



Effect of different methods of storage upon the vitality of scarified and nonscarified seed of alfalfa, sweet clover, and red clover
by William Daniel Hay

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Montana State University
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Abstract:

It is believed the experiments and observations reported in this paper justify the following conclusions: The total vitality of non-scarified seed of sweet clover and red clover will decrease slowly during the first seven years of storage. Non-scarified alfalfa seed of good maturity and high hard seed content will lose vitality gradually. Alfalfa seed less mature or of low hard seed content may show a rapid decline in vitality during the first two years of storage, but will fall off gradually thereafter.

Scarified seed of alfalfa will lose total vitality rapidly during the first two or three years of storage, but scarified seed of sweet clover and red clover lose vitality gradually when in storage. Scarified seed of these three crops will not retain its vitality as well as non-scarified seed.

The hard seed content of alfalfa decreases rapidly during the first year of storage and gradually during the following years.

With sweet clover and red clover, the hard seed content of the seed in cold storage falls off rapidly during the first or second year in storage, but the seed stored in the laboratory decreases slowly in hard seed content during storage.

Seed stored with 12 percent moisture loses vitality more rapidly in storage than dry seed. Cold storage is better than storage in the laboratory for seed with 12 percent moisture.

There is no advantage in keeping non-scarified alfalfa seed in cold storage. With scarified seed, however, both germination and total vitality are maintained better in cold storage than in the laboratory. The germination of red clover and sweet clover is higher for seed kept in cold storage than for seed stored in the laboratory.

The total vitality of sweet clover does not seem to be greatly affected by the method of storage. The total vitality of red clover seed will be maintained better in cold storage than in the laboratory but the advantage of low temperatures will not be apparent until after the seed has been in storage from two to four years.

Where cold storage is advantageous as a means of maintaining vitality or increasing the germination, storage in air-tight bottles is most efficient. When seed is stored in the laboratory, there is no difference between storage in air-tight bottles or in sacks.

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EFFECT OF DIFFERENT METHODS OF STORAGE UPON THE VITALITY OF
SCARIFIED AND NON-SCARIFIED SEED OF ALFALFA, SWEET CLOVER
AND RED CLOVER

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SEED OF ALFALFA, SWEET CLOVER AND RED CLOVER

INTRODUCTION

The phenomenon known as "impermeable" or "hard seed", occurring in the seeds of leguminosae, has been recognized for many years. However, it was not until rather recently that workers in the various fields of agriculture became interested in the practical importance of this problem.

Hard seeds were so named because they are not readily permeable to water, hence remain hard under conditions which normally are favorable to germination. Farmers, seedsmen and agronomists have been concerned mainly with the relation of hard seeds to plant production and in the development of methods to overcome the effect of hard seeds upon germination. Freezing, excessive heat, chemicals and scarification have been tried as methods of making hard seeds permeable, but scarification by machinery designed to scratch or crack the seed coat has proven the most practical method of inducing prompt germination. However, the development of scarification has added other problems to an already complex situation. One of the most important of these is the effect of scarifying upon the keeping quality of seed stocks which must necessarily be carried over from year to year.

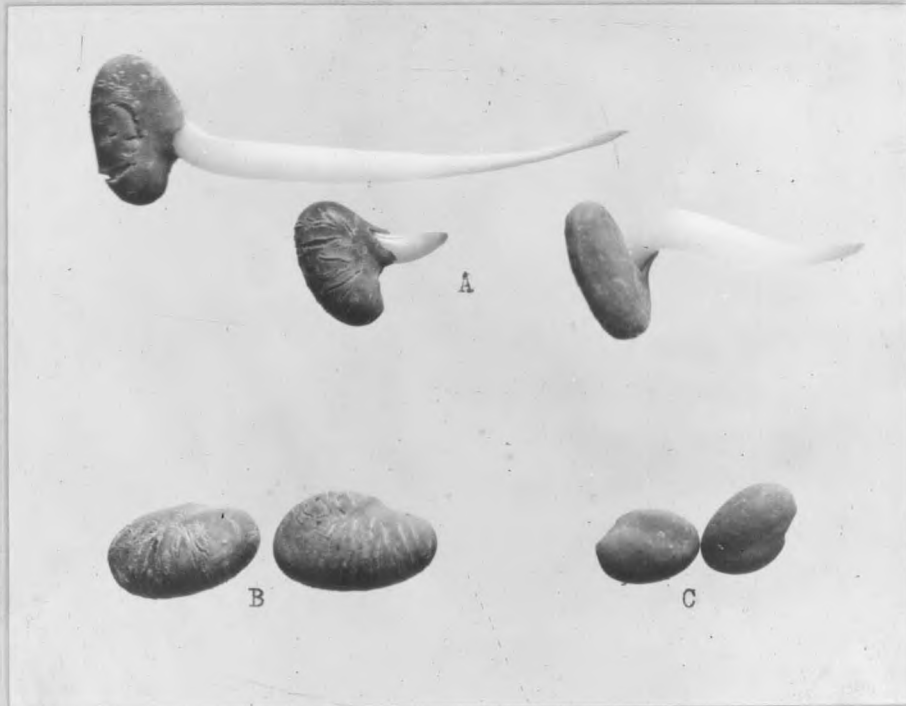


Figure 1. Appearance of hard seeds, germinated seeds and decayed seeds (X 6): A, germinated seeds; B, decayed seeds; C, hard seeds.

REVIEW OF LITERATURE

Scarifying has been successful as a method of overcoming hard seeds in legumes because the seat of impermeability lies so near the surface of the seed.

Nelson (12) working with sweet peas and other large seeded legumes found evidence which led him to believe that impermeability does not lie in the seed coat itself, but in a varnish-like covering on the seed surface produced by the pod. Schmidt (14) believed that hardness of seeds is due to a waxy substance covering the seed coat and consisting of one layer in alfalfa and two layers in sweet clover.

Coe and Martin (2), however, believed that impermeability in sweet clover seed was due to an impervious layer known as the "light line". They describe the light line as extending entirely around the seed coat in the outer layer of the thick walled cells known as Malpighian cells. They found that structurally, permeable and impermeable seeds differ mainly in the amount of thickening which occurs in the walls of the Malpighian cells. They state that the thickening of the Malpighian cells is more complete in the impermeable seeds, leaving fewer and smaller canals across the light line as well as closing the cell lumina in the region of the light line.

Miss Lute, (11), working with alfalfa, concluded that the absorption of water through the seed coat is governed by the palisade cells and not by either the cuticle or the light line. She was able to observe no structural difference between hard and permeable seeds.

White (7), after a microscopical examination of the seed coats of about 70 species of impermeable seeds concluded that, "As a general rule in small and medium-sized seeds the cuticle is well developed, and represents the impermeable part of the seed-coat; whilst in the case of large seeds the cuticle is extremely unimportant and inconspicuous. In these seeds the extreme resistance which they exhibit appears to be located in the palisade cells."

Whitcomb (17), stated that Michalowski of Germany and Nilson of Sweden were among the first to develop machines for reducing the hard seed content of legumes by scratching or breaking the seed coat. The machine perfected by Michalowski consisted of two rollers between which the seed was passed. One roller was roughened like a file, the other was covered by a rubber mat. Nilson's machine scratched the seeds by throwing them against an emery cylinder which revolved at a speed of 3,200 revolutions per minute. Later machines used sandpaper as the abrasive and scarified the seed by forcing it against the sandpaper with motor driven fans. Still later developments employed the use of centrifugal force to throw the seeds against roughened surfaces.

At first investigators were enthusiastic about scarification because laboratory tests showed that practically all of the hard seeds could be eliminated by careful scarifying. Seedsmen quickly adopted scarification because it made seed sales easier by increasing the prompt germination. However, more recent investigators who have conducted field tests and studied the longevity of seeds have begun

to doubt the advisability of scarifying except where a lot of seed has an unusually high hard seed content.

Graber (9) states that, "While the results of experiments indicate the effectiveness of scarification for the improvement of immediate germination, its influence on the longevity of alfalfa seed seems to be deleterious in character."

Whitcomb (17) concluded that, "Field tests indicate that leguminous seeds which contain appreciable amounts of hard seeds are seldom benefited by treatment aimed to reduce the hard seed content except in the case of sweet clover which is in the hull or which contains 50 percent or more of hard seeds."

In reporting on his investigations with hard seeds, Schmidt (15) said, "Scarification of alfalfa seed need not be practiced."

Since seedsmen and farmers frequently keep seed in storage for two or more years, the effect of continued storage upon the vitality of the seed, particularly if scarified, becomes important.

In studying longevity, Dorph-Peterson (4) found that seeds of legumes with good initial germination retained it in the third year. After three years the germination declined, but the hard seed content remained nearly constant.

Wahlen (16) found red clover to germinate 24.4 percent with 56.8 percent hard seeds after being stored for 14 years in bottles at room temperatures. Alsike clover germinated 33.3 percent with 59.8 percent hard seeds.

Lafferty (10) reported that a sample of red clover seed having

an original germination of 94 percent with 5 percent hard seeds germinated 33 percent with 4 percent hard seeds when stored in paper bags in the laboratory for two years, and 0 with 3 percent hard seeds after 12 years. White clover and alsike lost vitality more gradually, but were nearly as low as the red clover by the end of the 12-year period.

Graber (9) found that alfalfa seed stored in a cool dry basement showed a fairly proportionate decrease in germination with age. Three lots of seed germinated 47 percent after they had been in storage for 10 to 12 years.

Dowell (5) bases the following conclusions on the results of four years' work:

1. "Scarified seed of either alfalfa or sweet clover may be stored one year without serious loss in viability.
2. "Scarified seed of both alfalfa and sweet clover lose viability rapidly after one year in storage.
3. "Unscarified sweet clover seed may be kept in storage several years without loss in viability.
4. "Hard seeds in alfalfa become viable after one or more years in storage."

The method of storage and degree of hardness play an important part in the longevity of the seed. Duval (6) found that the vitality of seeds was best preserved when the seeds were carefully harvested and stored in a dry comparatively cool place. The results of his tests show that alfalfa and red clover lost vitality very rapidly

when stored in the soil at three depths: 6 to 8 inches, 18 to 22 inches, and 36 to 42 inches. Goss (8) reporting on a continuation of Duval's work found that there were no viable seeds of alfalfa left after six years in storage but red clover still had a few viable seeds after 21 years. Seed of some species of weeds, however, germinated over 90 percent after being stored in the soil for 21 years. After the first few years, practically all the viable seeds of red clover and alfalfa were hard seeds.

In 1879, Beal (1) buried 20 lots of fresh seeds from 21 species in uncorked bottles. The seeds were mixed with sand in the bottles and buried 20 inches below the surface on a sandy knoll. Tests were made at five year periods. There were no viable seeds of white clover at the end of the first five year period.

Darlington (3) reporting on a continuation of Beal's experiment, found that certain species of weeds, notably *Amaranthus*, *Oenothera* and *Brassica* still had good germination after 40 years.

One of the most convincing records of longevity in hard seeds is that reported by Ohga (13) in which he secured 100 percent germination from seeds of Hindu lotus which he estimated had been buried not less than 120 years, and might have been buried as long as 200, or even 400 years. These seeds were found from one-half to two-thirds of a meter below the surface.

Ewart (7) secured 70.3 percent germination from seeds of *Melilotus gracilis* after they had been stored in a dry, airy, dark cupboard for 50 years. He states that, "Even the most resistant seeds after 50 to

100 years show a pronounced decrease in the percentage of germination, and the general trend of the curves is such as to show that the probable extreme duration of vitality for any known seed may be set between 150 and 250 years."

EXPERIMENTAL

Purpose of Study

This report gives the results of a study planned to determine; (1) the effect of different methods of storage on the vitality of scarified and non-scarified seeds of alfalfa, red clover and sweet clover; (2) the effect of scarification on the vitality of these seeds during storage; (3) the length of time that these seeds may be stored without serious loss of vitality.

Laboratory and field germination tests were used as the measure of vitality. The tables and graphs have been arranged so as to present the data from several angles, and to give the reader all the information available from this study.

Method of Procedure

In June, 1924, one lot each of alfalfa, sweet clover and red clover was divided into three parts. Part one was carried through the experiment without scarification. Using the "Ames Huller and Scarifier",* part two was scarified at a speed of 2,040 revolutions

*A photograph of the "Ames Huller and Scarifier" used in this experiment is shown in Figure 2. The seed passes through the fan "B", and around the loop "C", which is lined with coarse sand paper.



Figure 2. Ames Huller and Scarifier used in scarifying seed for these experiments. B, fan which forces seed around loop C. C, loop lined with coarse sandpaper for scratching the seed coat.

per minute, and part three at the rate of 2,885 revolutions per minute. After scarifying parts two and three, each of the three parts of the original lot was divided into six lots and stored as follows:

- A. Cloth sack in seed laboratory, at temperatures ranging from 17 to 25 degrees centigrade.
- B. Air-tight bottle in seed laboratory, temperatures as above.
- E. Air-tight bottle in seed laboratory, moisture 12 percent,* temperatures as above.
- C. Cloth sack in cold storage, temperatures ranging from two to six degrees centigrade.
- D. Air-tight bottle in cold storage, temperatures as above.
- F. Air-tight bottle in cold storage, moisture 12 percent, temperatures as above.

Laboratory and field germination tests were made at the time the seed was put in storage. Similar tests were made each spring thereafter to determine the vitality of the seed after storage.

In June, 1926, three additional lots each of alfalfa, red clover and sweet clover were added to this experiment. In this instance, the lots were divided into two parts, one scarified at 2,450 revolutions per minute, the other used as a check without scarification. The conditions under which the seed was stored for this part of the experiment were the same as for that started in June 1924, except that no seed was stored with 12 percent moisture.

*The seed stored with 12 percent moisture in 1924 had an average moisture content of 9.5 percent in 1932.

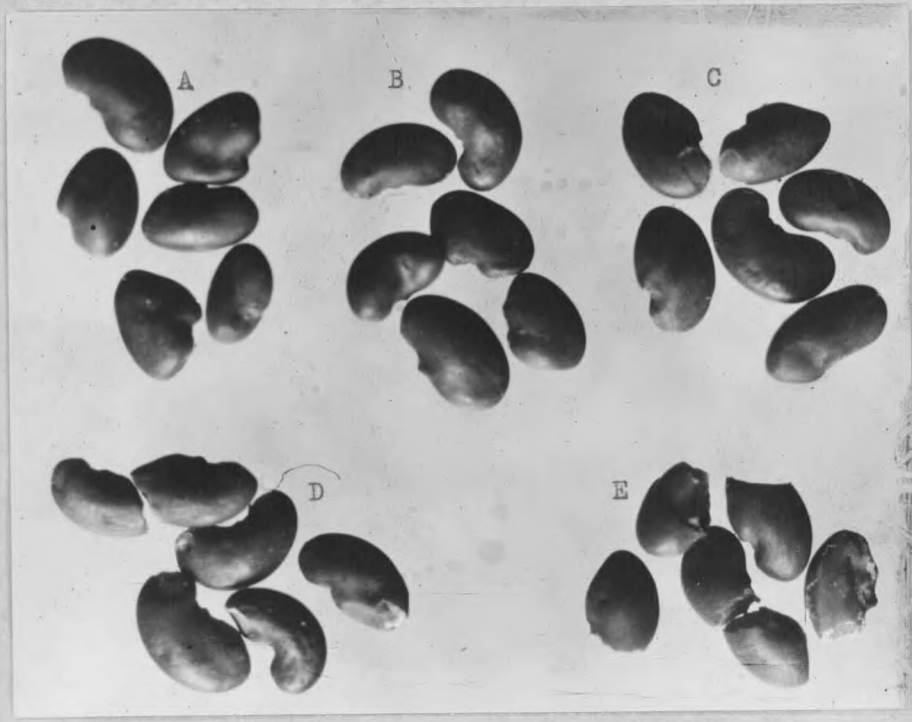


Figure 3. Appearance of seed after scarifying (X 6):
A, scarified but showing no injury; B, seed coat cracked or chipped; C, portion of cotyledon exposed but not broken; D, small portion of cotyledons broken away; E, about one-third of cotyledons broken away.

