleaned. Occasionally the amount runs as high as 15 percent. The seeds may be broken in various ways, but reference is made especially to those that are broken transversely. In determinations of purity, according to the rules of the Association of Official Seed Analysts of North America (*12*), pieces of not more than one-half the size of a seed are placed in "inert matter", while pieces exceeding one-half are placed in "pure-seed." Although this procedure results in placing pieces from the larger end of the seeds

which contain no plumules with the seeds used for germination, it has been retained as the simplest working basis for seeds of most species.

From the 1930 crop, 11 cleaned samples were selected for germination experiments. All were of the Bison variety, grown in seven different counties, well distributed over North Dakota. Each sample was separated carefully into five divisions which gave an average composition in percentage by weight as follows: (1) Perfect seeds, 80.5; (2) slightly cracked, 6.8; (3) only small pieces broken off, 4.3; (4) plumule ends; more than one-half of a seed, 1.8; (5) plumule ends, less than one-half, 2.3. The separation into the five groups involved a considerable element of personal judgment, particularly in group 3, where minute pieces of seed coat may be broken from the plumule end in as much as 20 to 30 percent of the seeds. Such seeds were not used. The separations were made on 20 g by a single experienced worker after various comparative trials had been made by different workers and many pieces had been weighed. Seeds were tested in soil in the germinating chamber and a field planting was made about May 20. The soil in the field plot was firm and in good condition, and although the weather turned unusually warm a few days after the seeds were planted, germination and growth were good. The counts recorded in the field are of plants finally produced. The results of the tests are shown in table 7 and figure 2.[3]

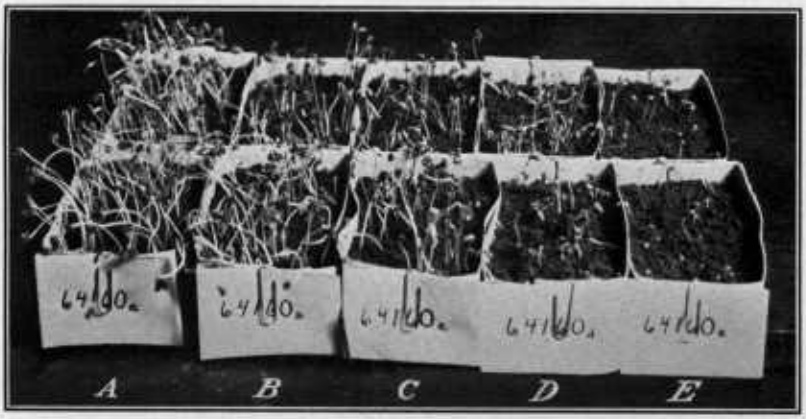


FIGURE 2.—Germination of normal and of broken seed of flax in soil in the germinating chamber, showing sample no. 64160, in front, and no. 63473, behind: *A*, Normal seed; *B*, slightly cracked seed; *C*, seed with only small pieces broken off; *D*, plumule ends, more than one-half of a seed; *E*, plumule ends, less than one-half of a seed.

It was somewhat of a surprise that even a few plants were produced by the small pieces. The variation in the samples in the field was striking, but it seemed to be mainly accidental as similar differences were not found in the soil tests in the chamber. No other sample gave such a high percentage of plants in the field from the normal seeds as no. 64160, yet all of the broken lots from this sample gave very poor results. The behavior of this sample in the chamber

[3] Special credit is due Isabel Barrett for the laboratory work on this experiment as well as for work on other projects over several years. Charlotte and Anita Mary Blake did a considerable amount of the work on the earlier projects.

was quite similar to that of no. 63473; in fact it gave the highest number of sprouts from group 2.

TABLE 7.—*Germination (percent) of perfect and of broken flaxseed in soil in the germination chamber and in the field*