Blotting paper was used as the substratum for making the laboratory germination tests. Duplicate tests of 100 seeds each were made at a constant temperature of 20 degrees centigrade. Preliminary counts were made in three days and the final counts in six days.

The field tests were made in three foot rows one foot apart using two replications of 100 seeds. In making the field tests care was taken to provide as near optimum soil and moisture conditions as possible. Thirty to 50 days were required for the field tests.

RESULTS AND DISCUSSION

Tables I to IV, VII to X and XIII to XVI give the results of the laboratory and field germination tests secured during this experiment. The "total vitality" of the seed from year to year, determined by adding the percentages of prompt germination and hard seeds, is given in Tables V, VI, XI, XII, XVII and XVIII. In Figures 4 to 6, 10 to 12, and 16 to 18, comparisons of the effect of storage on the germination and hard seed percentages of scarified seed and non-scarified seed are shown graphically. These results were obtained by averaging all methods of storage. Figures 7 to 9, 13 to 15, and 19 to 21 show the effect of different methods of storage upon the germination and hard seed percentages when all tests for each method of storage were averaged.

Experiments With Alfalfa Seed

Scarifying alfalfa seed increased the initial laboratory germination. These increases in germination were carried through the first

Table I
 Laboratory germination of scarified and non-scarified alfalfa seed
 stored under different conditions

Lot No.	Scarification	Storage method	1924		1925		1926		1927		1928		1929		1930		1931	
			Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %
1	none	A	61	36	62	20	48	20	43	18	48	14	46	8	41	7	43	6
		B			57	17	35	10	57	6	40	10	46	4	47	4	48	2
		E			47	12	32	7	34	1	24	2	18	3	23	2	17	6
		C			51	28	41	21	38	12	33	13	33	14	35	9	27	8
		D			55	27	49	22	53	18	46	28	53	11	53	7	46	8
		F			54	25	44	20	41	23	40	36	48	8	37	12	41	9
1	2040 R.P.M.	A	73	25	71	9	33	4	36	6	36	7	29	9	32	3	35	4
		B			71	8	52	6	29	6	38	5	33	6	31	2	33	3
		E			52	4	28	3	21	3	21	2	26	0	13	1	12	2
		C			65	13	44	9	34	9	28	9	35	6	28	4	23	2
		D			64	18	49	12	54	9	49	6	38	10	42	6	34	5
		F			61	15	47	11	45	9	42	8	37	9	34	4	37	5
1	2885 R.P.M.	A	81	15	67	7	25	4	23	2	27	3	25	4	27	1	22	1
		B			75	1	32	3	23	1	24	3	23	2	18	1	20	1
		E			51	2	17	1	7	1	4	0	1	1	3	0	1	0
		C			75	7	54	4	40	4	22	2	18	1	21	1	10	1
		D			63	6	60	4	57	2	48	4	47	1	41	1	25	2
		F			69	2	58	6	48	6	38	4	45	2	35	3	20	0

*See page 11 for detailed explanation of storage methods.

Table II
 Laboratory germination of scarified and non-scarified alfalfa seed
 stored under different conditions

Lot No.	Scarifi- cation	Storage method	1926		1927		1928		1929		1930		1931	
			Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent		
2	none	A	52	45	67	21	66	13	66	14	68	8	69	8
		B			66	25	67	15	71	8	71	7	73	2
		C			57	31	63	25	63	26	63	21	57	23
		D			57	37	63	22	62	27	66	20	59	16
2	2450 R.P.M.	A	64	20	74	8	63	3	42	7	44	3	39	0
		B			73	7	62	2	46	1	45	2	40	2
		C			80	5	81	7	73	3	68	4	68	2
		D			77	7	82	4	73	2	69	2	71	2
3	none	A	37	57	57	33	68	19	64	17	70	12	67	11
		B			67	18	72	16	72	16	71	10	71	8
		C			55	35	60	25	61	27	64	20	58	18
		D			55	27	61	31	58	28	57	21	66	20
3	2450 R.P.M.	A	61	18	72	7	60	3	40	5	37	1	35	2
		B			76	7	53	2	56	4	36	2	38	2
		C			70	8	71	2	61	6	73	1	58	3
		D			65	6	69	7	65	4	57	2	56	4
4	none	A	36	60	57	33	69	23	69	22	81	9	74	10
		B			59	34	68	26	71	23	80	6	74	8
		C			43	49	44	51	48	46	66	29	67	22
		D			52	46	46	49	56	37	45	40	58	31
4	2450 R.P.M.	A	63	26	77	9	62	10	52	7	51	5	52	4
		B			72	14	58	10	54	15	56	9	50	4
		C			68	17	76	11	78	7	76	5	67	4
		D			69	16	77	12	78	11	73	8	65	4

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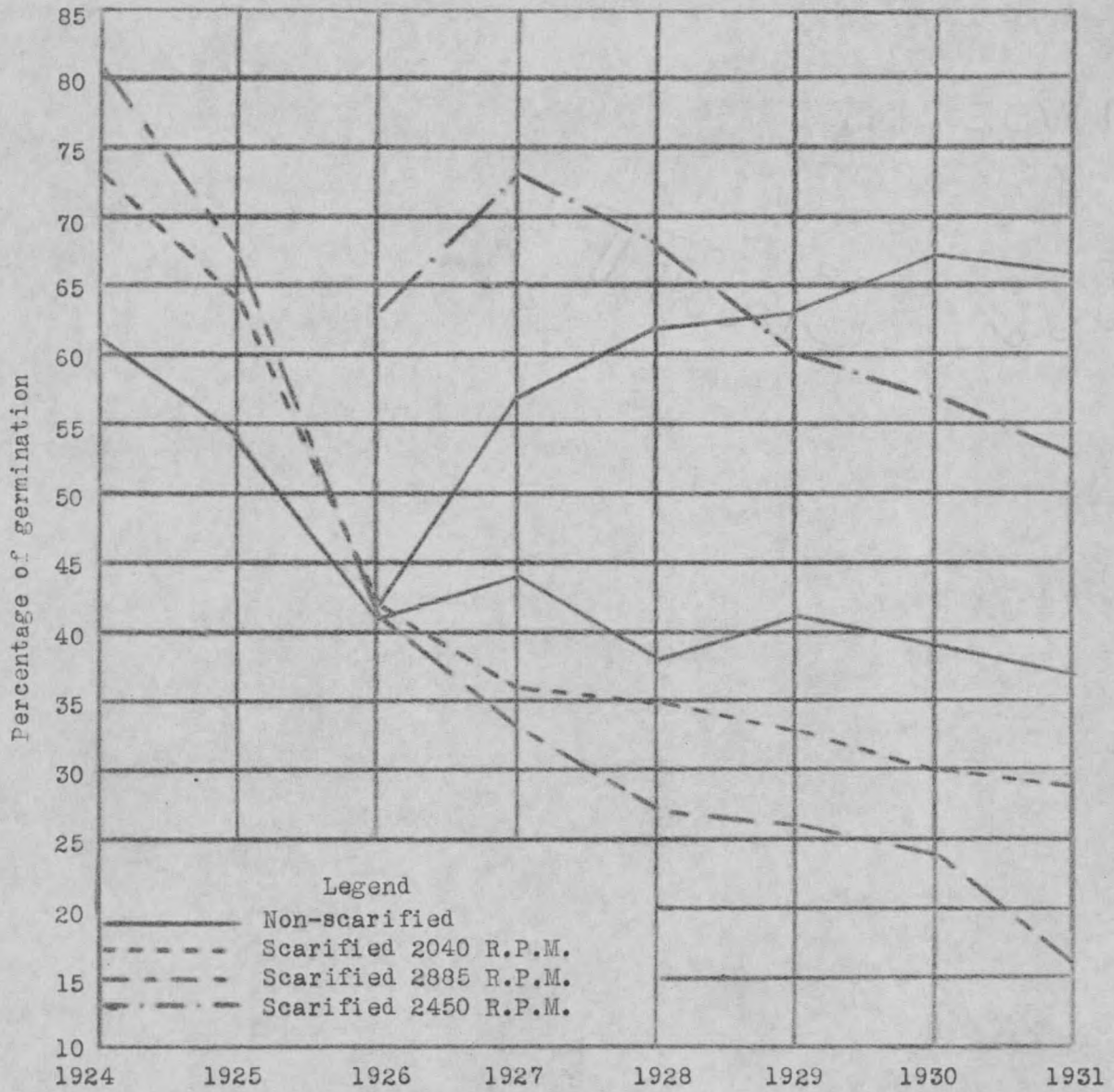


Figure 4. Laboratory germination of scarified and non-scarified alfalfa seed.

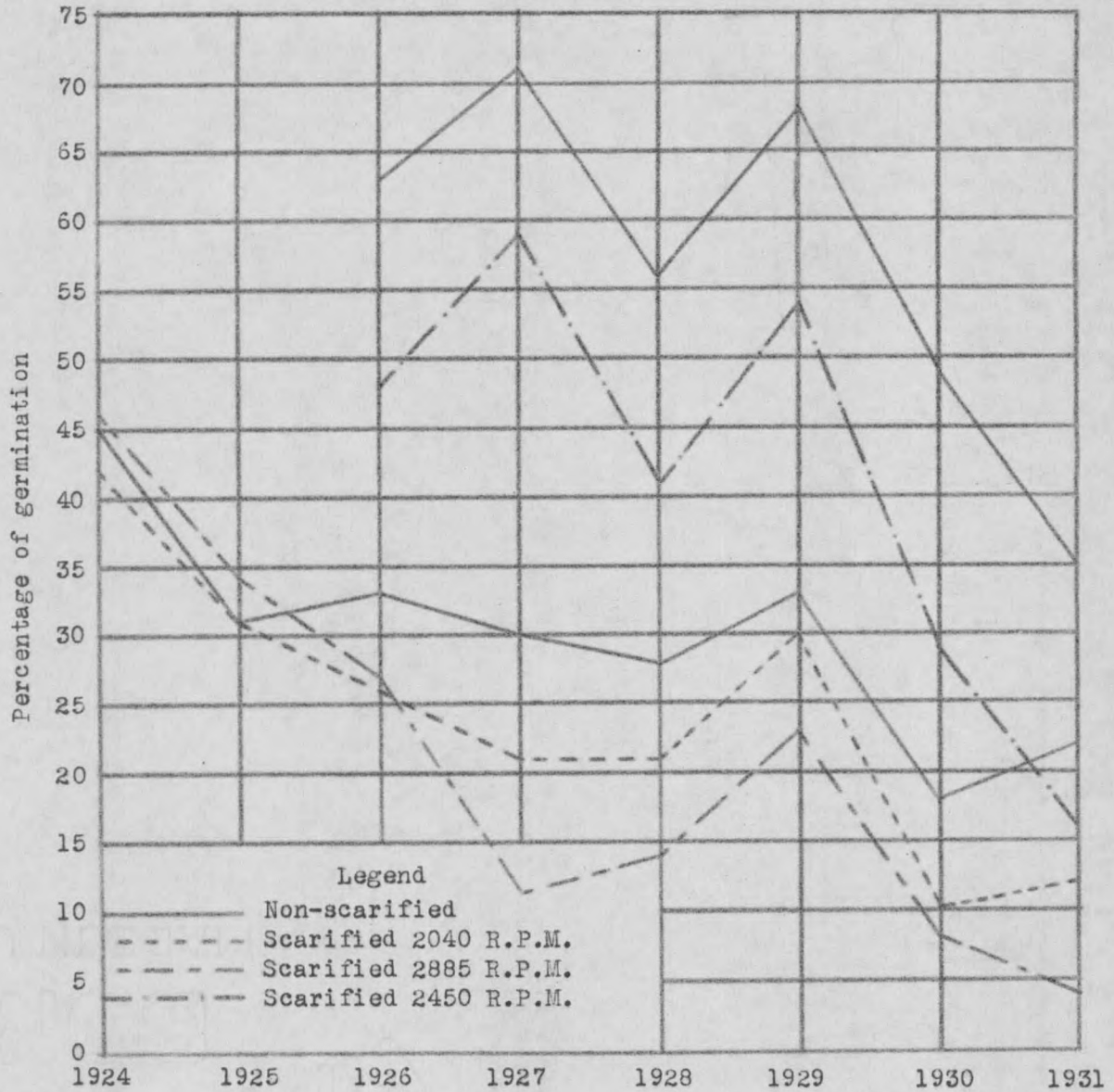


Figure 5. Field germination of scarified and non-scarified alfalfa seed.

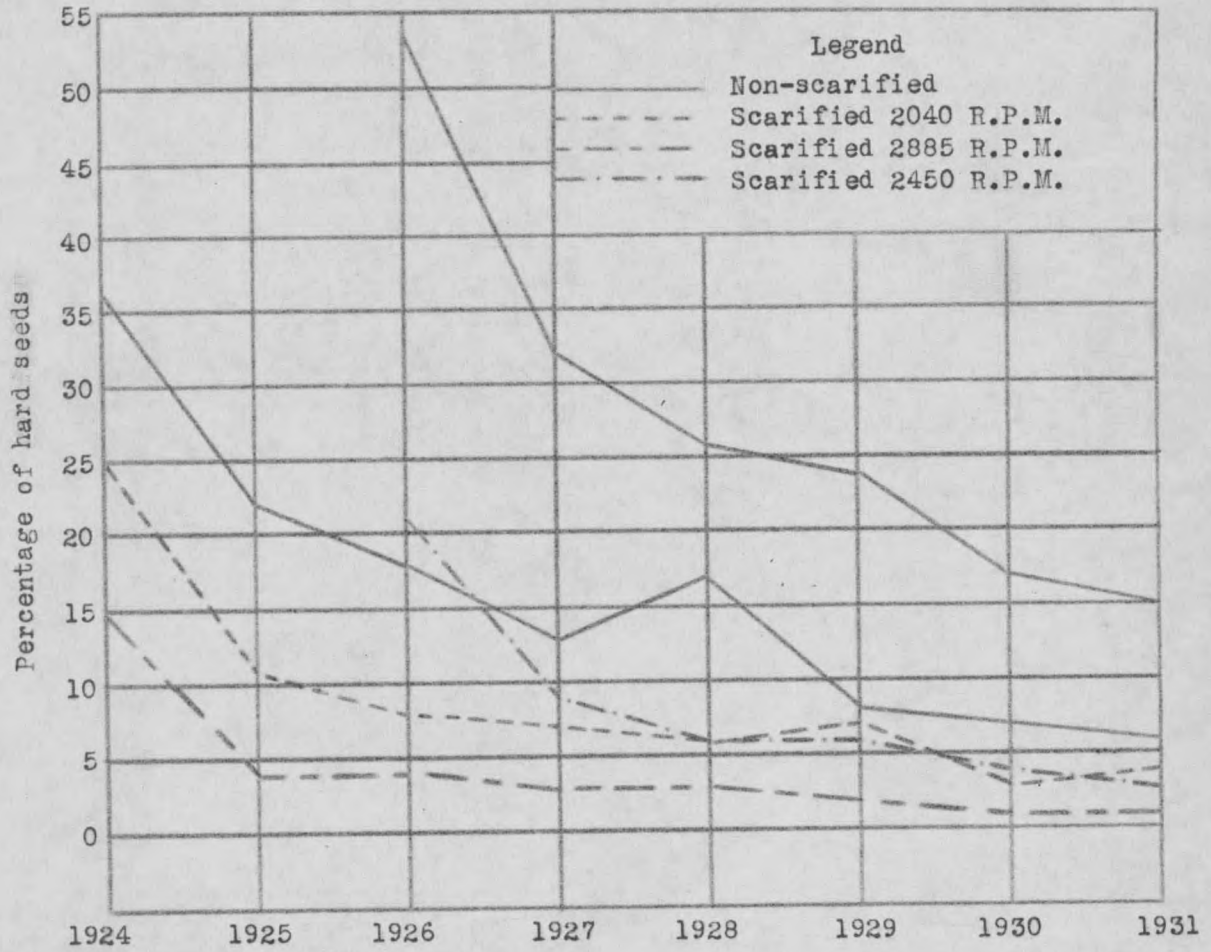


Figure 6. Hard seed content of scarified and non-scarified alfalfa seed.

year of storage, but after two years, the germination of the scarified seed was practically the same as that of the non-scarified seed, and for the remainder of the experiment was lower than that of the non-scarified lot. The initial germination of the non-scarified alfalfa seed was 61 percent;* when scarified at 2,040 revolutions per minute, 73 percent; and at 2,885 revolutions, 81 percent. (Table I). If an average of all methods of storage can be taken as representative, the germination after two years of storage was 41 percent for the non-scarified seed, and 42 and 41 percent respectively for the scarified seed. In 1931, after seven years of storage, the germination was 37, 29, and 16 percent respectively. (Figure 4). The hard seed*content of both scarified and non-scarified alfalfa decreased rapidly during the first year, and more gradually thereafter. The initial hard seed content was 36 percent for the non-scarified seed, 25 percent for the seed scarified at 2,040 revolutions per minute, and 15 percent for that scarified at 2,885 revolutions per minute. In 1925, after one year of storage it was 21, 11, and 4 percent, and in 1931, after seven years, 7, 3, and 1 percent respectively. (Figure 6).

Seed containing 12 percent moisture and stored in air-tight bottles in the laboratory showed the most marked decrease in germination. (Figure 7). The initial germination of the non-scarified

*The germination as stated by seed companies on their labels is the sum of the percentages of prompt germination and hard seeds but the percentage of germination as used in this paper does not include hard seeds.

*The term hard seed is used in this paper to designate seeds which remained impermeable to water during the six day germination test.

Table III
Field germination of scarified and non-scarified alfalfa seed
stored under different conditions

Lot No.	Scarifi- cation	Storage method	1924 Germ. %	1925 Germ. %	1926 Germ. %	1927 Germ. %	1928 Germ. %	1929 Germ. %	1930 Germ. %	1931 Germ. %
1	none	A	45	36	41	40	34	36	13	32
		B		30	34	45	27	38	23	23
		E		32	23	15	20	8	6	6
		C		24	36	19	18	26	24	18
		D		34	33	34	34	53	26	29
		F		31	33	26	27	36	17	23
1	2040 R.P.M.	A	42	27	26	19	22	28	10	16
		B		38	15	24	27	32	17	14
		E		28	21	13	14	14	3	3
		C		36	23	19	14	22	13	14
		D		30	29	25	25	44	13	16
		F		26	41	25	22	39	7	11
1	2885 R.P.M.	A	46	25	20	9	15	20	6	8
		B		31	23	11	15	17	9	2
		E		29	16	4	3	2	1	1
		C		41	31	11	13	14	7	5
		D		44	36	20	21	33	14	5
		F		36	39	14	16	34	14	6

Table IV
Field germination of scarified and non-scarified alfalfa
seed stored under different conditions

Lot No.	Scarifi- cation	Storage method	1926 Germ. %	1927 Germ. %	1928 Germ. %	1929 Germ. %	1930 Germ. %	1931 Germ. %
2	none	A	52	70	51	64	41	47
		B		78	49	67	40	22
		C		63	57	69	42	31
		D		77	43	67	48	26
2	2450 R.P.M.	A	40	60	42	50	18	11
		B		50	35	47	24	10
		C		49	50	63	47	14
		D		64	42	64	35	11
3	none	A	63	74	51	77	36	20
		B		79	55	83	45	24
		C		77	56	66	51	30
		D		69	54	65	78	33
3	2450 R.P.M.	A	45	60	27	42	24	6
		B		60	31	41	12	14
		C		57	37	69	33	20
		D		55	48	56	29	9
4	none	A	74	71	66	73	56	41
		B		73	71	66	50	38
		C		60	54	63	40	53
		D		66	69	54	61	53
4	2450 R.P.M.	A	58	62	44	39	25	5
		B		61	40	41	42	20
		C		69	48	72	26	35
		D		65	44	66	29	35

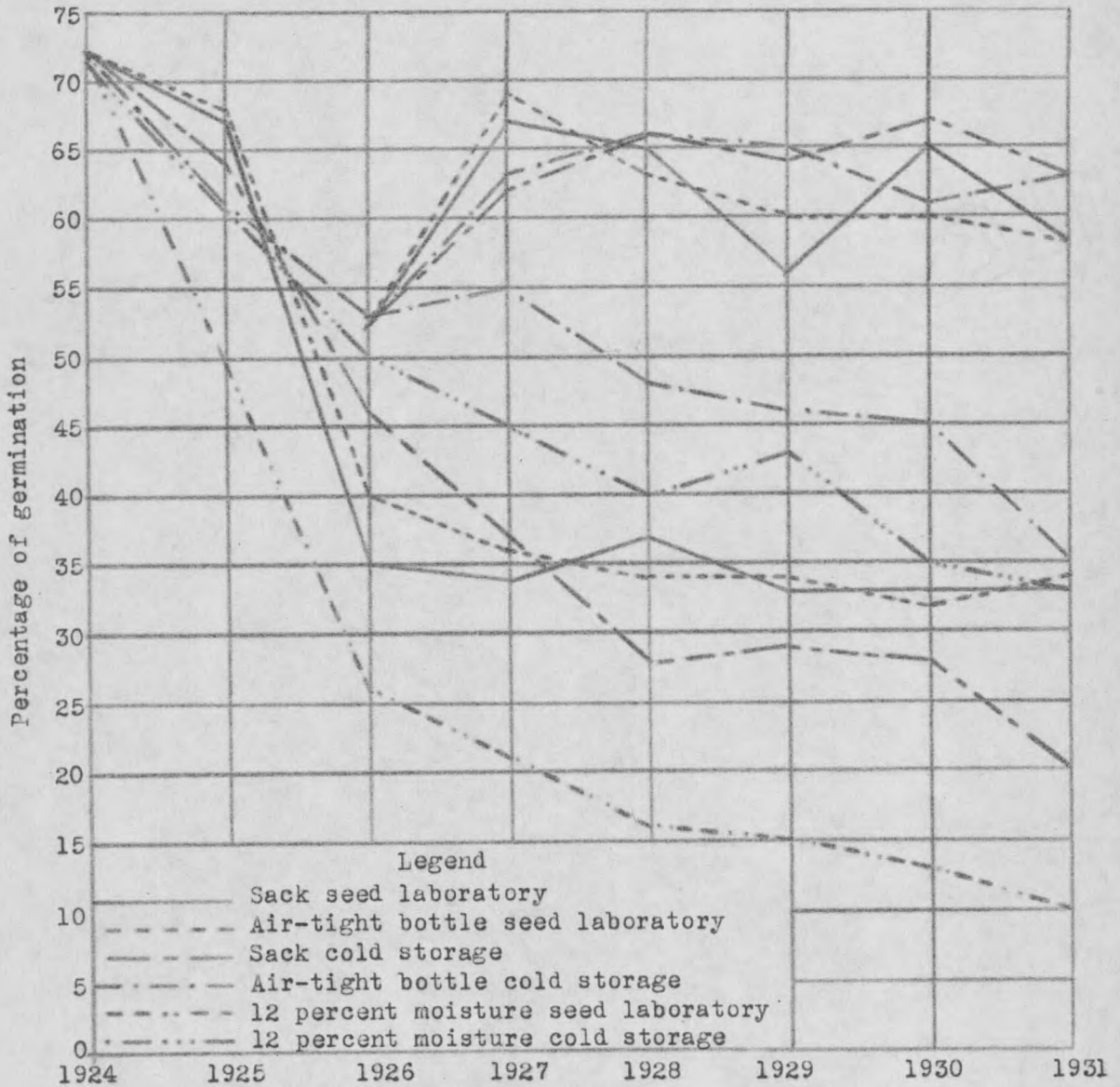


Figure 7. Laboratory germination of alfalfa seed comparing different methods of storage. (See page 13)

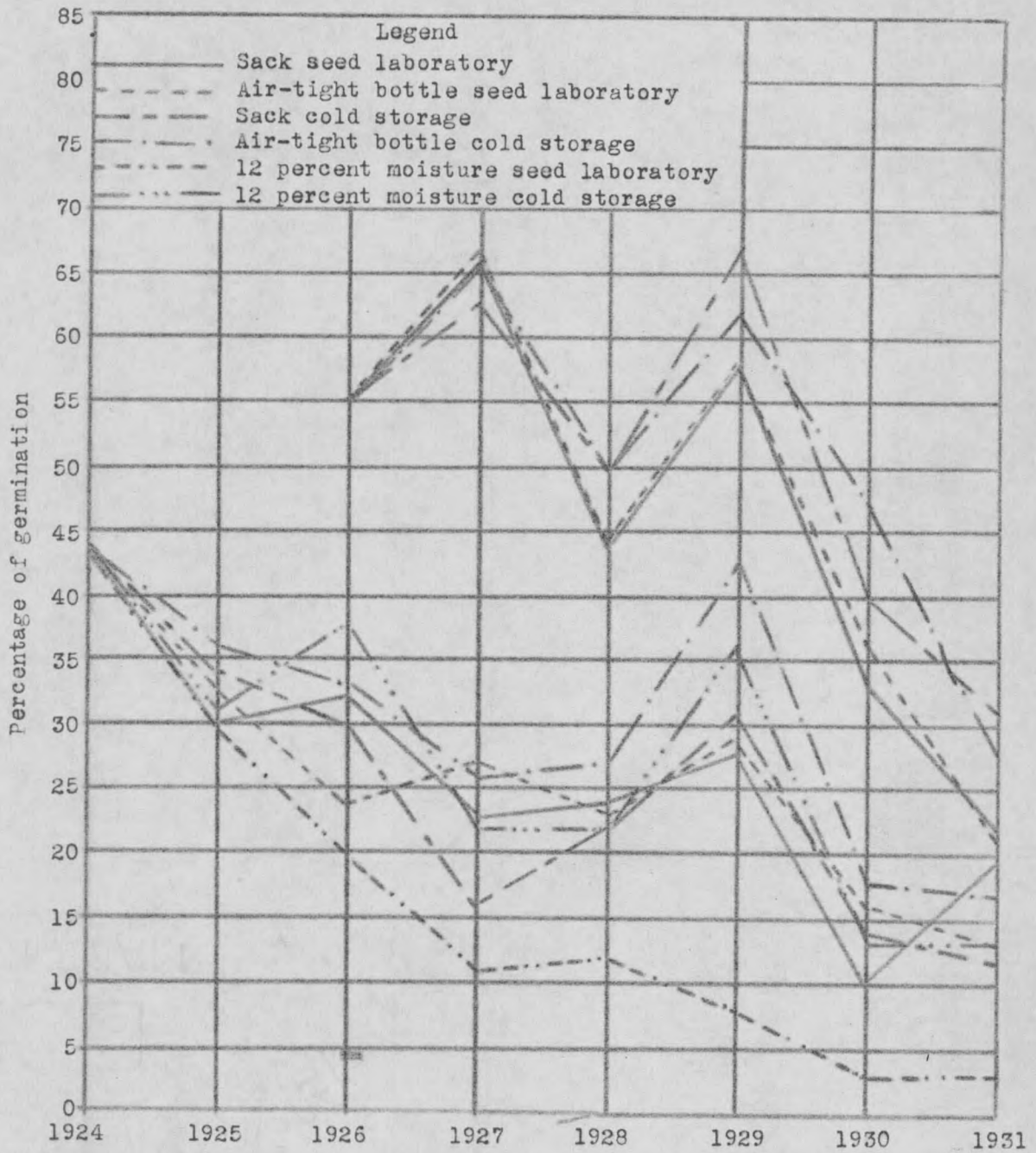


Figure 8. Field germination of alfalfa seed comparing different methods of storage. (See page 13)

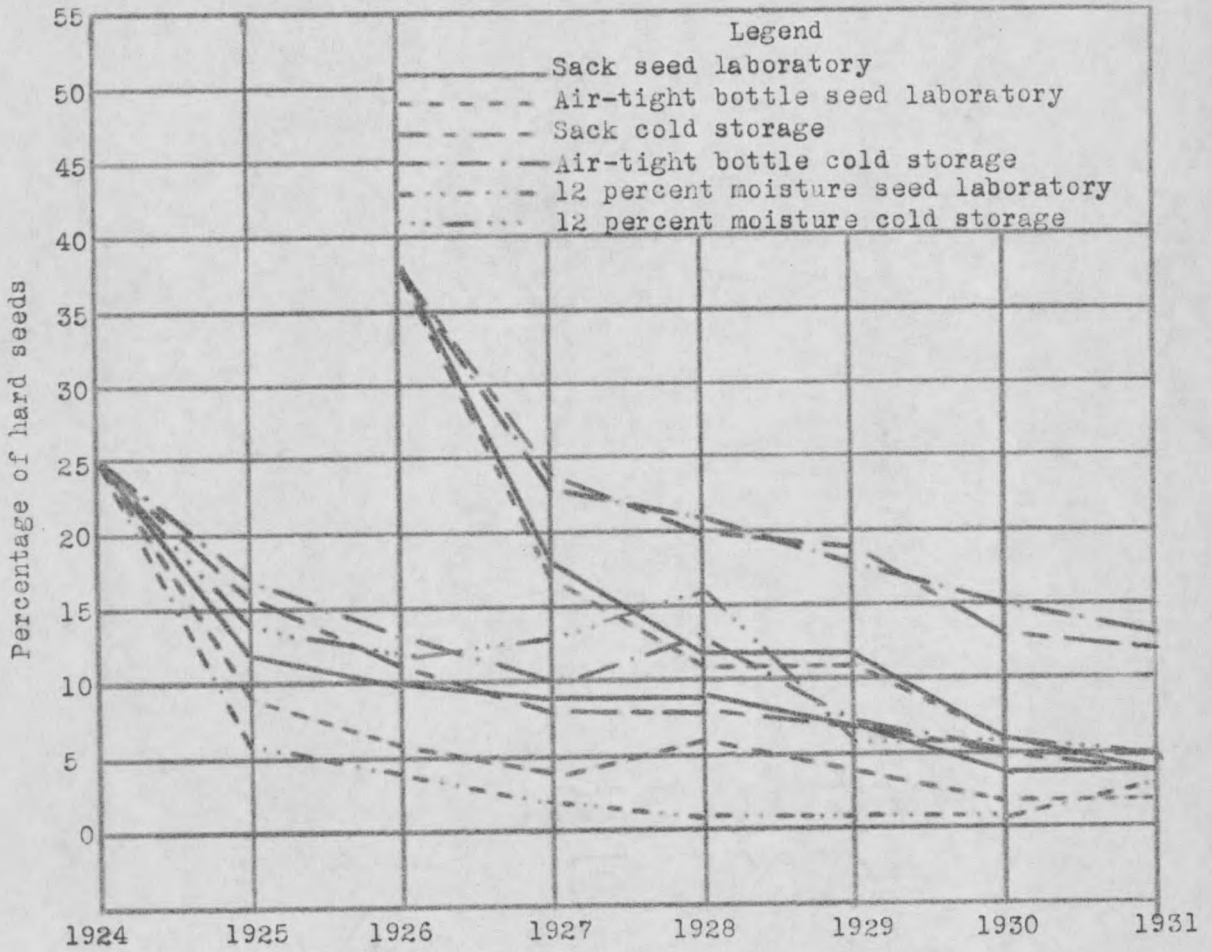


Figure 9. Hard seed content of alfalfa comparing different methods of storage. (See page 13)

alfalfa seed was 61 percent plus 36 percent hard seed. (Table I). In the second year, the non-scarified seed stored in the laboratory at 12 percent moisture germinated 47 percent plus 12 percent hard seed. The final germination in 1931 was 17 percent plus 6 percent hard seed. This loss in germination was even more pronounced for the scarified seed stored in the laboratory with 12 percent moisture. The 1931 germination of this seed scarified at 2,040 revolutions per minute was 12 percent plus 2 percent hard seed, and that scarified at 2,885 revolutions per minute was only 1 percent, with no hard seeds. On the other hand seed with 12 percent moisture did not decrease any more rapidly in germination than the dry seed when kept in cold storage. (Figure 7).