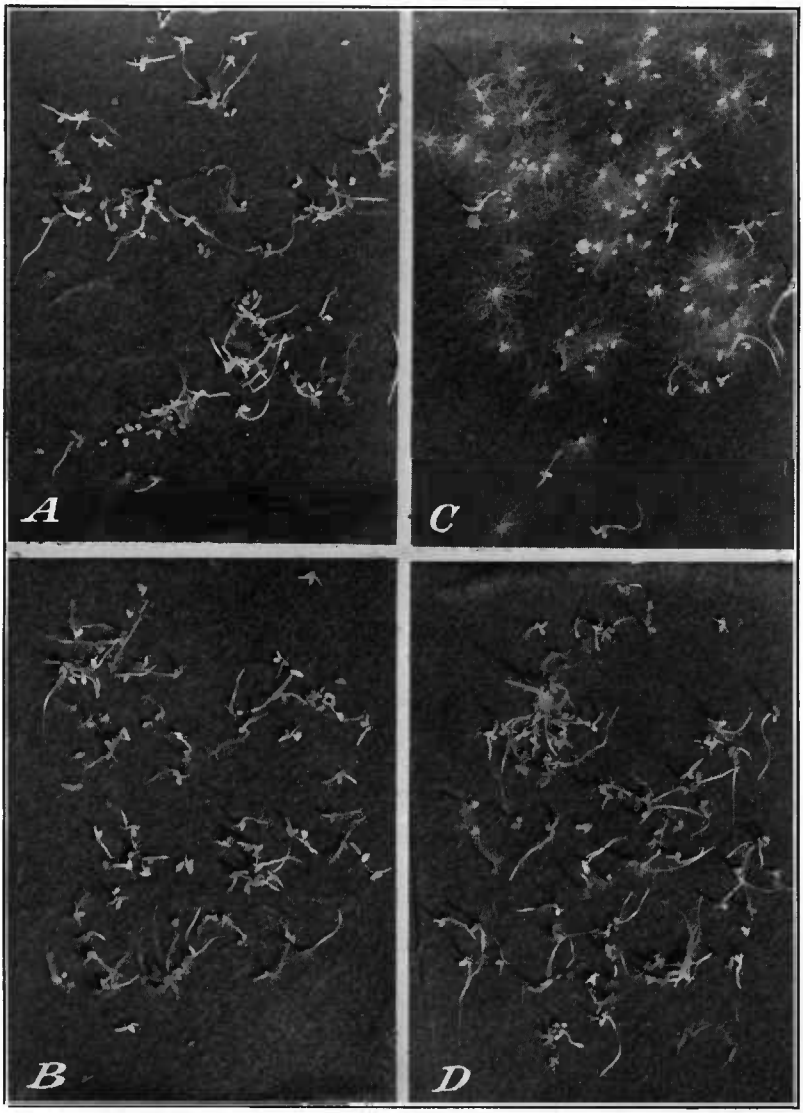
Sample no.	Perfect seed		Cracked seed		Slightly broken seed		More than half a seed		Less than half a seed	
	Chamber	Field	Chamber	Field	Chamber	Field	Chamber	Field	Chamber	Field
64160	97	90	86	12	73	7	51	0	9	0
63473	91	69	64	52	55	50	48	19	28	7
Average of 11 samples	89	63	73	30	57	20	38	8	13	3
Weak growths	2	-------	7	-------	11	-------	17	-------	15	-------

GERMINATION AND LONGEVITY OF HULLED TIMOTHY AND OTHER HULLED SEEDS[4]

Several workers who have reported (*1, 2*) on the relative germination of hulled (naked caryopses) and unhulled (enclosed by lemma and palea) grains of timothy (*Phleum pratense L.*) found a considerably lower average germination for the hulled grains, but they did not carry the study further. McRostie (*5*) concluded (on the basis of one lot only?) that no serious deterioration should take place in 3 or even 4 years of storage. Newton and Ficht (*6*) found a rather rapid decline in germination of the hulled grains, but this was not reflected in the field because the rate of seeding was sufficiently heavy to provide enough plants. From their germination tests the one lot used appears to have been of representative character. The present writer reported (*10*) upon a survey of 77 samples received in the year 1923–24. From these, 10 samples which contained from 36 to 63 percent of hulled grains were selected and stored with the samples of clovers already discussed. These have been tested in May of each year, using each time 200 each of hulled and unhulled, and placing the separations from a given sample on the same blotter in the chamber. Only samples which showed a high initial germination of the hulled grains were used. The average initial germination was 95.2 for the hulled and 98.6 for the unhulled.