Figure 7 also shows that there was no advantage in having the seed in air-tight bottles when stored in the laboratory. From 1926 on, however, the seed stored in air-tight bottles in cold storage gave the highest germination. After 1927 seed kept in sacks in cold storage had lower germination than seed kept in sacks in the laboratory.

The germination of alfalfa under field conditions was not increased by scarifying. The initial germinations were 45 percent for the non-scarified seed, 42 percent for that scarified at 2,040 revolutions per minute and 46 percent for that scarified at 2,885 revolutions per minute. (Table III). With the exception of the seed stored in the laboratory with 12 percent moisture the field germination of the non-scarified seed fell off slowly during the length

Table V
 Percent total vitality*of scarified and non-scarified alfalfa seed
 stored under different conditions

Lot No.	Scarifi- cation	Storage method	1924	1925	1926	1927	1928	1929	1930	1931
1	none	A	97	82	68	61	62	54	48	49
		B		64	45	63	50	50	51	50
		E		59	39	35	26	21	25	23
		C		79	62	50	46	47	44	35
		D		82	71	71	74	64	60	54
		F		79	64	64	76	56	49	50
1	2040 R.P.M.	A	98	80	37	42	43	38	35	39
		B		79	58	35	43	39	33	36
		E		56	31	24	23	26	14	14
		C		78	53	43	37	41	32	25
		D		82	61	63	55	48	48	39
		F		76	58	54	50	46	38	42
1	2885 R.P.M.	A	96	74	29	25	30	29	28	23
		B		76	35	24	27	25	19	21
		E		53	18	8	4	2	3	1
		C		82	58	44	24	19	22	11
		D		69	64	59	52	48	42	27
		F		71	64	54	42	47	38	20

*Percent total vitality determined by adding percent prompt germination and percent of hard seeds.

Table VI
 Percent total vitality of scarified and non-scarified
 alfalfa seed stored under different conditions

Lot No.	Scarification	Storage method	1926	1927	1928	1929	1930	1931
2	none	A	97	88	79	80	76	77
		B		91	80	79	78	75
		C		88	88	89	84	80
		D		94	85	89	86	75
2	2450 R.P.M.	A	84	82	66	49	47	39
		B		80	64	47	47	42
		C		85	88	76	72	70
		D		84	86	75	71	73
3	none	A	94	90	87	81	82	78
		B		85	88	88	81	79
		C		90	85	88	84	76
		D		82	92	86	78	86
3	2450 R.P.M.	A	79	79	63	45	38	37
		B		83	55	60	38	40
		C		78	73	67	74	61
		D		71	76	69	59	60
4	none	A	96	90	92	91	90	84
		B		93	94	94	86	82
		C		92	95	94	95	89
		D		98	95	93	85	89
4	2450 R.P.M.	A	89	86	72	59	56	56
		B		86	68	69	65	54
		C		85	87	85	81	71
		D		85	89	89	81	69

of the experiment. The scarified seed lost vitality more rapidly (Figure 5) although the decrease was not as pronounced as was the case with the blotter tests. Figure 8 shows the effect of different methods of storage on field germination. Seed stored in the laboratory with 12 percent moisture lost vitality very rapidly. There was no great difference between the other methods of storage, although seed kept in air-tight bottles in cold storage consistently gave slightly higher germination.

It will be noted that the field germination of alfalfa seed was higher in 1929 than in 1928. This believed to be due to the almost ideal conditions under which the field tests were made in 1929, whereas, the tests in other years were made under more nearly average conditions. Sweet clover and red clover also showed higher germination resulting from the exceptionally favorable conditions prevailing in 1929.

The total vitality of the alfalfa seed, determined by adding the percentages of prompt germination and hard seeds, is shown in Tables V and VI. Scarification did not affect the total vitality of the seed scarified in 1924, but lowered the vitality of that scarified in 1926. The seed stored in 1924 showed rapid decreases in total vitality during the first two years of storage but fell off slowly during the remainder of the experiment. The non-scarified seed retained its vitality to a greater degree than the scarified seed. The seed stored in the laboratory with 12 percent moisture lost vitality most rapidly while that stored in air-tight bottles in cold

Table VII
Laboratory germination of scarified and non-scarified sweet clover seed
stored under different conditions

Lot No.	Scarification	Storage method	1924		1925		1926		1927		1928		1929		1930		1931	
			Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %	Germ. %	H. S. %
1	none	A	20	72	24	66	14	71	16	69	17	68	18	55	15	68	12	69
		B			22	69	17	68	17	67	17	67	16	72	17	71	12	68
		E			3	75	2	58	2	68	1	63	1	60	3	57	4	53
		C			58	59	55	32	49	21	41	36	34	29	35	27	40	21
		D			41	46	50	40	48	39	48	41	43	37	47	34	44	27
		F			58	24	44	30	48	24	50	27	35	20	34	28	23	20
1	2040 R.P.M.	A	48	43	51	34	34	45	45	30	39	34	30	38	39	33	29	43
		B			52	36	47	34	34	38	39	37	32	42	32	29	33	31
		E			31	32	23	35	21	25	23	28	18	24	12	27	15	31
		C			75	18	61	21	47	16	48	17	36	17	28	13	42	11
		D			64	27	62	22	65	18	55	20	55	21	49	16	54	13
		F			69	16	54	18	48	14	42	16	36	16	42	8	25	8
1	2885 R.P.M.	A	61	30	59	26	38	22	38	21	35	20	25	19	36	12	33	25
		B			65	22	35	16	39	17	22	16	31	16	33	21	35	16
		E			33	16	5	14	2	12	3	9	1	10	2	12	1	4
		C			81	6	70	7	45	5	40	8	27	8	36	6	29	4
		D			80	12	62	13	54	7	67	7	49	7	40	7	44	5
		F			77	11	57	9	28	9	33	7	21	6	10	9	12	5

storage had a consistent advantage over the other methods of storage.

The three lots of alfalfa added to this experiment in 1926 were selected because of their exceptionally high hard seed content.

Although these lots were in storage only five years, the results are similar to those obtained from the seed stored in 1924. The field germination was lower with the scarified seed but the initial laboratory germination was increased by scarification. The hard seed content of these lots decreased rapidly during the first two years of storage but the germination increased. (Table II). After two years of storage, however, the germination slowly decreased. The loss in vitality in both the laboratory and field tests was slowest with the samples of highest hard seed content and the scarified seed lost vitality most rapidly. From the standpoint of total vitality there was no advantage in favor of any method of storage for the non-scarified seed stored in 1926. In the case of scarified seed, however, cold storage began to show a decided advantage after the second year.

(Table VI).

Experiments With Sweet Clover Seed

The results secured from the experiments with sweet clover seed differ from those obtained with alfalfa seed in four important points: (1) the loss of vitality in storage was not as rapid; (2) the hard seed content did not decrease rapidly during the first year of storage but decreased gradually during the entire length of the experiment; (3) scarifying increased the field germination which benefit was still apparent after the seed had been in storage for six years

Table VIII
 Laboratory germination of scarified and non-scarified sweet clover seed
 stored under different conditions

Lot No.	Scarifi- cation	Storage method	1926		1927		1928		1929		1930		1931	
			Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent	Germ. Percent	H.S. Percent
2	none	A	18	55	15	61	16	55	14	53	11	57	8	56
		B			19	59	17	49	15	53	16	53	9	48
		C			22	55	25	58	44	31	36	34	54	9
		D			22	51	34	44	29	45	34	35	44	8
2	2450 R.P.M.	A	72	9	67	5	54	6	49	9	38	5	39	7
		B			68	7	66	12	53	5	47	6	35	4
		C			76	3	70	6	68	2	54	4	56	2
		D			72	8	75	4	62	6	52	4	44	1
3	none	A	35	43	24	40	14	53	25	45	26	47	21	40
		B			50	59	21	37	25	43	31	51	19	35
		C			29	57	48	33	35	35	33	29	51	8
		D			37	53	44	52	37	33	41	24	55	9
3	2450 R.P.M.	A	59	16	60	14	67	11	50	10	42	12	29	6
		B			66	5	54	7	50	13	40	7	26	10
		C			81	9	71	8	61	7	55	3	46	2
		D			64	8	69	11	57	5	55	5	44	2
4	none	A	18	71	25	58	16	63	21	67	14	63	17	49
		B			20	65	25	58	18	62	18	68	15	64
		C			25	63	32	48	54	49	50	52	41	27
		D			17	70	27	54	26	56	28	53	40	34
4	2450 R.P.M.	A	70	16	46	16	63	12	47	17	45	11	34	8
		B			63	10	65	10	47	11	39	12	45	6
		C			75	11	74	8	65	7	56	8	55	3
		D			73	9	70	6	67	7	56	7	48	4

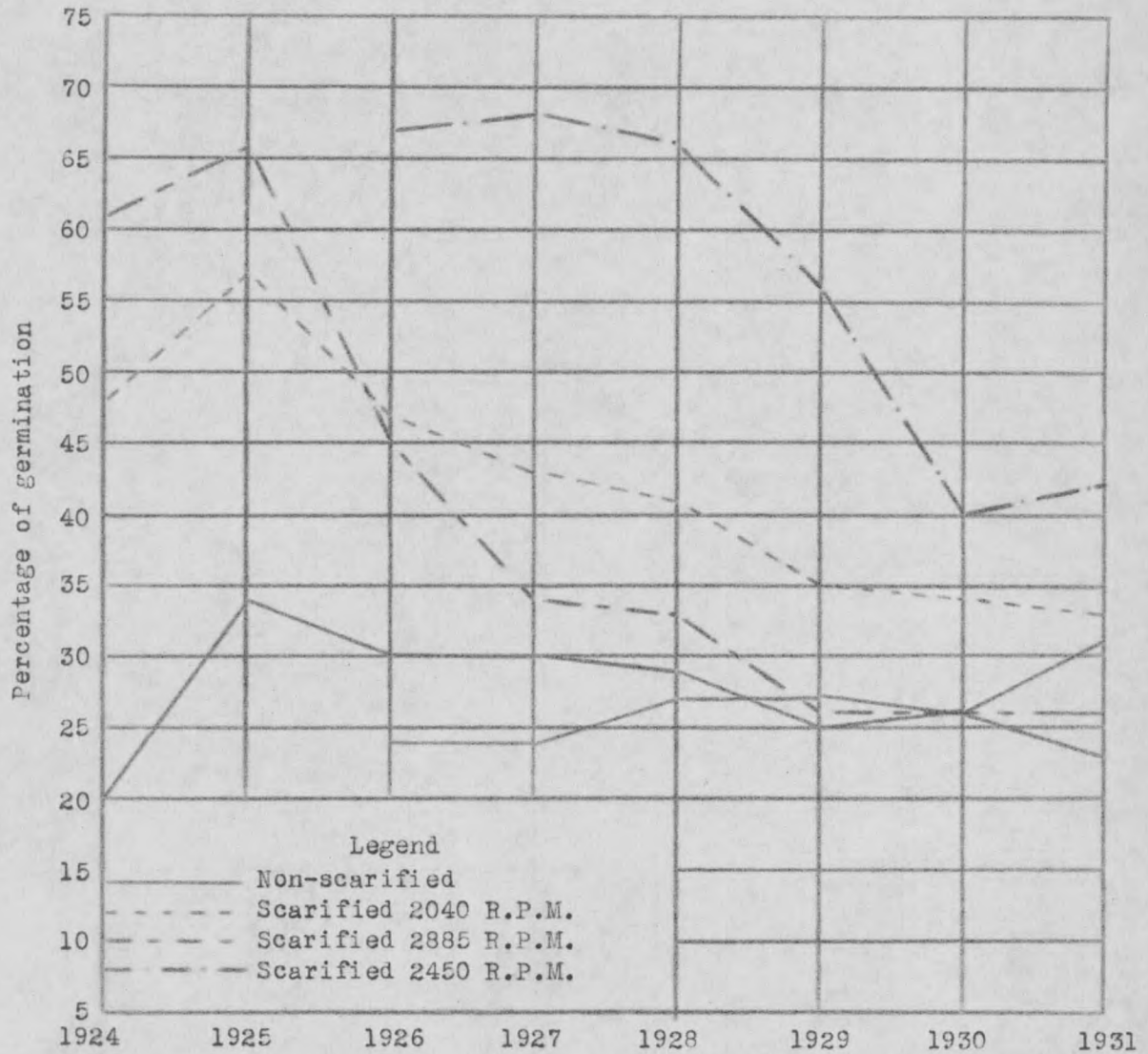


Figure 10. Laboratory germination of scarified and non-scarified sweet clover seed.

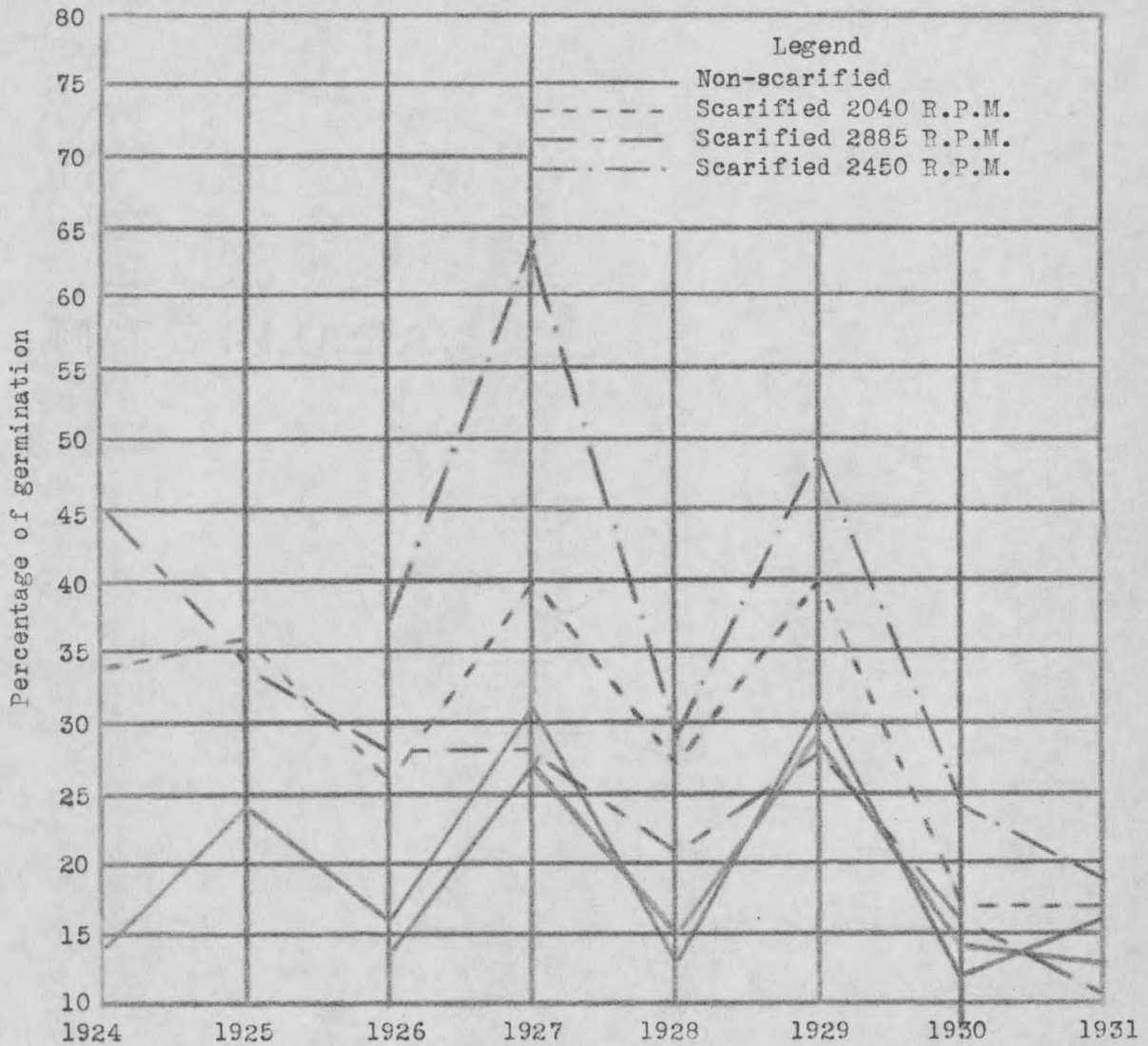


Figure 11. Field germination of scarified and non-scarified sweet clover seed.

but disappeared in the seventh year; (4) seed kept in cold storage gave higher germination both in the laboratory and in the field than seed stored in the laboratory although the hard seed content of the seed stored in the laboratory remained the highest.

The initial laboratory germination of the non-scarified sweet clover seed stored in 1924 was 20 percent; for the seed scarified at 2,040 revolutions per minute, 48 percent; and for that scarified at 2,885 revolutions per minute, 61 percent. The initial hard seed content was 72, 43 and 50 percent respectively. (Table VII). In 1926, after two years in storage the average germination of all methods of storage was 30 percent for the non-scarified seed, 47 percent for that scarified at 2,040 revolutions per minute and 44 percent for the seed scarified at 2,885 revolutions per minute. In 1931, after seven years, it was 22, 33, and 26 percent respectively. (Figure 10). The hard seed content after two years was 50, 29, and 15 percent; after seven years, 45, 23, and 10 percent respectively. (Figure 12). The seed scarified at 2,885 revolutions per minute did not retain its vitality as long as that receiving the less severe scarification at 2,040 revolutions per minute.

As was the case with alfalfa the seed stored in air-tight bottles in the laboratory with 12 percent moisture lost vitality more rapidly than the seed stored in any other manner although the hard seed content of the non-scarified seed stored by this method remained high. Against an initial germination of 20 percent plus 72 percent hard seed for the non-scarified seed, the germination in

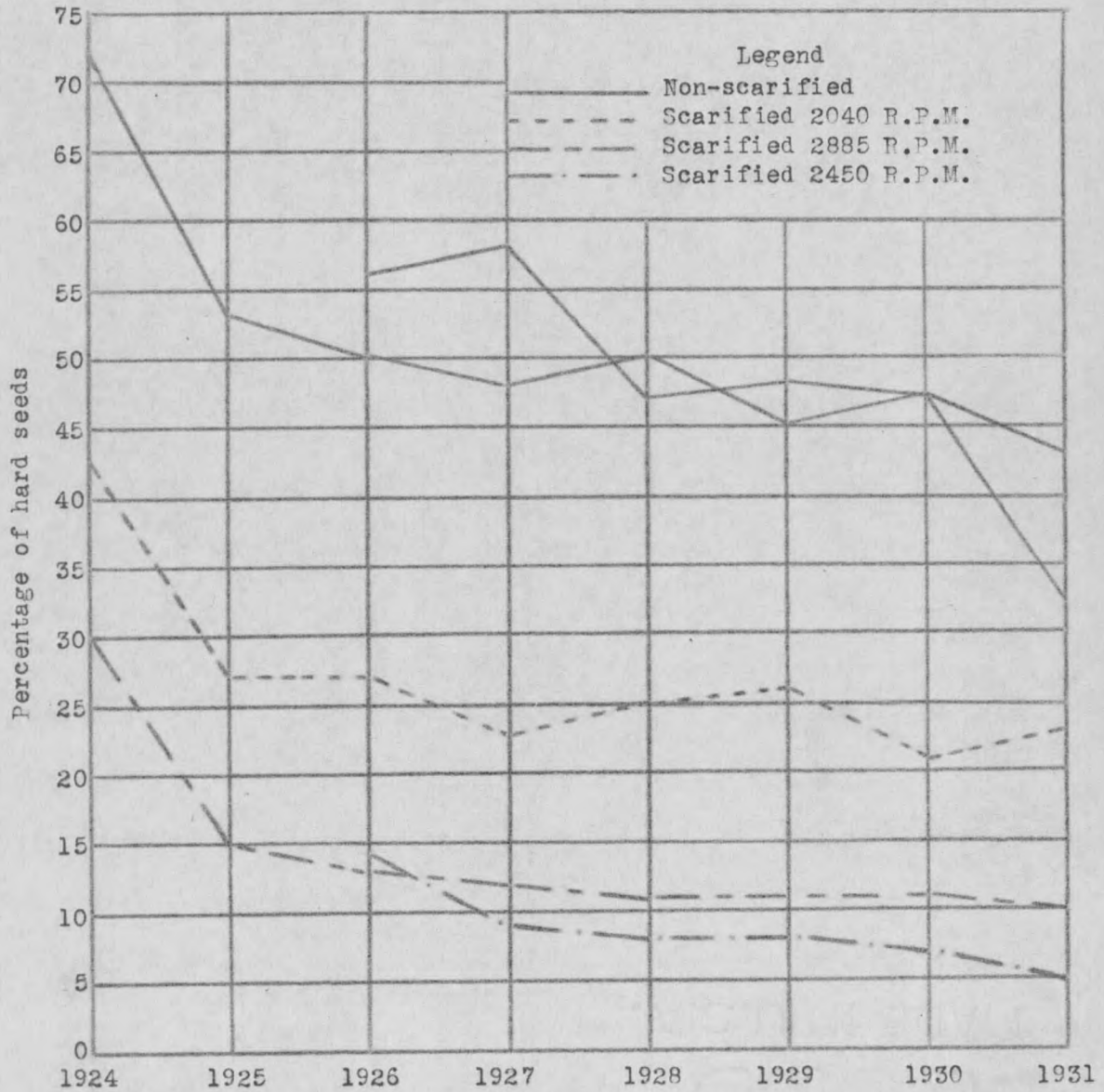


Figure 12. Hard seed content of scarified and non-scarified sweet clover seed.

1926 was 2 percent plus 58 percent hard seed and in 1931, 4 percent plus 53 percent hard seed. For the seed scarified at 2,040 revolutions per minute the initial germination was 48 percent plus 43 percent hard seed, in 1926, 23 percent plus 35 percent hard seed and in 1931, 15 percent plus 31 percent hard seed. The seed scarified at 2,885 revolutions per minute had an initial germination of 61 percent plus 30 percent hard seed. In 1926 it was 5 percent plus 14 percent hard seed and in 1931, 1 percent plus 4 percent hard seed, (Table VII). This lowered vitality due to storage in the laboratory with 12 percent moisture was also very marked in the field tests. (Table IX).

Seed with 12 percent moisture did not lose vitality so rapidly when kept in cold storage, but lost vitality more rapidly than seed stored with less moisture. This point will be best understood by studying Table XI.

The storage of non-scarified sweet clover seed, at low temperatures increased the germination and lowered the hard seed content by approximately 100 percent in comparison with the seed stored in the laboratory. (Table VII). The beneficial effect appeared after one year of storage and held true after seven years. The scarified seed also showed an advantage in favor of cold storage, but to a lesser degree. Excluding the seed stored with 12 percent moisture, the average germination of the non-scarified seed after one year in cold storage was 50 percent plus 42 percent hard seed and for the seed stored in the laboratory, 23 percent plus 67 percent hard seed.

Table IX
Field germination of scarified and non-scarified sweet clover
seed stored under different conditions

Lot No.	Scarifi- cation	Storage method	1924 Germ.%	1925 Germ.%	1926 Germ.%	1927 Germ.%	1928 Germ.%	1929 Germ.%	1930 Germ.%	1931 Germ.%
1	none	A	14	13	8	24	9	25	5	16
		B		13	7	19	7	31	5	12
		E		3	6	22	4	16	6	5
		C		34	26	37	15	41	17	18
		D		37	28	45	23	37	21	27
		F		41	23	41	22	41	16	17
1	2040 R.P.M.	A	34	30	27	36	26	40	8	18
		B		35	27	32	25	37	23	15
		E		17	10	47	11	20	7	6
		C		40	28	38	31	42	26	17
		D		47	37	55	39	63	25	33
		F		46	27	34	31	36	13	12
1	2885 R.P.M.	A	45	25	24	36	27	37	20	17
		B		27	25	40	20	34	21	9
		E		19	7	6	6	2	2	1
		C		44	41	20	23	30	16	11
		D		41	41	42	34	51	27	23
		F		46	28	25	15	15	8	4

Table X
Field germination of scarified and non-scarified sweet clover
seed stored under different conditions

Lot No.	Scarifi- cation	Storage method	1926 Germ.%	1927 Germ.%	1928 Germ.%	1929 Germ.%	1930 Germ.%	1931 Germ.%
2	none	A	15	13	9	14	3	6
		B		11	8	13	1	2
		C		28	19	35	18	17
		D		21	15	34	16	13
2	2450 R.P.M.	A	40	39	21	42	26	15
		B		46	24	45	21	22
		C		56	36	58	24	20
		D		54	36	43	27	17
3	none	A	18	20	17	26	14	8
		B		33	9	28	11	11
		C		39	24	45	34	17
		D		47	16	44	29	24
3	2450 R.P.M.	A	30	41	28	46	22	21
		B		43	30	46	30	18
		C		58	19	52	23	13
		D		56	31	55	24	20
4	none	A	11	23	15	27	7	16
		B		31	12	18	6	8
		C		28	18	36	14	24
		D		26	14	29	12	17
4	2450 R.P.M.	A	42	43	25	53	25	18
		B		35	33	49	23	22
		C		44	36	45	15	25
		D		58	34	56	15	16

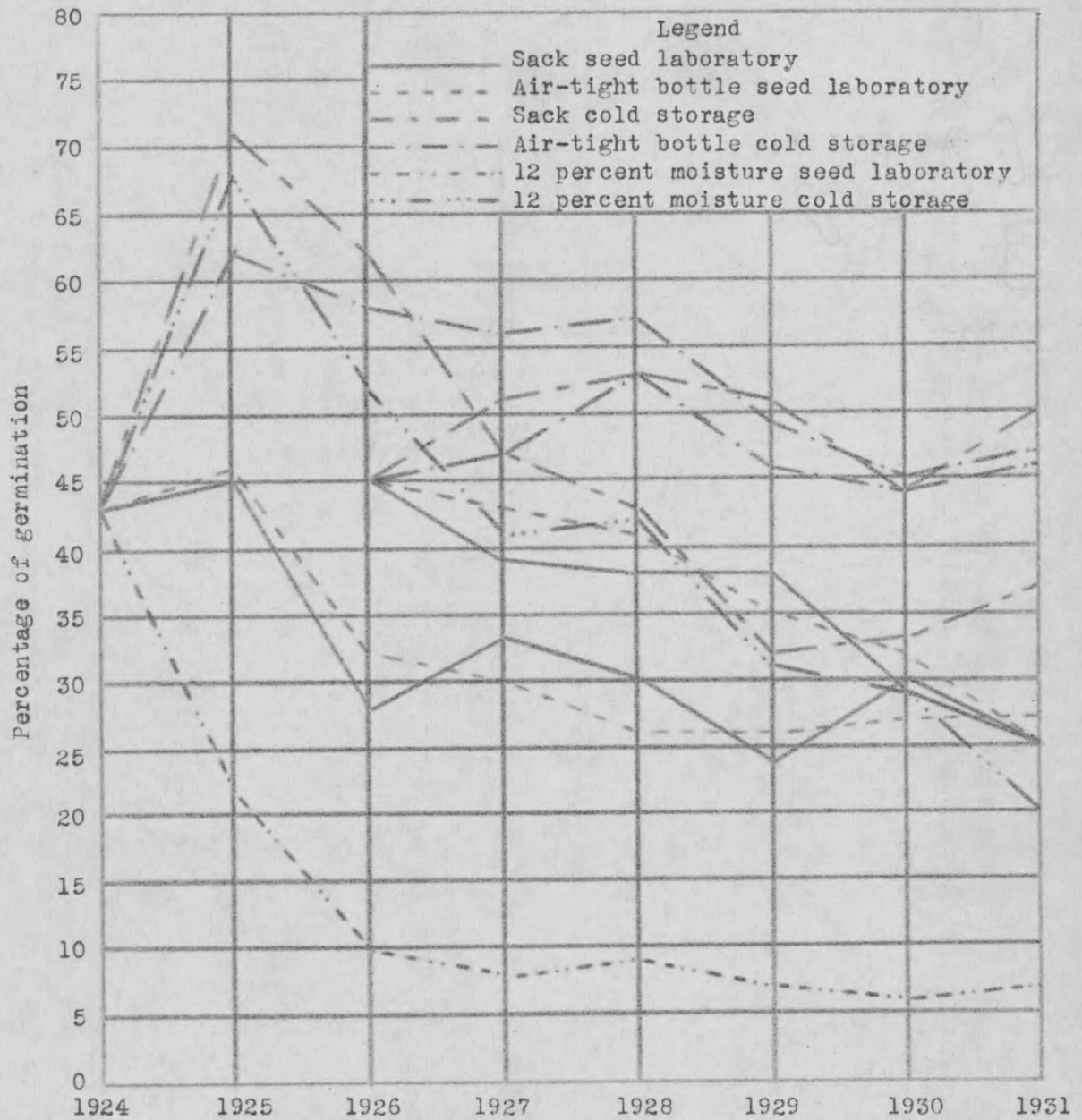


Figure 13. Laboratory germination of sweet clover seed comparing different methods of storage. (See page 13)

After seven years, it was 42 percent plus 24 percent hard seed and 12 percent plus 68 percent hard seed respectively.

After one year in cold storage the field germination of the non-scarified seed was 36 percent and after one year in the laboratory, 13 percent. After seven years, 22 and 14 percent respectively.

For the seed scarified at 2,040 revolutions per minute the germination was 70 percent plus 22 percent hard seed after one year in cold storage, and 52 plus 36 percent hard seed after one year in the laboratory. After seven years the germination was 48 and 31 percent respectively and the hard seed content 12 and 37 percent respectively. The field germination was 44 percent after one year in cold storage and 33 percent after one year in the laboratory. After seven years it was 25 and 16 percent respectively.

The seed scarified at 2,885 revolutions per minute had 81 percent germination plus 9 percent hard seed after one year in cold storage, and 62 percent plus 24 percent hard seed after one year in the laboratory. After seven years the germination was 36 and 34 percent respectively; the hard seed content 4 and 20 percent respectively. The field germination was 43 and 26 percent respectively after one year of storage and 17 and 13 percent respectively after seven years.

Figures 13 and 14 show that the difference between storing the seed in air-tight bottles or sacks did not favor either method consistently.