Figure 3 shows that the viability of the unhulled seeds remained essentially unimpaired for 5 years, after which it declined with increasing rapidity. The hulled grains lost viability steadily from

[4] In North Dakota and neighboring States the term "hulling" is in common use for the process of removing the covering (pod, pericarp) from the seeds of legume forage crops. Especially in sweetclover, the seeds are termed "unhulled" in their original condition and "hulled" after the pericarp has been removed. It should be noted that in this sense the term "hulled" refers to the result of a mechanical operation. Scientific writers have often described the grains of grasses as "hulled" when normally enclosed by the lemma and palea after threshing. "Hull-less" varieties are those which normally are freed from the lemma and palea in threshing. The naked condition in timothy and in the common varieties of millet is abnormal. Perhaps "deglumed" would be a better term for these, but it appears impossible to establish a simple and precise terminology for so many variants. The usage employed in the present paper is that commonly used commercially.



Germination of hulled and unhulled timothy seed after 8 years' storage: *A* and *C*, hulled; *B* and *D*, unhulled; *A* and *B*, sample no. 42260; *C* and *D*, sample no. 43869. No. 42260 gave the best results for hulled seed and no. 43869 the poorest.

the first, and in the better samples the results tended to approach those of the unhulled grains. In addition to these differences there were variations between individual samples, distinct breaks occurring in various years.

Personal judgment might seem to account for some of the apparent irregularities, but these usually concerned only certain samples, no general differences appearing in all of the samples in any one year. The sprouted grains from the test in 1932 of one of the best and one of the poorest samples are shown in plate 1. A soil test of no. 42260 made in the chamber on the same date gave 40 and 83 percent

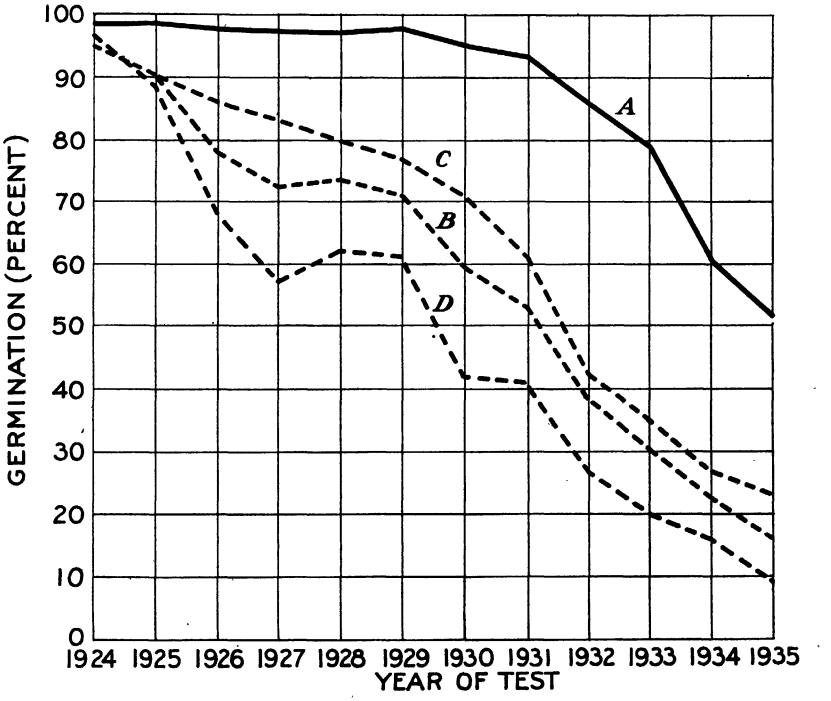


FIGURE 3.—Germination of hulled and unhulled timothy in storage. Average for unhulled (*A*) and hulled (*B*) in 10 samples; average of 6 best (*C*) and 4 poorest (*D*) of the hulled.

for the hulled and unhulled as compared with 61 and 92 for the blotter test and 89 and 98 for a soil test of a fresh check sample.

It was noted in 1934 that germination continued after the 8-day period, and when the seeds were left for 9 days more, an average additional 6 and 17 percent was recorded for the hulled and unhulled seeds, respectively. There were many grains producing shoots but no roots (therefore not counted as germinating), these averaging 5 and 6 percent, respectively, for the hulled and unhulled, but with the greatest variation in the latter. The unhulled seeds of sample no. 43869 retained their vitality best of all the samples, but the hulled seeds made one of the poorest showings. The information regarding this sample indicated that it was overripe and had stood in the shock, but was not damaged by rain.

It appears from these tests that while the hulled seeds usually germinate more poorly than the unhulled, in some samples they may be little inferior at first but lose vitality more rapidly than the unhulled. There may even be wide differences in rate of loss between the two kinds in one sample.

For several years comparative tests have been made whenever samples were available of the germination of the naked caryopses of grains which normally remain enclosed by the lemma and palea, particularly those of emmer (*Triticum dicoccum*) and quackgrass (*Agropyron repens*). The results are summarized in table 8.

TABLE 8.—*Germination of various seed in hulled and unhulled condition*

Kind of seed	Samples	Average content of hulled seed	Average germination	
			Hulled	Unhulled
	Number	*Percent*	*Percent*	*Percent*
Oats (*Avena sativa*)	12	13	81	97
Emmer (*Triticum dicoccum*)	1	(1)	18	74
	1	20	98	95
Proso millets (*Panicum miliaceum*)	19	22	51	94
Foxtail millets (*Setaria italica*)	9	18	53	91
Bromegrass (*Bromus inermis*)	1	10	72	95
Reed canary grass (*Phalaris arundinacea*)	1	37	16	78
Quackgrass (*Agropyron repens*)	1	100	5	----------
	1	100	31	----------
	1	70	24	88
	1	93.6	15	91
Yellow bristle grass (*Setaria lutescens*)	4	100	24	----------
Green bristle grass (*Setaria viridis*)	13	56	46	86
Buckwheat (*Fagopyrum esculentum*)	1	3	98	98
Wild buckwheat (*Polygonum convolvulus*)	6	----------	27	17

[1] Old and moldy.

In these tests it was found that the hulled seeds germinated more poorly, but with large variations, some samples showing no differences between the hulled and the unhulled. The hulled oats varied from 63 to 98 percent and with little relation to the amount of hulled grains present.

The millets are probably of most importance. A record has not been kept of the percentage of hulled grains in all samples, but in the proso millets it frequently reached 20. In the foxtail millets it was much lower. The bristle grasses were obtained from samples of alfalfa and sweetclover, chiefly from the 1927 crop which contained large quantities of these seeds. The lemma and palea envelop the caryopsis closely, but are frequently removed by the close hulling which the seed receives. The radicle of the embryo often is broken in the process. The yellow bristle grass, because of its larger size, is nearly always hulled and very often broken. An outstanding sample among the bristle grasses was one in which 93 percent of the grains were hulled and 87 percent of them germinated, the highest germination in the entire group. In another sample containing 50 percent hulled seed, 71 percent germinated, the second highest test, while of the unhulled seed 70 percent germinated, the lowest by 12 percent, for the group. Bristle grass germinated readily in all cases.

In quackgrass, the lemma and palea adhere tightly and the radicle projects distinctly so that it is very often broken a little. The fourth sample reported in table 8 was secured from a dealer who stated

that it came from new-crop sweetclover which had just been hulled and scarified. The first test was made April 1. On May 1 and June 1, the hulled quackgrass gave the same germination, but on December 1 it gave only 4 percent, the unhulled 91 as before.

Wild buckwheat is a common impurity, and in alfalfa or other small seeds it becomes considerably broken. The embryo lies close to the surface, on one angle, and so is likely to be injured in hulling, which in this case means removal of the pericarp. The germination tests on this seed were unsatisfactory, as the normal seeds failed to respond in 3 cases out of 4. Nor did they respond to any extent to chipping, testing in soil at 18° C., or on blotters at 14°. The ordinary buckwheat (*Fagopyrum*) is not at all comparable to wild buckwheat, for its embryo lies in the center of the seed.

LONGEVITY OF PERENNIAL SOWTHISTLE SEEDS

The achenes of *Sonchus arvensis* have germinated readily with the usual 20°–30° C. alternation as previously reported (*9*), and quite uniformly have produced about 95 percent. Many tests have been made, but no regular annual ones. Fresh seed has been collected nearly every year and as tested May 1, 1935, these lots showed a poor growth for the 1929 crop and none for the crops of 1922 to 1928.

SUMMARY

Annual germination tests were made upon various seeds stored in the laboratory up to 20 years. Under these conditions the viability of good alfalfa and sweetclover seed declined steadily from about 95 to about 60 percent in 20 years. Red clover dropped to about 10 percent.