The initial field germination of sweet clover was increased more

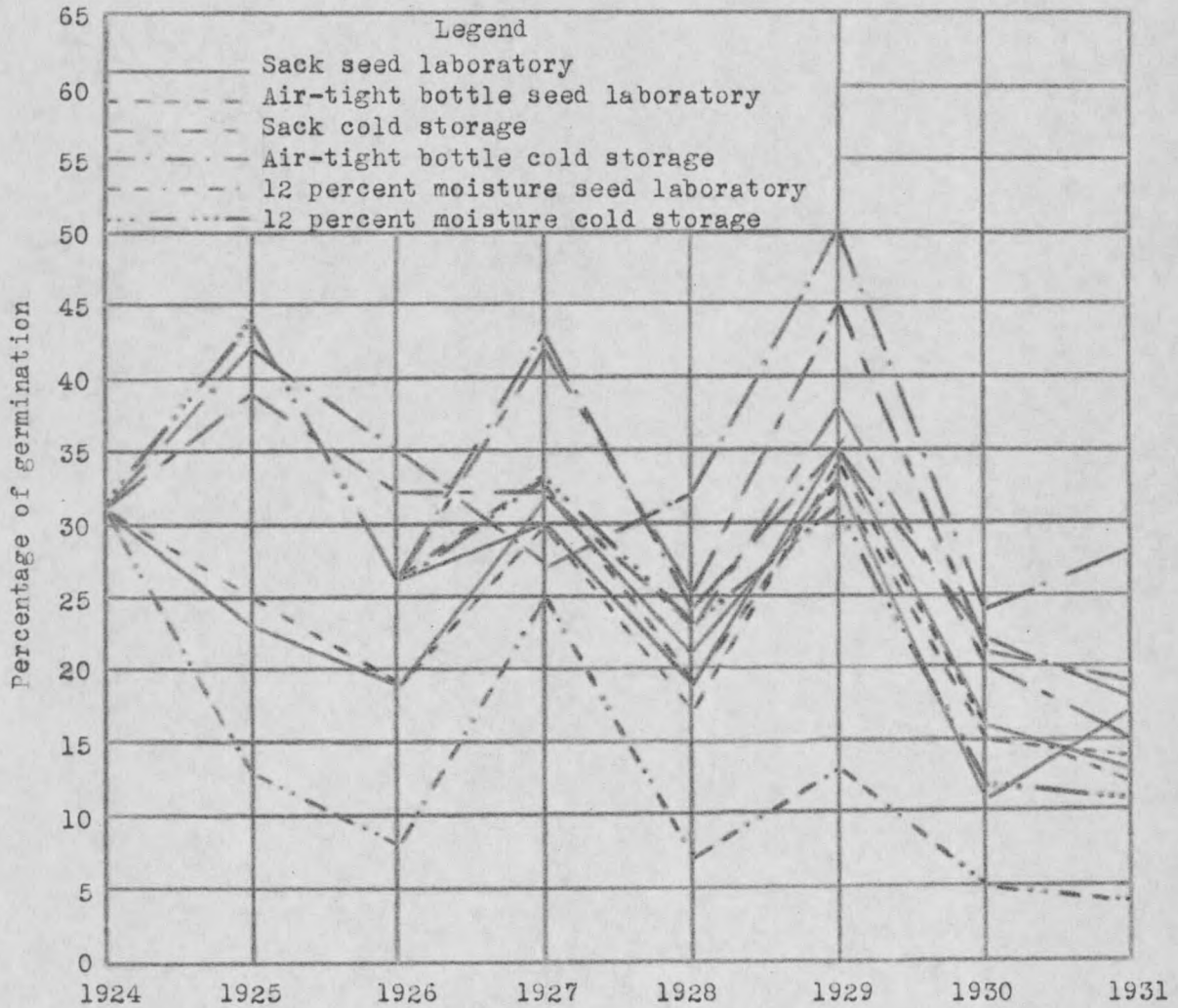


Figure 14. Field germination of sweet clover seed comparing different methods of storage. (See page 13)

than 100 percent by scarifying. Although the scarified seed lost vitality more rapidly there was still a slight advantage in favor of scarification at 2,040 revolutions per minute after seven years of storage. Beginning in 1927 seed scarified at 2,885 revolutions per minute gave approximately the same germination as the non-scarified seed. (Figure 11). The initial field germination was 14 percent for the non-scarified seed, 34 percent for that scarified at 2,040 revolutions per minute and 45 percent for that scarified at 2,885 revolutions per minute. In 1927 after three years of storage the average field germination for all methods of storage was 31, 40, and 28 percent respectively. After seven years it was 16, 17, and 11 percent respectively. As with alfalfa, the field germination of the seed stored in air-tight bottles in the laboratory with 12 percent moisture decreased rapidly but that kept in cold storage fell off more slowly. (Figure 14). Taken as a whole, the field germination of the sweet clover decreased gradually during the entire period of the experiment.

For the seed stored in 1924 the total vitality of the scarified seed was slightly lower than that of the non-scarified seed after the first year in storage. (Table XI). This lowered vitality due to scarifying became more pronounced as the experiment progressed. Seed stored with 12 percent moisture in the laboratory had the lowest total vitality during the experiment although seed kept in cold storage with 12 percent moisture was very little better. There was no significant difference between the other methods of storage, and taken as a whole, the total vitality of the sweet clover seed decreas-

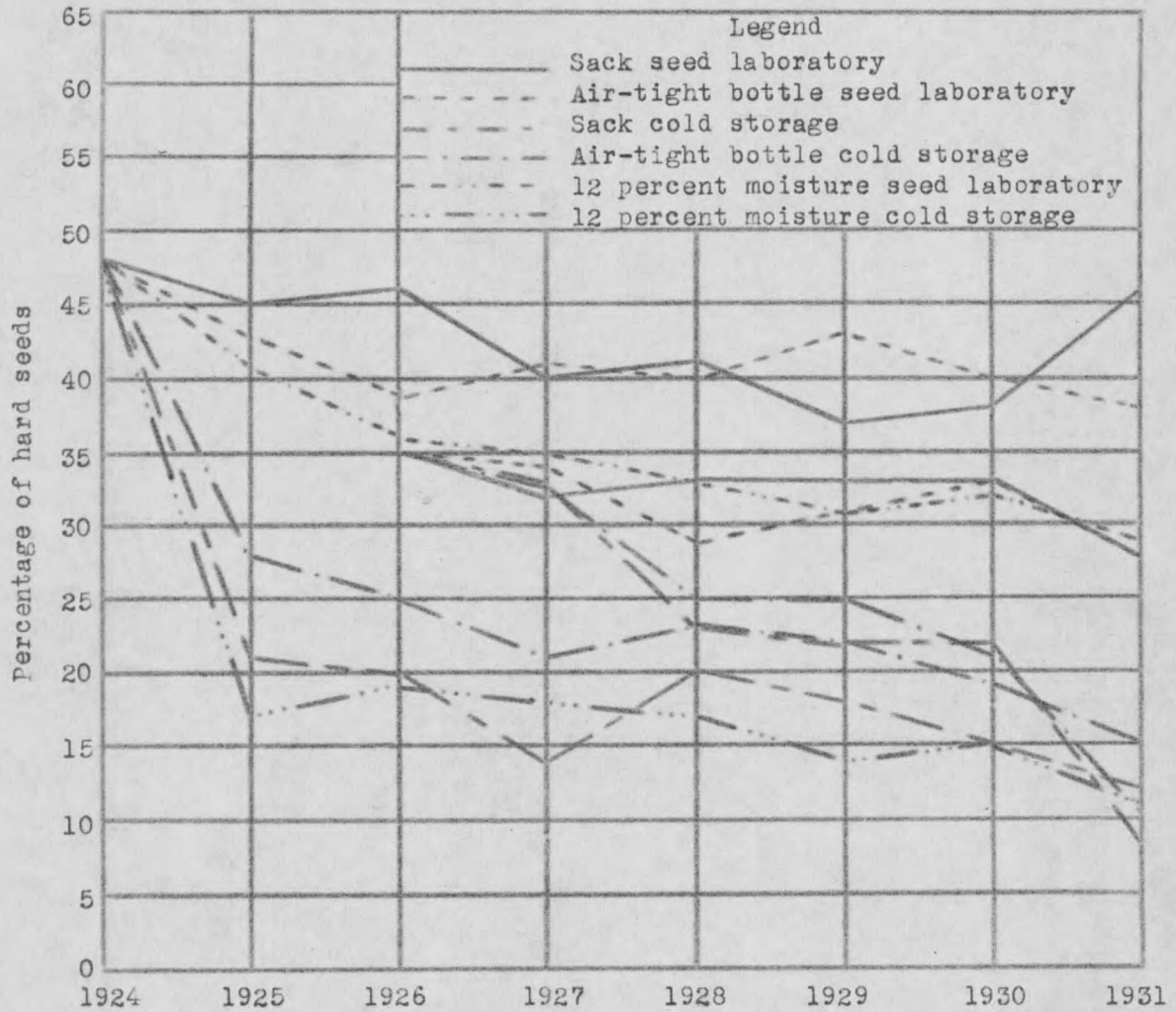


Figure 15. Hard seed content of sweet clover comparing different methods of storage. (See page 13)

Table XI
 Percent total vitality of scarified and non-scarified sweet clover seed
 stored under different conditions

Lot No.	Scarifi- cation	Storage method	1924	1925	1926	1927	1928	1929	1930	1931
1	none	A	92	90	85	85	85	73	83	81
		B		91	85	84	84	88	88	80
		E		78	60	70	64	61	60	57
		C		97	87	70	77	63	62	61
		D		87	90	87	89	80	81	71
		F		82	74	72	77	55	62	43
1	2040 R.P.M.	A	91	85	79	75	73	68	72	72
		B		90	81	72	76	74	61	64
		E		63	58	46	51	42	39	46
		C		92	82	63	65	53	41	53
		D		91	84	83	75	76	65	67
		F		85	72	62	58	42	50	33
1	2885 R.P.M.	A	91	85	60	59	55	44	48	58
		B		87	51	56	38	47	54	51
		E		49	19	14	12	11	14	5
		C		87	77	50	48	35	42	31
		D		92	75	61	74	56	47	49
		F		88	66	37	40	27	19	17

Table XII
 Percent total vitality of scarified and non-scarified sweet
 clover seed stored under different conditions

Lot No.	Scarification	Storage method	1926	1927	1928	1929	1930	1931
2	none	A	73	76	71	67	68	64
		B		78	66	68	69	57
		C		77	63	75	70	63
		D		73	78	74	69	52
2	2450 R.P.M.	A	81	72	60	58	43	46
		B		75	78	58	53	41
		C		79	76	70	58	58
		D		80	79	68	56	45
3	none	A	78	64	67	70	73	61
		B		89	58	68	82	54
		C		86	81	70	62	59
		D		80	76	70	65	64
3	2450 R.P.M.	A	75	74	78	60	54	35
		B		71	61	63	47	36
		C		90	79	68	58	48
		D		72	80	62	60	46
4	none	A	89	83	79	88	77	66
		B		85	83	80	86	79
		C		88	80	83	82	68
		D		87	81	82	81	74
4	2450 R.P.M.	A	86	62	75	64	56	42
		B		73	75	58	51	51
		C		88	82	72	64	58
		D		82	76	74	63	52

ed gradually during the length of the experiment.

The three samples of sweet clover added to this experiment in 1926 have shown the same results as have been described for the seed stored in 1924. Both laboratory and field germinations were increased by scarifying. (Tables VIII and X). The hard seed content decreased slowly (Figure 12) and the loss in total vitality was gradual. (Table XII). The seed kept in cold storage gave higher germination than seed stored in the laboratory (Figure 13) but the difference in total vitality was not so pronounced. (Table XII). Both laboratory and field germinations were increased by one year in cold storage.

Experiments With Red Clover Seed

The initial laboratory germination of red clover seed was increased by scarification. (Table XIII). The field germination of the seed scarified at 2,040 revolutions per minute showed a slight advantage in favor of scarifying for the first two years, but after that time it was about the same as that of the non-scarified seed. (Figure 17). On the other hand, field germination was lowered by scarification at 2,885 revolutions per minute.

The laboratory germination of the non-scarified seed at the beginning of storage was 41 percent, for the seed scarified at 2,040 revolutions per minute 60 percent, and for that scarified at 2,885 revolutions per minute, 75 percent. The initial hard seed content was 58, 39, and 23 percent respectively. (Table XIII). In 1926, after two years of storage, the average germination was 69, 73, and 70 percent; the hard seed content 26, 13, and 5 percent respectively.

Table XIII
Laboratory germination of scarified and non-scarified red clover seed
stored under different conditions

Lot No.	Scarification	Storage method	1924		1925		1926		1927		1928		1929		1930		1931	
			% Germ.	% H. S.	% Germ.	% H. S.	% Germ.	% H. S.	% Germ.	% H. S.	% Germ.	% H. S.	% Germ.	% H. S.	% Germ.	% H. S.	% Germ.	% H. S.
1	none	A	41	58	55	44	53	43	50	44	55	37	45	44	50	37	58	28
		B			56	42	57	40	58	39	53	42	54	38	58	33	58	24
		E			55	42	50	33	30	31	37	29	23	28	21	25	22	25
		C			83	17	86	12	84	13	88	10	80	12	77	8	79	5
		D			79	20	84	13	79	18	81	14	86	12	87	8	91	6
		F			83	16	82	14	82	16	88	8	86	10	86	9	88	7
1	2040 R.P.M.	A	60	39	73	27	69	21	53	21	64	19	45	20	52	13	46	16
		B			72	24	69	20	66	18	59	22	62	15	48	16	62	11
		E			78	13	58	12	41	8	32	10	22	11	24	6	28	7
		C			88	9	92	3	85	5	86	4	89	2	65	5	61	1
		D			86	13	88	9	84	11	88	6	90	5	84	5	87	2
		F			80	15	86	11	86	10	89	5	86	4	87	4	82	1
1	2885 R.P.M.	A	75	23	72	17	63	9	35	12	42	11	32	8	30	6	39	6
		B			79	15	68	8	45	7	39	10	38	10	36	5	25	10
		E			70	9	47	3	24	2	14	1	9	1	3	4	3	1
		C			87	4	84	3	76	1	77	1	73	2	51	1	47	0
		D			82	10	80	6	79	4	81	3	86	1	74	1	73	2
		F			86	1	81	2	76	2	80	2	80	1	73	1	59	0

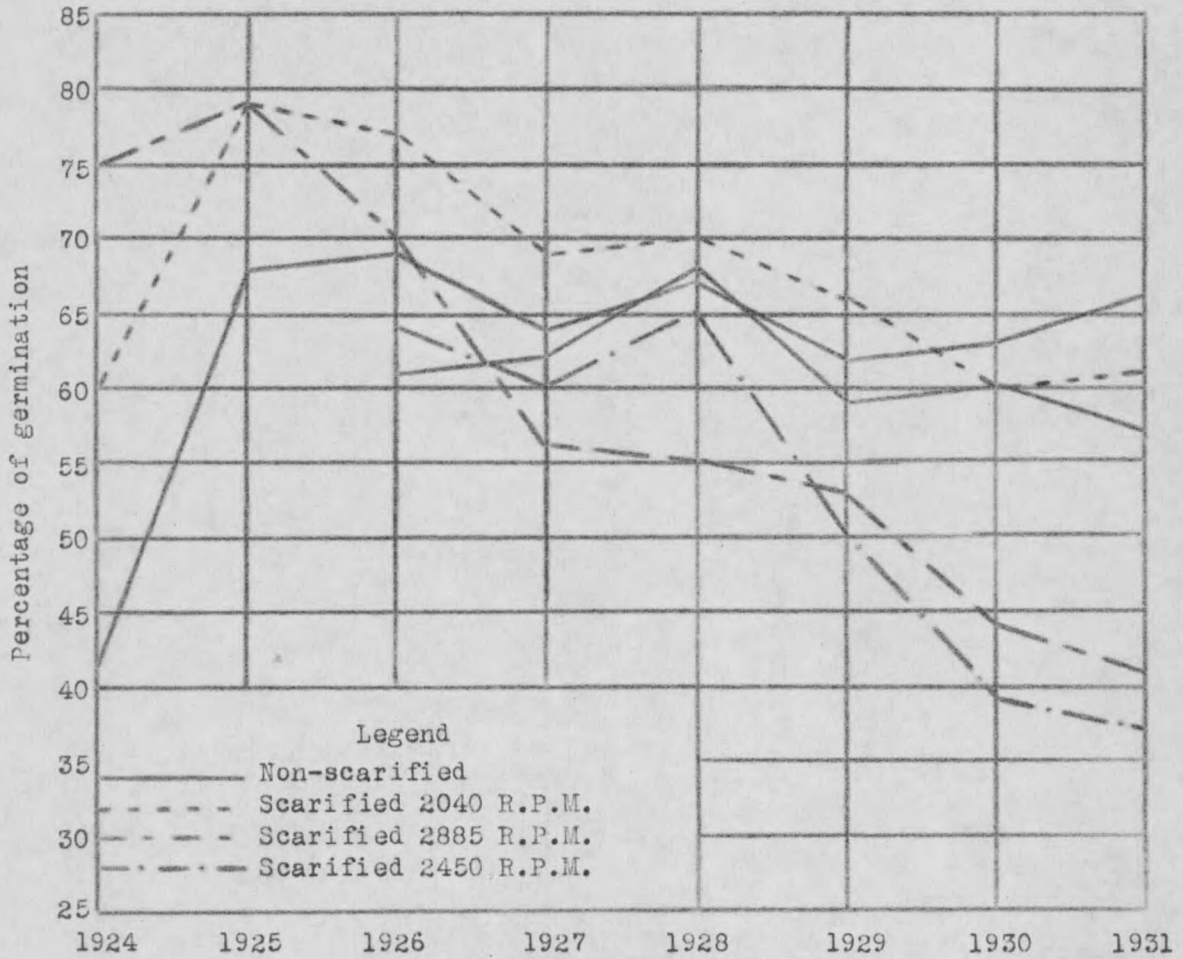


Figure 16. Laboratory germination of scarified and non-scarified red clover seed.