Hard seeds in alfalfa became permeable to a large extent during the spring months, and while few hard seeds remained after 1 year, from 1 to 4 percent were present even after 20 years. In red clover there was a slower decrease in hard seeds, and in sweetclover very little, two samples retaining at 20 years one-half and four-fifths, respectively, of their original hard-seed content. Some samples which originally contained few hard seeds retained their vitality as well as others. Seeds of alfalfa and sweetclover touched with frost when maturing showed greater retention of hard seeds than did normal lots, but in some cases these did not produce normal sprouts when scarified.

In field plantings of samples containing a high percentage of hard seeds, alfalfa produced from one-fourth to one-half more plants than was indicated by blotter test, while alfalfa which did not contain a large amount of hard seeds and sweetclover both with and without hard seeds, produced only about one-half as many plants as indicated by the blotter test.

Twenty-year-old seeds of alfalfa and sweetclover, and also fresh seeds discolored by frost but of nearly normal weight, gave results in the field only slightly lower in proportion to their blotter test than the normal seeds. Broken and quite immature seeds gave only about one-half as good results.

Soybeans declined steadily but retained an average viability of 30 percent at 9 years.

Broken seeds of flax gave poor germination, but even pieces of less than one-half of a seed gave a maximum of 12 (average 3) percent of plants in the field.

Normal grains of timothy retained normal viability 5 or 6 years, then declined rapidly to 60 percent in 10 years. Hulled (deglumed) grains from the same samples declined steadily to about 20 percent in 10 years, but the better lots decreased to only 70 percent in 6 years.

Millets, especially the proso types, often had a considerable proportion of grains without glumes, and these germinated poorly. Grains of green bristle grass, found in samples of clover and deglumed through clover hulling, were similarly injured. Grains of quackgrass were commonly broken in the same process but gave as high as 30 percent germination.

Seeds of perennial sowthistle retained their viability for 5 years only. Wide differences were observed in the behavior of apparently similar samples, and the causes and extent of variations in such tests is discussed.

LITERATURE CITED

(1) Goss, W. L.
1916. GERMINATION OF HULLED AND UNHULLED TIMOTHY SEEDS AS THEY OCCURRED IN SAMPLES RECEIVED AT THE SEED LABORATORY. Assoc. Off. Seed Anal. North America Proc. (1915) 8: 21.

(2) Harling, Mrs. E. P.
1923. HULLED AND UNHULLED TIMOTHY. Seed World 13 (6): 24.

(3) Leggatt, C. W.
1927. THE AGRICULTURAL VALUE OF HARD SEEDS OF ALFALFA AND SWEET CLOVER UNDER ALBERTA CONDITIONS. Sci. Agr. 8: 243–266, illus.

(4) Lute, A. M.
1928. IMPERMEABLE SEED OF ALFALFA. Colo. Agr. Expt. Sta. Bull. 326, 36 pp., illus.

(5) McRostie, G. P.
1923. HULLED VERSUS UNHULLED TIMOTHY SEED. . . . Seed World 13 (9): 26.

(6) Newton R., and Ficht, J.
1926. EXPERIMENTS WITH TIMOTHY. Alberta Univ., Col. Agr. Research Bull. 3, 87 pp., illus.

(7) Sifton, H. B.
1920. LONGEVITY OF THE SEEDS OF CEREALS, CLOVERS, AND TIMOTHY. Amer. Jour. Bot. 7: 243–251.

(8) Stevens, O. A.
1918. VARIATIONS IN SEED TESTS RESULTING FROM ERRORS IN SAMPLING. Jour. Amer. Soc. Agron. 10: 1–19, illus.

(9) ———
1924. PERENNIAL SOW THISTLE: GROWTH AND REPRODUCTION. N. Dak. Agr. Expt. Sta. Bull. 181, 44 pp., illus.

(10) ———
1925. GERMINATION OF HULLED TIMOTHY SEED. Seed World 17 (4): 14.

(11) ——— and Long, H. D.
1926. SWEET CLOVER SEED STUDIES. N. Dak. Agr. Expt. Sta. Bull. 197, 20 pp., illus.

(12) United States Department of Agriculture.
1927. RULES FOR SEED TESTING. U. S. Dept. Agr. Circ. 406, 13 pp. (Revised, 1928).

(13) Whitcomb, W. O.
1931. HARD SEEDS IN LEGUMES: INTERPRETATION OF THEIR VALUE AND METHODS OF TREATMENT. Mont. Agr. Expt. Sta. Bull. 248, 63 pp., illus.