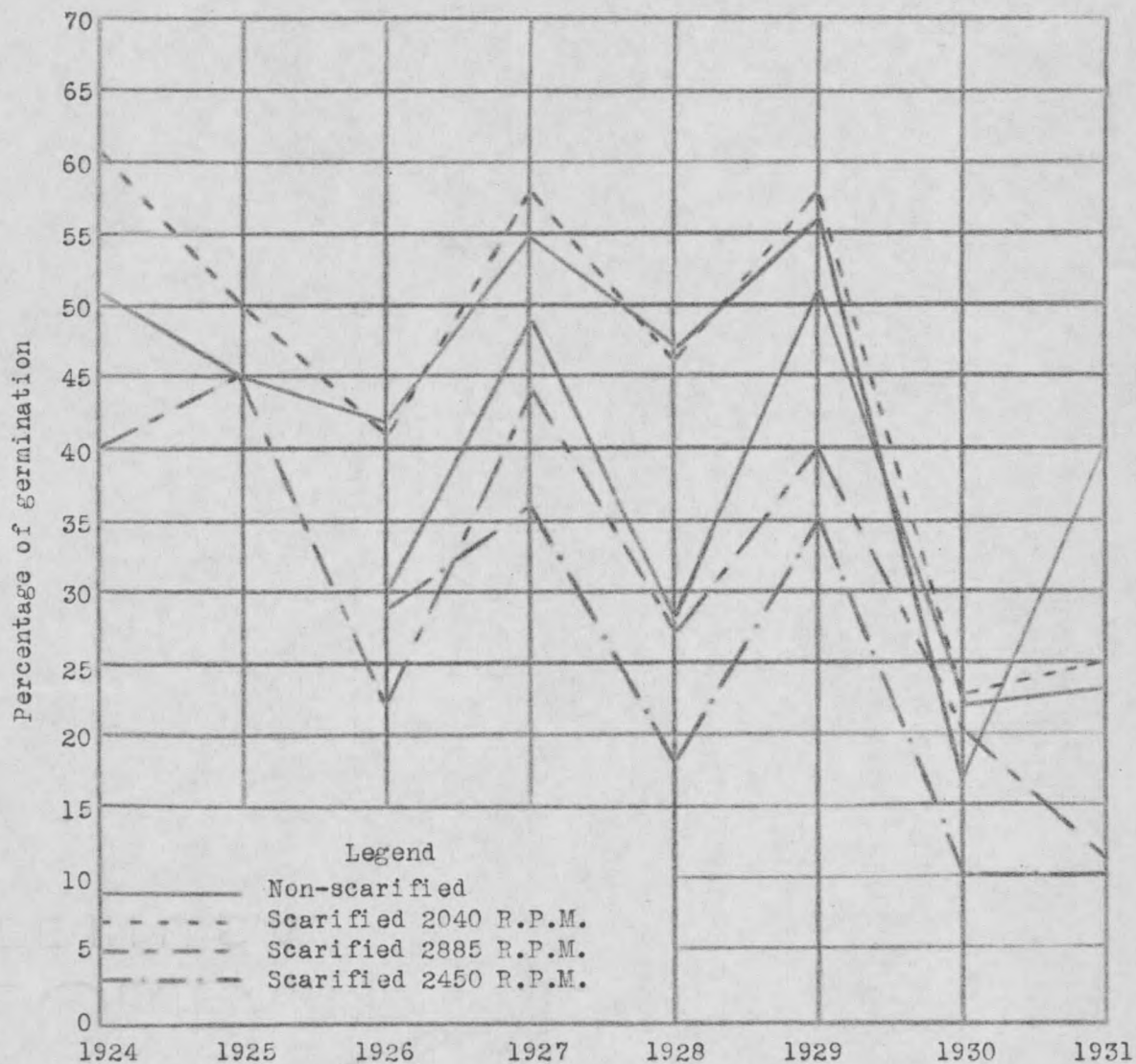


Figure 17. Field germination of scarified and non-scarified red clover seed.

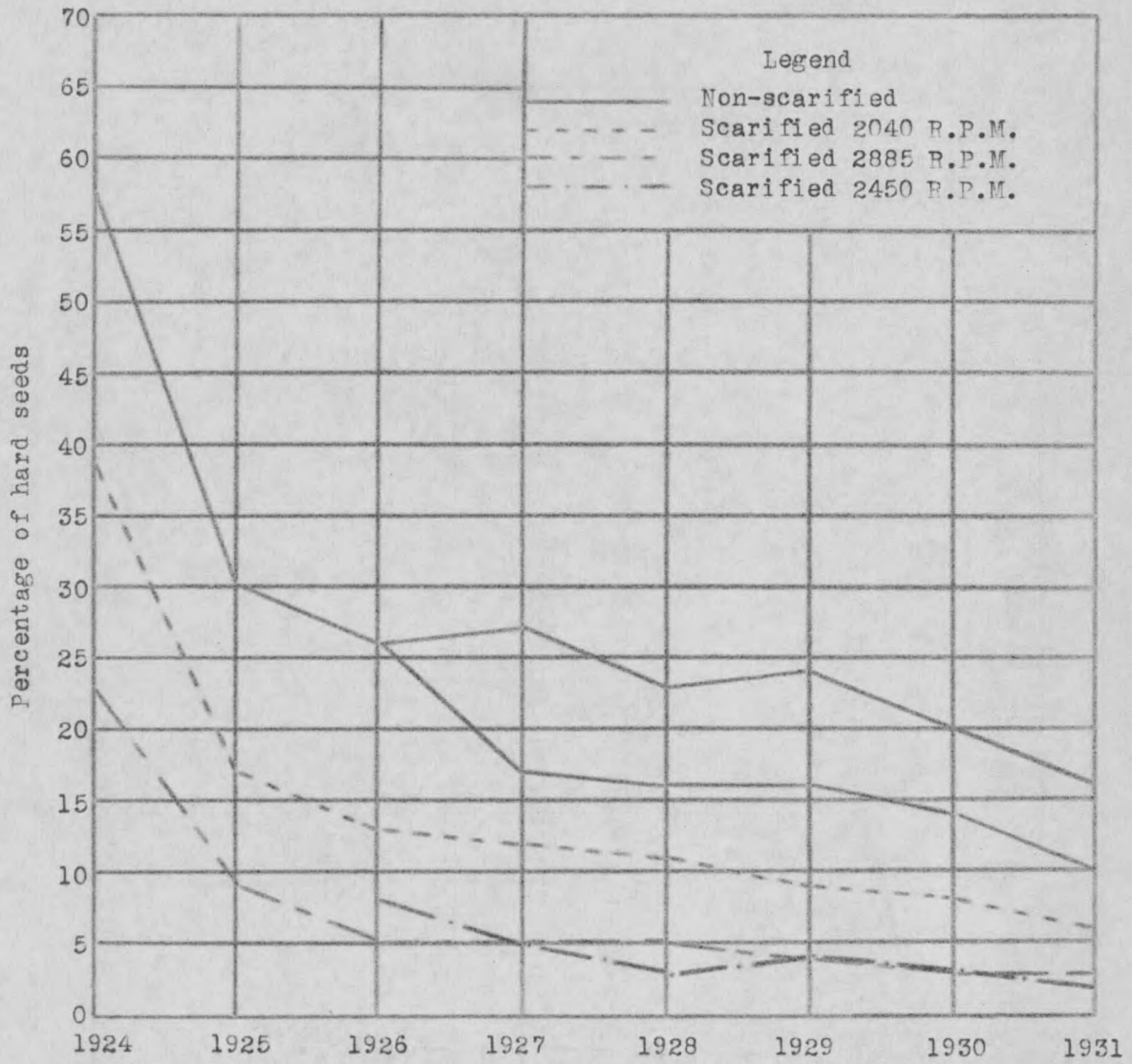


Figure 18. Hard seed content of scarified and non-scarified red clover seed.

Table XIV
 Laboratory germination of scarified and non-scarified red clover seed
 stored under different conditions

Lot No.	Scarifi- cation	Storage method	1926		1927		1928		1929		1930		1931	
			Germ. H.S. Percent		Germ. H.S. Percent		Germ. H.S. Percent		Germ. H.S. Percent		Germ. H.S. Percent		Germ. H.S. Percent	
2	none	A	56	25	56	16	65	15	53	17	39	20	37	12
		B			56	17	61	11	48	23	44	18	38	14
		C			62	9	64	9	67	7	66	7	66	7
		D			58	12	63	13	60	9	62	11	60	5
2	2450 R.P.M.	A	73	5	65	2	50	5	53	4	28	6	20	2
		B			55	2	59	2	37	4	25	3	20	3
		C			48	4	71	0	53	2	41	1	43	0
		D			52	4	71	3	56	2	46	1	42	1
3	none	A	58	28	50	14	64	16	56	28	40	17	46	19
		B			57	21	53	16	50	10	41	19	33	12
		C			57	14	71	13	57	13	66	13	54	8
		D			53	21	70	21	62	11	56	10	61	5
3	2450 R.P.M.	A	46	10	46	9	52	5	30	3	15	5	18	5
		B			46	12	41	4	33	6	17	5	20	1
		C			42	8	48	1	49	3	31	5	24	0
		D			46	6	60	7	39	6	37	3	46	3
4	none	A	70	24	70	22	73	18	69	25	63	13	64	17
		B			77	19	73	20	66	20	66	16	58	17
		C			74	23	79	16	82	15	77	17	86	8
		D			77	17	82	14	79	16	78	12	81	10
4	2450 R.P.M.	A	73	9	86	2	73	5	50	4	39	1	32	2
		B			75	3	83	2	54	3	35	1	36	2
		C			78	3	93	1	81	4	77	0	72	1
		D			79	7	85	5	72	4	74	2	65	1

Table XV
Field germination of scarified and non-scarified red clover
seed stored under different conditions

Lot No.	Scarifi- cation	Storage method	1924 Germ.%	1925 Germ.%	1926 Germ.%	1927 Germ.%	1928 Germ.%	1929 Germ.%	1930 Germ.%	1931 Germ.%
1	none	A	51	34	47	45	29	54	10	34
		B		42	28	59	31	58	8	43
		E		33	21	12	25	19	5	7
		C		53	49	64	49	75	7	48
		D		51	53	72	76	88	28	59
		F		59	56	77	70	41	42	56
1	2040 R.P.M.	A	61	50	47	50	38	50	12	26
		B		47	41	52	46	53	29	31
		E		40	23	25	17	20	3	3
		C		56	56	66	60	63	10	13
		D		43	46	73	59	82	33	50
		F		62	31	81	56	79	53	27
1	2885 R.P.M.	A	40	39	21	29	22	33	11	16
		B		32	30	30	15	23	12	5
		E		40	15	15	12	5	2	0
		C		60	24	66	32	44	15	9
		D		54	24	63	49	63	57	19
		F		47	21	59	35	70	25	19

Table XVI
Field germination of scarified and non-scarified red clover
seed stored under different conditions

Lot No.	Scarifi- cation	Storage method	1926 Germ. %	1927 Germ. %	1928 Germ. %	1929 Germ. %	1930 Germ. %	1931 Germ. %
2	none	A	22	41	21	33	11	9
		B		35	21	33	7	15
		C		51	29	57	28	24
		D		49	26	46	21	28
2	2450 R.P.M.	A	23	29	21	16	15	4
		B		36	15	22	11	3
		C		34	17	33	10	11
		D		38	20	46	21	10
3	none	A	31	32	29	41	14	10
		B		38	24	31	15	11
		C		46	31	53	38	34
		D		52	23	53	31	16
3	2450 R.P.M.	A	29	24	14	23	4	7
		B		34	12	21	2	3
		C		26	15	34	8	7
		D		20	10	33	12	9
4	none	A	36	59	36	60	27	21
		B		66	26	57	35	33
		C		52	31	82	23	38
		D		66	37	66	22	37
4	2450 R.P.M.	A	34	40	20	32	9	6
		B		42	21	23	4	4
		C		62	30	66	13	34
		D		52	22	67	15	27

(Figure 16). After seven years of storage the germination was 66, 61, and 41 percent; the hard seed content 16, 6, and 3 percent respectively.

The initial field germination was 51 percent for the non-scarified seed, 61 percent for the seed scarified at 2,040 revolutions per minute and 40 percent for the seed scarified at 2,885 revolutions per minute. (Table XV). In 1926, after two years of storage, the field germination was 47, 47, and 21 percent respectively and after seven years, 41, 25, and 11 percent respectively. (Figure 17).

Red clover seed stored in air-tight bottles in the laboratory with 12 percent moisture lost vitality more rapidly than the seed stored in any other manner, but this loss of vitality was not so rapid as with sweet clover and alfalfa. In 1926, after two years of storage in the laboratory, the germination of the non-scarified seed was 50 percent plus 33 percent hard seed as against an initial germination of 41 percent plus 57 percent hard seed. (Table XIII). After seven years, it was 22 percent plus 25 percent hard seed. In 1924, the field germination was 51 percent, after two years, 21 percent, and after seven years, 7 percent. (Table XV).

For the seed scarified at 2,040 revolutions per minute, the initial germination was 60 percent plus 39 percent hard seed, after two years of storage in the laboratory with 12 percent moisture, 58 percent plus 12 percent hard seed, and after seven years 28 percent plus 7 percent hard seed. (Table XIII). Before storage, the field

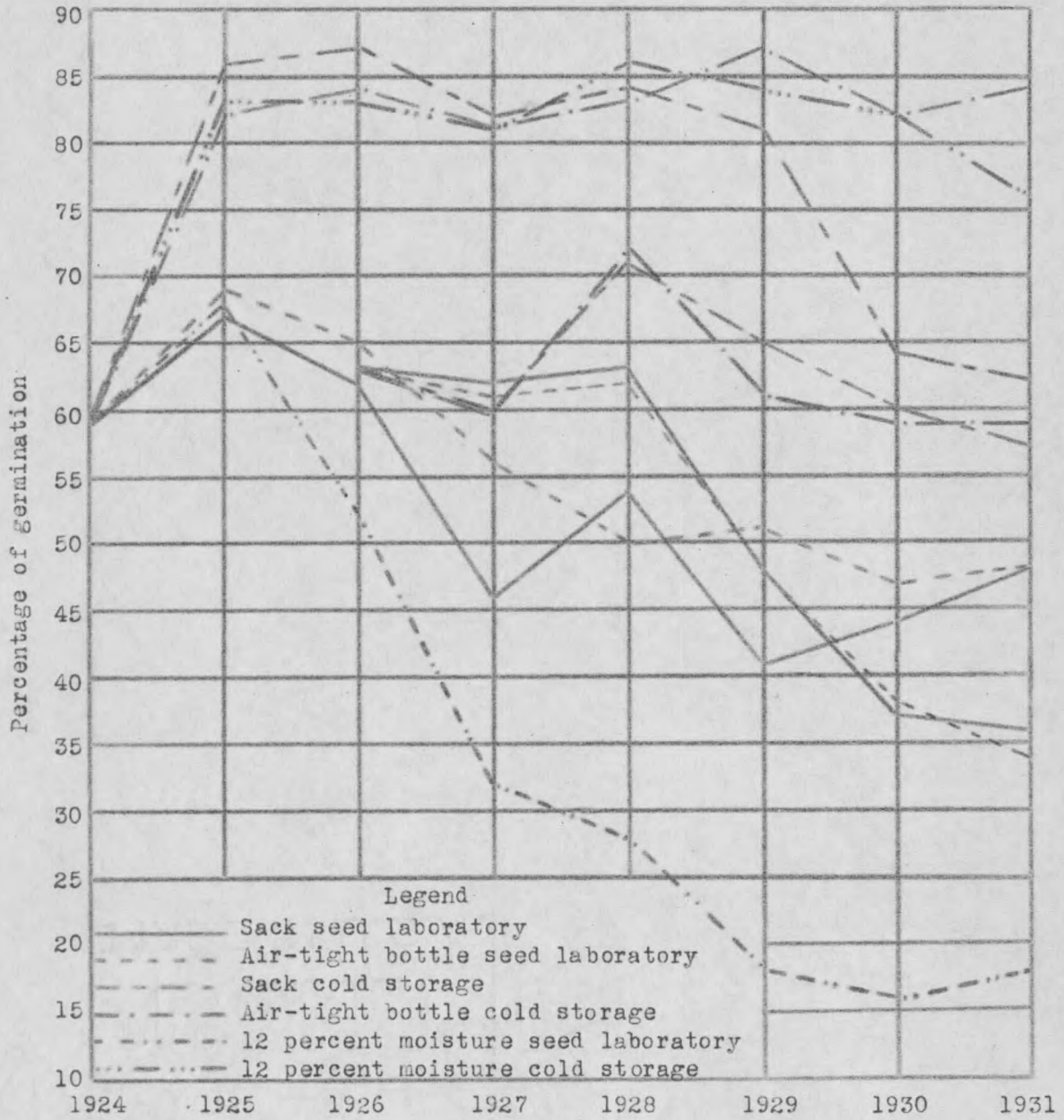


Figure 19. Laboratory germination of red clover seed comparing different methods of storage. (See page 13)

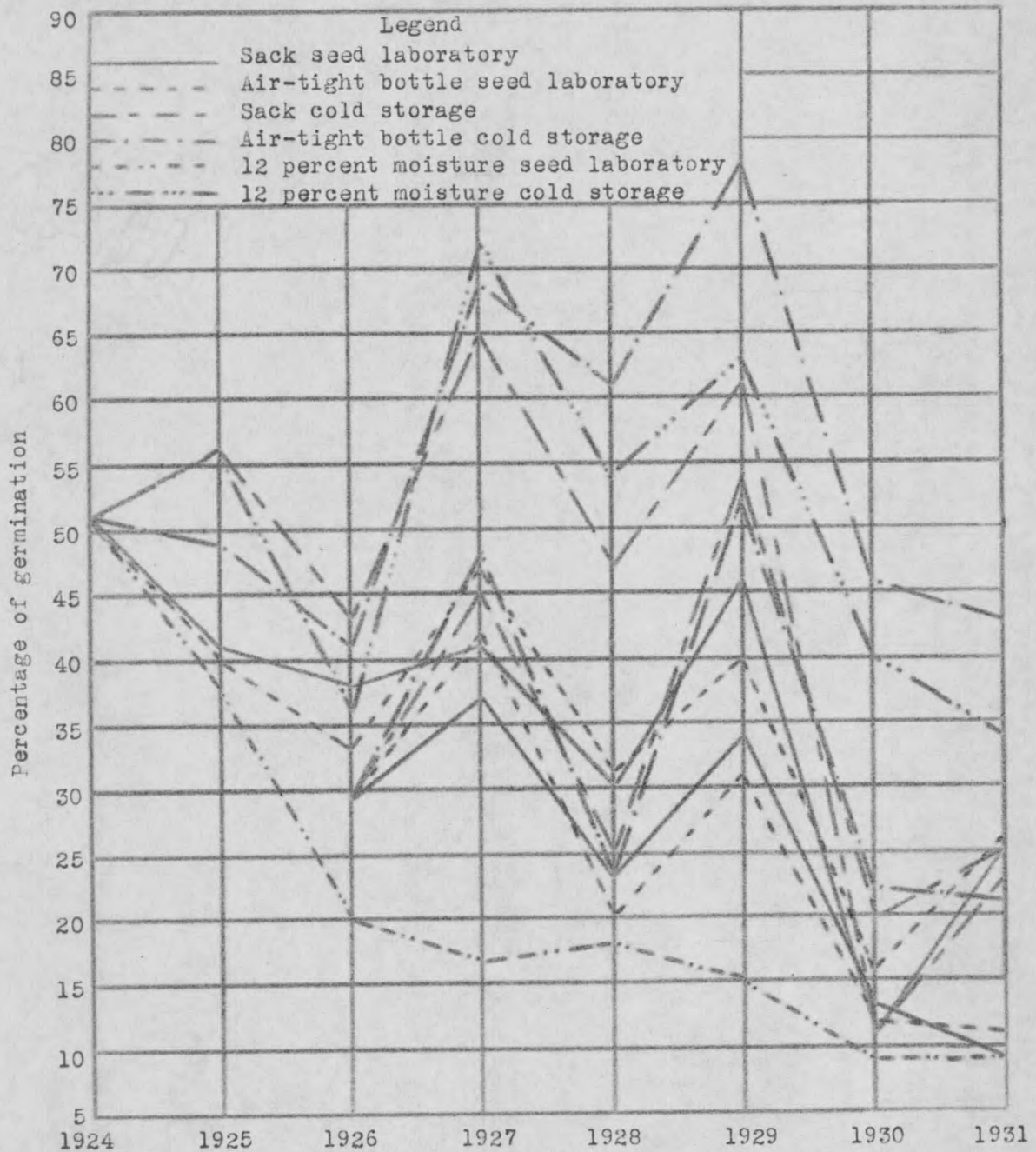


Figure 20. Field germination of red clover seed comparing different methods of storage. (See page 13)

germination was 61 percent, after two years, 23 percent, and after seven years, 3 percent. (Table XV).

With the seed scarified at 2,885 revolutions per minute, the initial germination was 75 percent plus 23 percent hard seed. After two years of storage in the laboratory with 12 percent moisture, 47 percent plus 3 percent hard seed, and after seven years, 3 percent plus 1 percent hard seed. (Table XIII). Before storage, the field germination was 40 percent, after two years, 15 percent, and after seven years, 0 percent. (Table XV). The seed kept in cold storage with 12 percent moisture did not lose vitality any more rapidly than dry seed. (Figures 19 and 20).

The storage of red clover seed at low temperatures increased the laboratory and field germination and lowered the hard seed content. Figures 19, 20, and 21 show that the effect of cold storage became apparent after the first year of storage and continued throughout the experiment. Excluding the seed stored with 12 percent moisture, the average germination of the non-scarified seed kept in cold storage for one year was 81 percent plus 18 percent hard seed and for that stored in the laboratory, 56 percent plus 43 percent hard seed. After seven years, it was 85 percent plus 5 percent hard seed and 58 percent plus 26 percent hard seed respectively. The field germination after one year in cold storage was 52 percent, and after one year in the laboratory, 38 percent. In 1931, after seven years, it was 53 and 38 percent respectively.

In 1925, after one year in cold storage, the average germination

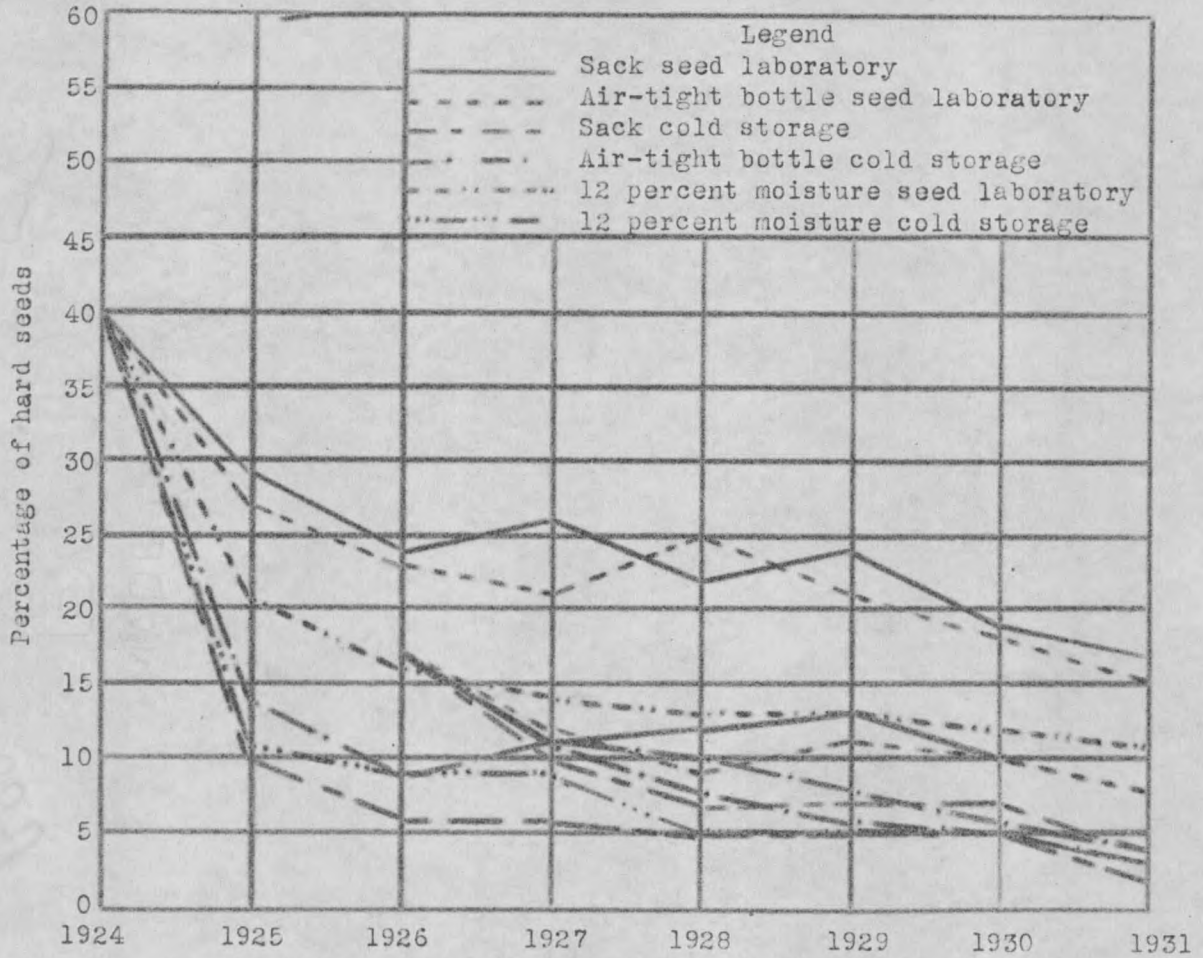


Figure 21. Hard seed content of red clover comparing different methods of storage. (See page 13)

Table XVII
 Percent total vitality of scarified and non-scarified red clover seed
 stored under different conditions

Lot No.	Scarification	Storage method	1924	1925	1926	1927	1928	1929	1930	1931
1	none	A	99	99	96	94	92	99	87	86
		B		98	97	97	95	92	91	82
		E		97	83	61	66	51	46	47
		C		100	98	97	98	92	85	84
		D		99	97	97	95	98	95	97
		F		99	96	98	96	96	95	95
1	2040 R.P.M.	A	99	100	90	74	83	65	65	62
		B		96	89	84	81	77	64	73
		E		91	80	49	42	33	30	35
		C		97	95	90	90	91	70	62
		D		99	97	95	94	95	89	89
		F		95	97	96	94	90	91	83
1	2885 R.P.M.	A	98	89	72	47	53	40	36	45
		B		94	76	52	49	48	41	35
		E		79	50	26	15	10	7	4
		C		91	87	77	78	75	52	47
		D		92	86	83	84	87	75	75
		F		87	83	78	82	81	74	59

Table XVIII
 Percent total vitality of scarified and non-scarified red
 clover seed stored under different conditions

Lot No.	Scarification	Storage method	1926	1927	1928	1929	1930	1931
2	none	A	81	72	80	70	59	49
		B		73	72	71	62	52
		C		71	73	74	73	73
		D		70	76	69	73	65
2	2450 R.P.M.	A	88	67	55	57	34	22
		B		57	61	41	28	23
		C		52	71	55	42	43
		D		56	74	58	47	43
3	none	A	86	64	80	84	57	65
		B		78	69	60	60	45
		C		71	84	70	79	62
		D		74	91	73	66	66
3	2450 R.P.M.	A	56	55	57	33	20	23
		B		58	45	39	22	21
		C		50	49	52	36	24
		D		52	67	45	40	49
4	none	A	94	92	91	94	76	81
		B		96	93	86	82	75
		C		97	95	97	94	94
		D		94	96	95	90	91
4	2450 R.P.M.	A	82	88	78	54	40	34
		B		78	85	57	36	38
		C		81	94	85	77	73
		D		86	90	76	76	66

of the seed scarified at 2,040 revolutions per minute was 87 percent plus 11 percent hard seed and for the seed stored in the laboratory, 73 percent plus 24 percent hard seed. After seven years, it was 74 percent plus 1 percent hard seed and 54 percent plus 13 percent hard seed respectively. The field germination was 50 and 49 percent respectively after one year in storage, and after seven years, 31 and 28 percent.

The seed scarified at 2,885 revolutions per minute had 85 percent germination plus 7 percent hard seed after one year in cold storage and 75 percent plus 16 percent hard seed after one year in the laboratory. After seven years, the germination was 60 and 32 percent respectively, and the hard seed content, 8 and 4 percent respectively. The field germination was 57 and 35 percent respectively after one year in storage, and 4 and 10 percent after seven years.

From the standpoint of total vitality, there was no advantage in keeping the non-scarified seed stored in 1924 in cold storage. However, the non-scarified seed stored in 1926 showed a decided advantage in favor of cold storage after four years in storage. (Tables XVII and XVIII). Scarified seed had higher total vitality after two years in cold storage than after two years in the laboratory. There was no consistent difference between seed stored in air-tight bottles and that stored in sacks.

The three samples of seed added to this experiment in 1926 gave results similar to those described for the seed stored in 1924, except that the initial field germination was not increased by scarification. (Table XVI). In comparison with the seed stored in the laboratory both scarified and non-scarified seed were benefited by

storage at low temperatures. There was no advantage in storing the seed in air-tight bottles either in the laboratory or in cold storage.

SUMMARY AND CONCLUSIONS

It is believed the experiments and observations reported in this paper justify the following conclusions:

The total vitality of non-scarified seed of sweet clover and red clover will decrease slowly during the first seven years of storage. Non-scarified alfalfa seed of good maturity and high hard seed content will lose vitality gradually. Alfalfa seed less mature or of low hard seed content may show a rapid decline in vitality during the first two years of storage, but will fall off gradually thereafter.

Scarified seed of alfalfa will lose total vitality rapidly during the first two or three years of storage, but scarified seed of sweet clover and red clover lose vitality gradually when in storage. Scarified seed of these three crops will not retain its vitality as well as non-scarified seed.

The hard seed content of alfalfa decreases rapidly during the first year of storage and gradually during the following years. With sweet clover and red clover, the hard seed content of the seed in cold storage falls off rapidly during the first or second year in storage, but the seed stored in the laboratory decreases slowly in hard seed content during storage.

Seed stored with 12 percent moisture loses vitality more rapidly

in storage than dry seed. Cold storage is better than storage in the laboratory for seed with 12 percent moisture.

There is no advantage in keeping non-scarified alfalfa seed in cold storage. With scarified seed, however, both germination and total vitality are maintained better in cold storage than in the laboratory. The germination of red clover and sweet clover is higher for seed kept in cold storage than for seed stored in the laboratory. The total vitality of sweet clover does not seem to be greatly affected by the method of storage. The total vitality of red clover seed will be maintained better in cold storage than in the laboratory but the advantage of low temperatures will not be apparent until after the seed has been in storage from two to four years.

Where cold storage is advantageous as a means of maintaining vitality or increasing the germination, storage in air-tight bottles is most efficient. When seed is stored in the laboratory, there is no difference between storage in air-tight bottles or in sacks.

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